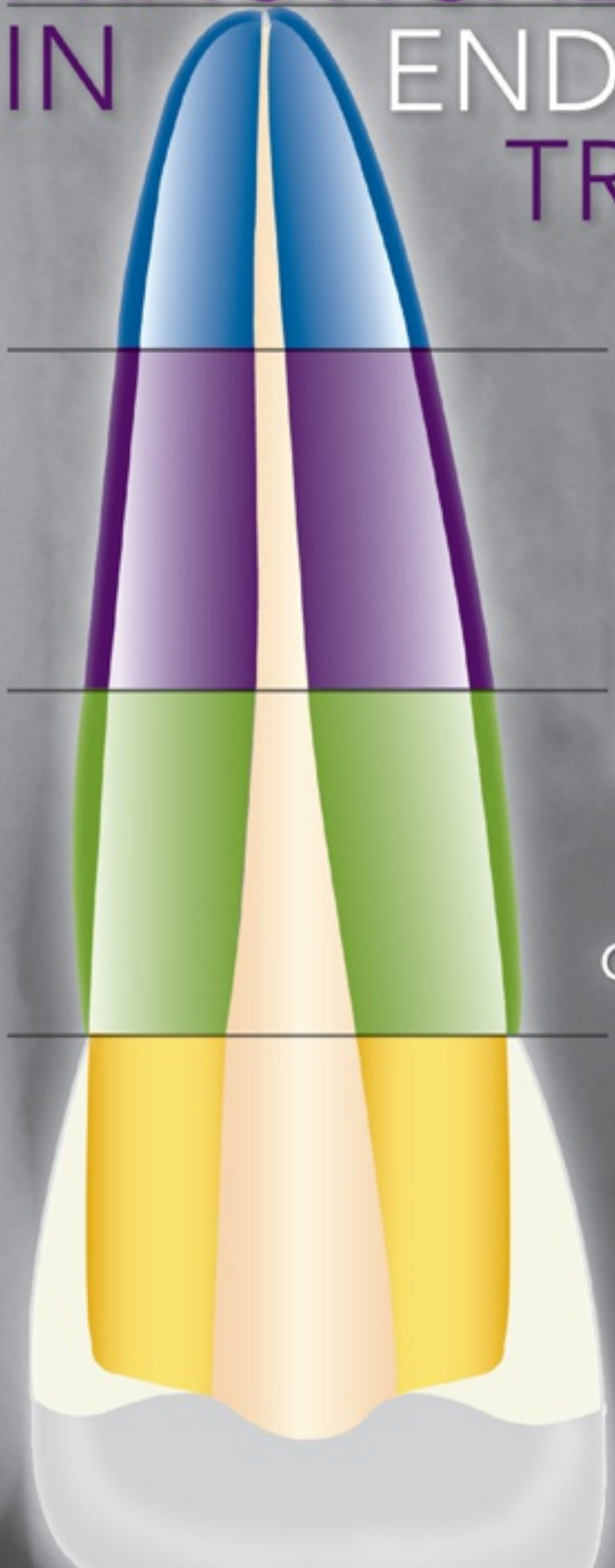
PRACTICAL LESSONS IN ENDODONTIC TREATMENT



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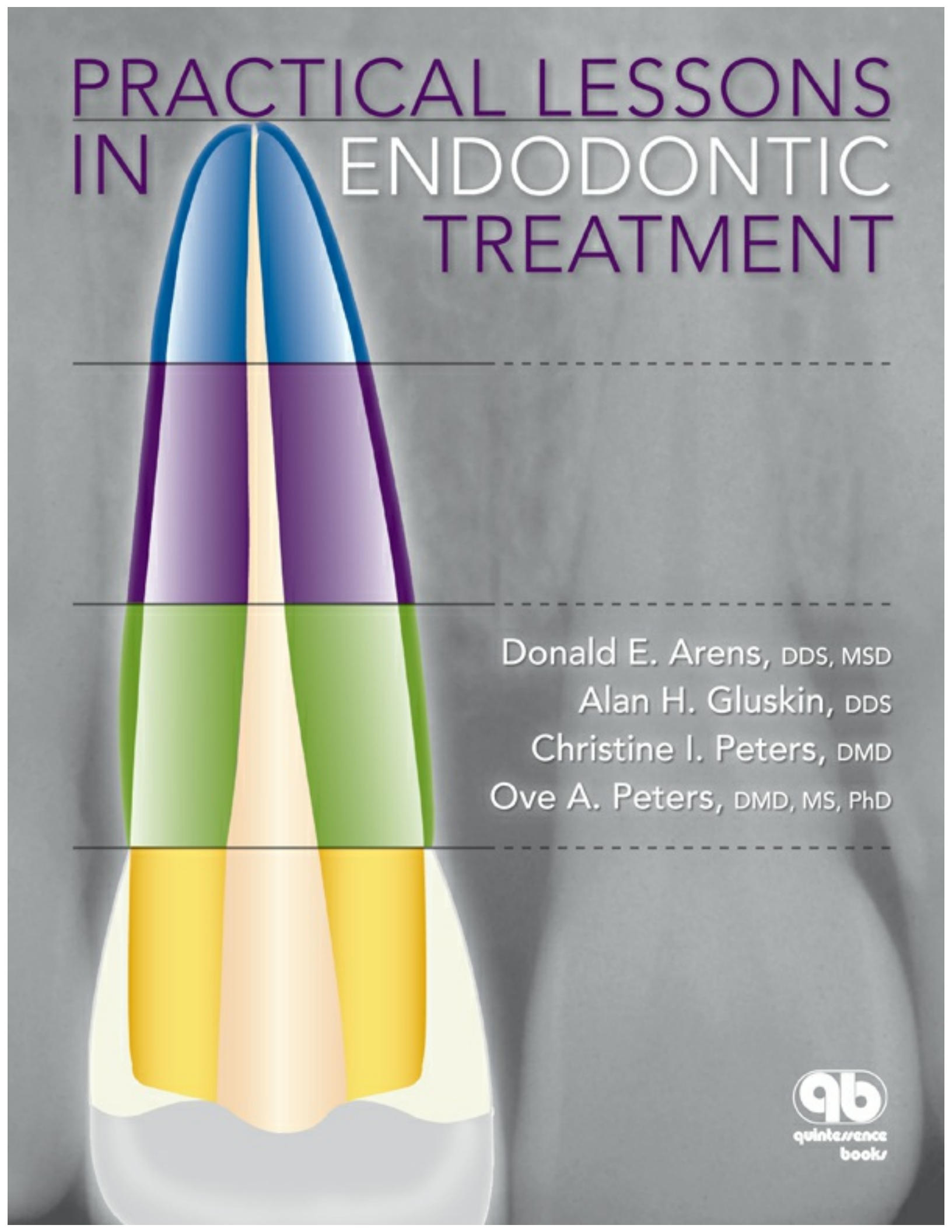

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Practical Lessons in Endodontic Treatment

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Preface

Contemporary endodontic therapy is based on a sound scientific foundation, but its clinical success is largely dependent on how well clinicians access, clean, shape, disinfect, and seal root canals. This text is first and foremost a practical manual, not a reference book. While we refer to the literature as necessary to corroborate and/or reinforce concepts with scientific evidence, we focus on the essential, practical strategies for providing reliable nonsurgical endodontic care to patients.

Traditional endodontic textbooks often overwhelm readers with the amount of theoretical information presented. In this book, every effort has been made to provide straightforward discussions that emphasize key concepts. Following the tradition of this book's popular predecessor, *Practical Lessons in Endodontic Surgery* (Quintessence), we have adopted an easy-to-use, workbook approach to nonsurgical root canal therapy. Each lesson presents a different component of endodontic therapy and includes simple step-by-step clinical procedures and concise tips and recommendations. Readers will find helpful solutions to myriad endodontic challenges.

With more than of 150 years of combined experience both in developing and teaching graduate endodontic programs and in managing private practices, we have had ample opportunity to critically assess and validate all the procedural changes and technologic improvements demonstrated in the text. We have integrated the latest clinical concepts and technologies with tried-and-true strategies in the diagnosis, treatment planning, and execution of endodontic therapy. Our goal is to assist dentists and their support staffs in the implementation of technologic and procedural recommendations that simplify daily routine, build confidence and skill, enhance treatment outcomes, and make root canal treatment more rewarding, profitable, and fun.

We wish to thank our families for their advice, understanding, and encouragement during the preparation of this manuscript and throughout the countless hours in editing and organization of the text. Few projects of this scope are achieved without the selfless devotion of family. It is to our families that we fondly dedicate this book.

PART ONE
Examination and Diagnosis

LESSON 1

Medical Evaluation and Antibiotic Precautions

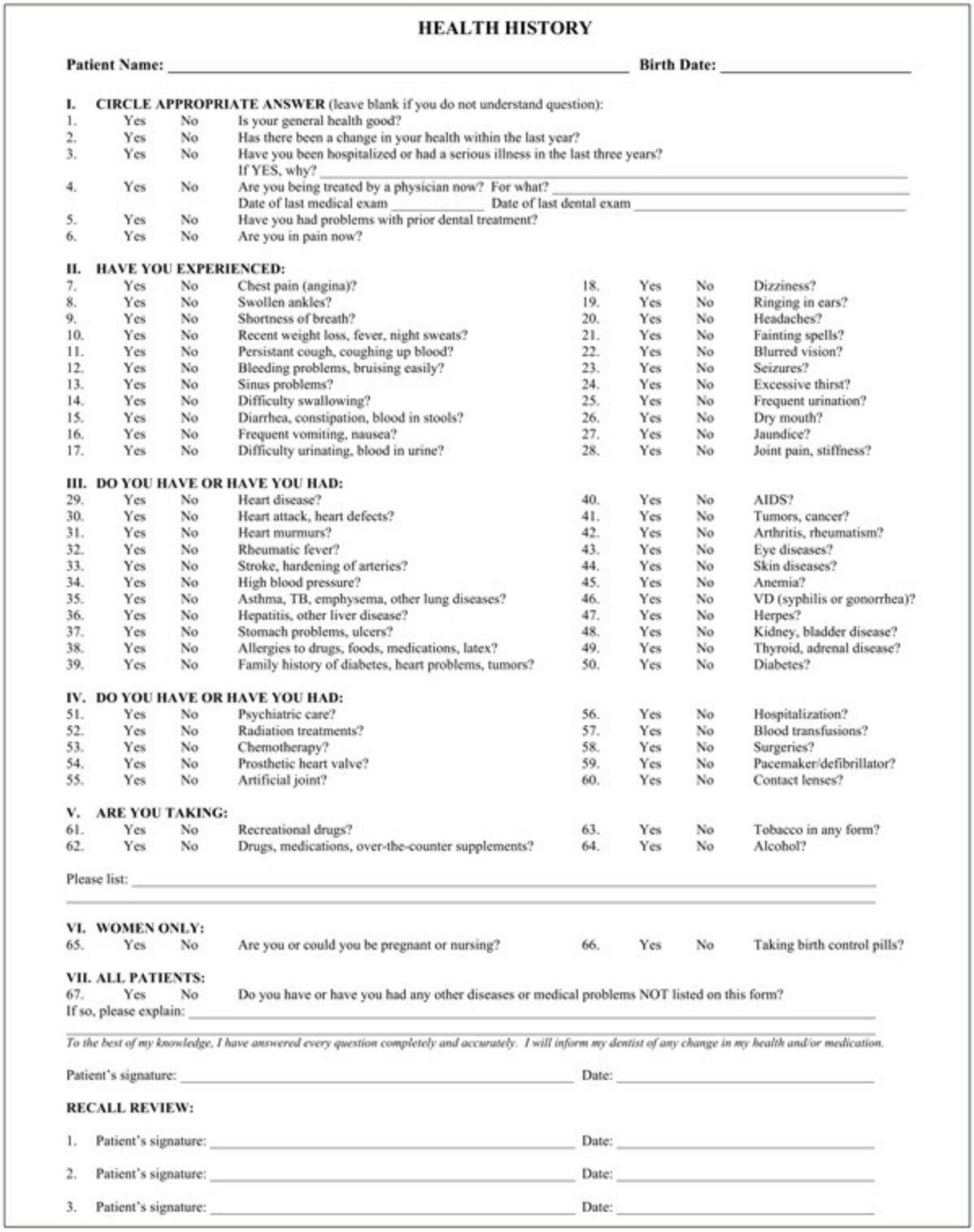
OBJECTIVE

To identify and respond to health issues that might compromise endodontic therapy.

OFFICE POLICY

A patient must complete a comprehensive medical/dental questionnaire before any dental treatment is initiated (Fig 1-1). It is the responsibility of the attending doctor to:

- Ascertain the responder's authority to make the patient's health care decisions if the responder to the questionnaire is someone other than the patient.
- Question the significance of all *yes* responses in the questionnaire.
- Ask the patient if any new medical problems have arisen since the last appointment.
- Verify the date of the patient's last appointment. No questionnaire should be considered valid if 1 year or more has passed since the patient's last appointment.



HEALTH HISTORY

Patient Name: _____ **Birth Date:** _____

I. CIRCLE APPROPRIATE ANSWER (leave blank if you do not understand question):

1. Yes No Is your general health good?
2. Yes No Has there been a change in your health within the last year?
3. Yes No Have you been hospitalized or had a serious illness in the last three years?
   If YES, why? _____
4. Yes No Are you being treated by a physician now? For what? _____
   Date of last medical exam _____ Date of last dental exam _____
5. Yes No Have you had problems with prior dental treatment?
6. Yes No Are you in pain now?

II. HAVE YOU EXPERIENCED:

7.	Yes	No	Chest pain (angina)?	18.	Yes	No	Dizziness?
8.	Yes	No	Swollen ankles?	19.	Yes	No	Ringing in ears?
9.	Yes	No	Shortness of breath?	20.	Yes	No	Headaches?
10.	Yes	No	Recent weight loss, fever, night sweats?	21.	Yes	No	Fainting spells?
11.	Yes	No	Persistant cough, coughing up blood?	22.	Yes	No	Blurred vision?
12.	Yes	No	Bleeding problems, bruising easily?	23.	Yes	No	Seizures?
13.	Yes	No	Sinus problems?	24.	Yes	No	Excessive thirst?
14.	Yes	No	Difficulty swallowing?	25.	Yes	No	Frequent urination?
15.	Yes	No	Diarrhea, constipation, blood in stools?	26.	Yes	No	Dry mouth?
16.	Yes	No	Frequent vomiting, nausea?	27.	Yes	No	Jaundice?
17.	Yes	No	Difficulty urinating, blood in urine?	28.	Yes	No	Joint pain, stiffness?

III. DO YOU HAVE OR HAVE YOU HAD:

29.	Yes	No	Heart disease?	40.	Yes	No	AIDS?
30.	Yes	No	Heart attack, heart defects?	41.	Yes	No	Tumors, cancer?
31.	Yes	No	Heart murmurs?	42.	Yes	No	Arthritis, rheumatism?
32.	Yes	No	Rheumatic fever?	43.	Yes	No	Eye diseases?
33.	Yes	No	Stroke, hardening of arteries?	44.	Yes	No	Skin diseases?
34.	Yes	No	High blood pressure?	45.	Yes	No	Anemia?
35.	Yes	No	Asthma, TB, emphysema, other lung diseases?	46.	Yes	No	VD (syphilis or gonorrhea)?
36.	Yes	No	Hepatitis, other liver disease?	47.	Yes	No	Herpes?
37.	Yes	No	Stomach problems, ulcers?	48.	Yes	No	Kidney, bladder disease?
38.	Yes	No	Allergies to drugs, foods, medications, latex?	49.	Yes	No	Thyroid, adrenal disease?
39.	Yes	No	Family history of diabetes, heart problems, tumors?	50.	Yes	No	Diabetes?

IV. DO YOU HAVE OR HAVE YOU HAD:

51.	Yes	No	Psychiatric care?	56.	Yes	No	Hospitalization?
52.	Yes	No	Radiation treatments?	57.	Yes	No	Blood transfusions?
53.	Yes	No	Chemotherapy?	58.	Yes	No	Surgeries?
54.	Yes	No	Prosthetic heart valve?	59.	Yes	No	Pacemaker/defibrillator?
55.	Yes	No	Artificial joint?	60.	Yes	No	Contact lenses?

V. ARE YOU TAKING:

61.	Yes	No	Recreational drugs?	63.	Yes	No	Tobacco in any form?
62.	Yes	No	Drugs, medications, over-the-counter supplements?	64.	Yes	No	Alcohol?

Please list: _____

VI. WOMEN ONLY:

65. Yes No Are you or could you be pregnant or nursing? 66. Yes No Taking birth control pills?

VII. ALL PATIENTS:

67. Yes No Do you have or have you had any other diseases or medical problems NOT listed on this form?

If so, please explain: _____

To the best of my knowledge, I have answered every question completely and accurately. I will inform my dentist of any change in my health and/or medication.

Patient's signature: _____ Date: _____

RECALL REVIEW:

1. Patient's signature: _____ Date: _____
2. Patient's signature: _____ Date: _____
3. Patient's signature: _____ Date: _____

Fig 1-1 Example of a comprehensive Health History Form.

INACCURATE QUESTIONNAIRE

It is the responsibility of the attending doctor to be constantly aware of hidden signs of disease(s) that may be unknown to the patient or accidentally or intentionally withheld by the patient, such as:

- Fire red (flushed) or ashy pale (pallor) skin color and/or ankle and leg swelling that might indicate an undiagnosed cardiac problem, such as high blood pressure or congestive heart failure, or severe alcoholism.

- A yellowish or bronze skin color that might indicate liver, kidney, or endocrine impairment.
- Facial blemishes, gingival and/or palatal sores, and exposed needle marks that might indicate the patient is an alcohol or drug abuser and as such could be a carrier of hepatitis or a sexually transmissible disease.
- Facial varicosities that might indicate drug and alcohol abuse that could interfere with the dynamics (intensity and duration) of a local anesthetic.

Dentists should also be alert to patients seen on an emergency basis where the offending tooth has all the appearances of having been treated multiple times in the past, such as an excessively large endodontic access opening and overly aggressive canal enlargement. This may very well indicate that the patient is seeking emergency treatment only to acquire a prescription for pain medication. This situation is even more suspicious when the patient requests a specific pain medication.

Whatever the circumstances, a physician consultation request is always an option (see Physician Release Form, Fig 10-1).

RISK FACTOR CONCERNS

Based on the responses to both written and verbal questioning, patients should be mentally categorized into risk levels, and the treatment decision(s) should be based on the demands of that risk. The most serious and dangerous threat to a patient following a dental procedure is infective endocarditis (IE), which is more commonly called *bacterial endocarditis*.

Etiology

Bacteria enter the bloodstream (bacteremia), lodge on abnormal heart valves or other damaged heart tissue, and stimulate an infection of the inner lining of the heart. Only certain bacteria are prone to cause IE, and those microorganisms are normally found in the mouth and upper respiratory system.

Who is at risk

According to the American Heart Association (AHA), the American Dental Association (ADA), the Infectious Diseases Society of America (IDSA), and the Pediatric Infectious Diseases Society (PIDS), anybody is subject to IE, and IE is just as likely to occur from an everyday activity as it is from a dental procedure (AHA, *Circulation*, April, 2007).

Prevention

Use of a prophylactic regimen of antibiotics can help prevent IE.

Caution

According to the AHA, the risk of taking preventive antibiotics often outweighs the benefits. As such, the AHA does not recommend the injudicious use of broad prophylactic regimens of antibiotics for every patient.

The AHA conclusion

Prophylactic antibiotics should be reserved for moderate- to high-risk patients who might experience the gravest outcomes (eg, death) if left unprotected. The AHA guidelines are based on its comprehensive risk factor studies and are not intended to represent the standard of care for dentistry or to be a substitute for a dentist's clinical judgment (Table 1-1).

Table 1-1 **AHA recommendations of prophylactic antibiotic regimens for IE**

Situation	Agent	Regimen
Standard: For the general population	Amoxicillin	Adults: 2.0 g, children: 50 mg/kg Sig: orally 1 h before procedure
For patients unable to take medication orally	Ampicillin	Adults: 2.0 g, children: 50 mg/kg Sig: IM or IV 30 minutes before procedure
For patients with a penicillin allergy	Clindamycin	Adults: 600 mg Sig: orally 1 h before procedure

IM = intramuscular; IV = intravenous; Sig = write on label.

RISK LEVELS

Negligible risks

The AHA does *not* recommend prophylactic antibiotics for patients that present to the office with the following conditions:

Cardiac conditions

• Repaired congenital heart defects
• Innocent heart murmurs
• History of rheumatic fever but no valve disease
• Coronary graft beyond a 6-month healing period
• Mitral valve prolapse, without valvar regurgitation
• Kawasaki syndrome, without valvar regurgitation
• A cardiac pacemaker/defibrillator (intravascular or epicardial)

Over-the-counter blood thinners

Patients taking over-the-counter blood thinners, such as aspirin, do not normally present a problem for routine endodontic procedures. Local coagulate methods, including pressure, epinephrine pellets (Epidri, Pascal), ferric sulfate products such as Stasis (Gingi-Pak) and Cuttrol (Icthys Enterprise), and calcium sulfate, are usually satisfactory in controlling hemorrhage even when the endodontic procedure involves a surgical intervention.

Pregnancy

- To avoid the possibility of inducing labor, endodontic care during the first trimester should be performed on an emergency basis only, and the treatment procedure and chair time at that appointment should be kept to a minimum.
- If the endodontic treatment is an elective procedure, it is wise to perform the service when the patient is in the second trimester.
- Antibiotics should be used sparingly, sedatives should be avoided, and the quantity of a vasoconstrictor used during treatment should be kept to a minimum.

Apprehension and anxiety

- Additional appointment time will be required to thoroughly explain the need and reasons for the endodontic procedure(s).
- Once it becomes apparent the patient is excessively fearful of the procedure, it is wise to suggest the use of a mild preoperative sedative.
- The use of rubber dam must be carefully and thoroughly explained, and to reduce the possibility of a sudden claustrophobic panic attack, the eyes and nose (airway) must be kept clear at all times.
- Though reassurance throughout the procedure will have a calming effect, the doctor and the assistant must be ever prepared for a patient's sudden, even violent body and hand movements provoked by the stress of the procedure.

Neurologic issues

Epilepsy, palsy, Parkinson disease, facial and head tics, dementia, or the convulsive and/or

emotionally disturbed patient.

- These patients are best served by prescribing appropriate preoperative sedatives or hypnotics, not prophylactic antibiotics.
- The doctor and assisting staff must be on constant alert for sudden patient movement(s) that could cause an inadvertent procedural accident.
- Referral is always an option.

Moderate risk

The AHA *does* recommend a prophylactic regimen of antibiotics for the following risk conditions:

Cardiac impairment

- Acquired valvar dysfunction (eg, rheumatic heart disease)
- Cardiomyopathy
- Mitral valve prolapse with valvar regurgitation and/or thickened leaflets

Prescription blood thinners

Patients on prescribed blood thinners such as Coumadin (Bristol-Myers Squibb) or any other warfarin-related drug are at moderate risk with routine endodontic and restorative procedures. As such, it is incumbent upon the attending doctor to make sure the international normalized ratio (INR) number is greater than 2.5 at the time an endodontic procedure is initiated! Do not take patients at their word for the prothrombin time (PT) number unless they show you a document of the date and test result.

The anticoagulant therapy of a Coumadin patient should never be discontinued without the permission of the patient's attending physician. As such, a Coumadin patient's physician should be contacted and asked to respond to the following questions before any treatment is initiated:

> I am planning to do a (routine/surgical) endodontic procedure on (patient's name). I understand you have (patient's name) on Coumadin therapy (warfarin). Do you know this patient's current INR count, or do you wish to test this patient at this time? If you discontinue the patient's Coumadin therapy, how many days should I wait until I can continue with my treatment plan?

An account of the verbal consultation (physician's name and phone number, date, time, responses to all questions, advice, and course and direction of action) should be recorded in the patient's chart. For even greater liability protection, a follow-up written response from the physician should be requested (see Physician Release Form, Fig 10-1).

Bleeding disorders

- Hemophilia, leukemia, neutropenia, and leukopenia; consult (both orally and in writing) with the attending physician. The missing factor(s) in a patient with hemophilia must be determined and replaced before any treatment is initiated.
- Treatment is best performed in a hospital setting, where an ample supply of blood is available and an emergency transfusion can be administered.
- Referral is always an option.

Respiratory conditions

Asthma, emphysema, severe bronchitis, smoker's cough, history of miner's (black) lung disease, tuberculosis, or lung cancer.

- Prescribing a mild sedative and keeping the length of treatment time short can help minimize the threat of a patient's hyperventilating and becoming anoxic during treatment (see lesson 6).
- Every effort should be made to keep the patient's airway open throughout the procedure. This is particularly true when applying and maintaining a rubber dam.
- Oxygen should be available at all times and administered whenever a patient's breathing becomes noticeably stressed.
- A physician should clear any patient having a history of tuberculosis or having had a lung removed before treatment is initiated.

Infectious diseases

- Patients with a known infectious disease require a physician consultation, barrier control, and appropriate (physicianprescribed) antibiotics.
- All office personnel involved in the treatment of such patients should be current with their hepatitis A and B inoculations (see lesson 12).

Immunologic disorders: Mononucleosis, Epstein-Barr

- The attending physician should be consulted, and an appropriate physician-prescribed antibiotic regimen should be administered.
- These patients are most receptive to treatment early in the day when they are least tired.

Endocrine imbalances

Addison disease, hypothyroidism, hyperthyroidism.

- The attending physician should be consulted.
- Appropriate physician-prescribed sedatives and/or antibiotics should be administered.

Uncontrolled diabetes

- The attending physician should be consulted.
- An appropriate physician-prescribed antibiotic regimen should be administered.
- The patient and the doctor should be aware that, depending on the severity of the diabetes, response to treatment (healing) could be delayed.

Hepatitis and HIV

- The attending physician should be consulted.
- The doctor and all attending office personnel should be current with their hepatitis A and B vaccinations.
- The doctor and the assisting staff must strictly adhere to the universally accepted infection-control protocol.
- An accidental "stick(s)" to a doctor, patient, or staff member demands immediate attention; the wound site must be washed with soap and rinsed with alcohol, Betadine (Purdue Pharma), or hydrogen peroxide. The stick incident must be recorded in both the patient's chart and the employee file (see lesson 12).

Osteoradionecrosis

Because the loss of vascularity inhibits a normal inflammatory response, which in turn impairs healing, a positive prognosis for endodontic treatment cannot be expected or offered.

High risk

The AHA *does* recommend a prophylactic regimen of antibiotics for patients who present to the office with a medical condition(s), the gravity of which presents the greatest of risks (ie, death). The following conditions demand a physician consultation and strict adherence to the AHA recommendations for preventing IE:

Severe cardiac impairment

- Severe hypertension. The danger of this condition lies in the possibility of sudden stroke or a cardiovascular crisis (eg, uncontrollable hemorrhage during treatment).
- A recent (within 12 months) myocardial infarct. With this situation, there is a danger of stress-related relapse, coagulant antagonisms, or hemorrhage during the procedure.
- A history of bacterial endocarditis.
- Prosthetic cardiac valves, including bioprosthetic and ho-mograft valves.
- Complex cyanotic congenital heart disease (eg, single ventricle states, transposition of the great

arteries, tetralogy of Fallot).
- Surgically constructed systemic pulmonary shunts or conduits.
- Most congenital cardiac malformations other than those listed for moderate- and negligible-risk patients.
- Acquired valvar dysfunction (eg, rheumatic heart disease).
- Mitral valve prolapse with valvar regurgitation and/or thickened leaflets.

Controversial risks

- Judgment, the dentist's choice: Antibiotic treatment decisions for endodontic cases are often based on the subjective opinion of the treating dentist—that is, evaluation of the patient's medical and dental history, clinical signs and symptoms, advice from the patient's physician, personal interpretation of the literature, recommendations of the ADA and AHA, and even past experience(s).
- The recommendation of the ADA Division of Science and the AHA: "To reduce the risk of bacterial endocarditis the dentist should administer antibiotics to heart patients undergoing endodontic therapy where instrumentation goes beyond the apex or when apical surgery is necessary."
- Conclusion: It is the prerogative of the attending dentist to prescribe an antibiotic regimen for a patient if he or she considers the reason to prescribe the drug is in the best interest of the patient and the rationale behind the decision is justifiable and defensible.

Prosthetic joint replacement

In 2003, an expert panel convened by the ADA, the American Academy of Orthopaedic Surgeons (AAOS), and infectious disease specialists updated their 1997 recommendations and concluded:
- Prophylactic antibiotic therapy is not indicated for patients with pins, plates, or screws, nor is it routinely indicated for most dental patients with total joint replacements.
- Prophylactic antibiotic therapy is advisable for a small number of patients who may be at risk of experiencing a hematogenous total joint infection. They are those with:
  - Inflammatory arthropathy (eg, rheumatoid arthritis, systemic lupus erythematosus)
  - Disease-, drug-, or radiation-induced immunosuppression
  - Insulin-dependent (type I) diabetes
  - A history of prior prosthetic joint infections
  - Physical weakness, feebleness, and malnourishment
  - Hemophilia

Drug interactions

Today, clinicians have the monumental task not only of being aware of the actions and reactions of the plethora of Food and Drug Administration (FDA)–cleared drugs but also of understanding the chemical interactions of the nonapproved FDA herbal medicine supplements. As such, the Patient's Medical Questionnaire must be specific with regard to asking patients to include both prescription and nonprescription over-the-counter supplements.

For instantaneous information regarding the mode of action and biologic effects (synergisms and antagonisms) of all drugs, a current issue of the *Physicians' Desk Reference* (PDR), or a computer Internet drug link should be referenced:

- For prescription drugs: http://www.rxlist.com/script/main/hp.asp;http://clinicalpharmacology.com
- For a review of diseases: http://library.dialog.com/bluesheets/html/bl0304.html
- For nutraceuticals: http://www.nutraceuticalsworld.com;http://www.ana-jana.org/

LEGAL PERSPECTIVES REGARDING THE USE OF ANTIBIOTICS

The courts recognize that each professional is entitled to and responsible for his or her own treatment decisions as long as the decision is based on sound principles that are reasonable, defensible, and in the best interest of the patient. However, the courts also recognize that patients have the right to make decisions regarding their own health and welfare, and those rights may at times conflict with the dentist's rights. The following examples represent such situations.

Case 1: Physician vs dentist recommendation

The patient brings a recommendation for premedication from his or her physician, and the dentist disagrees with the physician. Should the dentist ignore the recommendation or simply defer to the physician's judgment? "Neither approach is prudent," says Kathleen M. Todd, JD, Associate General Counsel, Division of Legal Affairs, ADA, and she supports her position as follows: "It is incumbent upon the dentist to inform the patient of all reasonable treatment options and to make sure the patient clearly understands the risks and benefits of each."

Of particular importance in this case would be an explanation of how and why his or her recommendation(s) might differ from that of the physician. However, if after the case is presented the patient insists the dentist follows the physician's advice, Todd states: "The greatest risk for the dentist would be to go against his or her better judgment." As such, the dentist is under no obligation to render a treatment that he or she feels is not in the patient's best interest. To avoid being accused of abandonment, a referral to another practitioner would be the best solution. All of the discussions, explanations, and decisions should be recorded, signed, and included in the patient's record.

Case 2: Patient refusal to follow dentist's recommendation

The dentist prescribes a regimen of antibiotics for a patient. After the case is presented, the patient refuses to take the medication. Todd states that it is incumbent upon the dentist to clearly explain to the patient that, in his or her opinion, "not taking the prescribed antibiotics places the patient at grave risk of experiencing a bacterial endocarditis." If the patient still chooses not to take the recommended antibiotics, the best solution is to refer the patient to another practitioner. All of the discussions, explanations, and decisions should be recorded, signed, and included in the patient's record.

Do no harm. Of greatest risk is performing a service for a patient that compromises one's beliefs and integrity. A referral is always a preferable option.

LESSON 2

Clinical Examination and Assessment of an Endodontic Patient

OBJECTIVE

To collect and evaluate examination data for the purpose of reaching a diagnosis and developing a treatment plan.

INTRODUCTION

The success of any endodontic treatment plan depends on the health of the pulp and periradicular bone. To determine those conditions, a thorough, systematic, and standardized clinical and radiographic evaluation regimen must take place. Though this lesson focuses on the specifics of comprehensive examination of a patient who is experiencing a nonemergency pulpal or periradicular problem that is not immediately diagnosable, there are times when the urgency of treatment requires immediate attention.

TREATMENT REQUIRING IMMEDIATE ATTENTION

Traumatic pulp exposure

In this type of case, the patient was involved in an accident that fractures the crown of a tooth (teeth) and exposes the pulp(s). Once the superficial bleeding is arrested, the pulp exposure is obvious, and if the visual and radiographic examination reveals no further damage, the treatment options will be pulp cap, pulpotomy, or pulpectomy and concomitant root canal therapy. However, though few diagnostic tests are needed to determine the treatment plan, the records (for potential litigation purposes) of a trauma case must include a comprehensive assessment of the patient:

- A review of the patient's past and present health history
- The patient's physical condition at the time he or she arrived at the office (ie, indication[s] of other bodily injury)
- A review of the patient's past dental history to determine if there had been a prior injury to this tooth (teeth) that might affect prognosis
- A clinical evaluation and description of the appearance and condition of the soft (facial and mucosal) and hard (alveoli and bone) tissues approximating the injured tooth (teeth)
- A detailed explanation of the accident

The patient should be advised to see a physician. If the patient already has seen a physician, the physician's name, address, and phone number, and the date and time the patient was seen also should be recorded.

At this time, it is incumbent upon the dentist to discuss and explain in depth the treatment procedures that may be required at this visit, those procedures that will be necessary at a later date(s), the prognosis of the proposed treatment plan, other available options, the fact that a final restoration will be required sometime in the future (possibly by someone else), and an estimation of the fee(s). If the dental trauma from the accident involves more than the coronal aspect of the tooth (teeth) (eg, root fracture, alveolar or jaw fracture or displacement, lip and facial lacerations, uncontrollable bleeding), there is always the option to refer the patient to an oral surgeon or to the hospital emergency room.

All patient (guardian) and doctor comments, particularly about time frames and fees, should be recorded, and if the patient (guardian) agrees to the treatment plan, a consent to treat must be in writing and signed by all parties. Once the dentist has legal and binding informed consent, the treatment may ensue.

Inadvertent operative incident

During the course of excavating an extensively decayed tooth, the pulp might be exposed.

Best-case scenario

The clinical and radiographic evaluation of a carious tooth indicates or suggests that the pulp might be exposed during excavation. The patient is informed of the potential problem, and the treatment options—including a pulp cap, pulpotomy, pulpectomy and root canal therapy, or extraction—are

thoroughly discussed (see lessons 36, 37, and 38). The benefits, prognosis, future treatment needs, and fees are carefully explained. A treatment plan is mutually agreed upon, and consent is given to proceed (see lesson 10).

Worst-case scenario

The possibility that the pulp might be exposed during the excavation has not been preliminarily discussed with the patient, in which case treatment must be interrupted or aborted if and when the exposure occurs. The options, benefits, and fees must now be discussed at a cost of valuable office time, and the patient, under stress, is forced to make a decision that she or he may reconsider, regret, and challenge at a later time. The alternative is for the dentist to make a treatment decision without the patient's approval and permission. Both resolutions are expensive, time-consuming, and lend themselves to latent liability questions about consent, rights, and fees.

Emergency patient

The third situation involves a patient who is in pain and/or swollen who has either called for an appointment or walked into the office seeking immediate endodontic attention.

EXAMINATION SEQUENCE FOR THE ENDODONTIC PATIENT

The remainder of this lesson concentrates on the sequential phases of a comprehensive examination and assessment process that leads to a diagnosis and appropriate endodontic treatment plan.

Phase 1: Triage

Since the efficient use of production time is important to a successful practice, the evaluation of a patient should begin at the time a patient calls or visits the office. Beyond asking routine personal questions for the legal record (eg, name, address, phone number) (see lesson 5), a trained receptionist asking a series of specific questions can gather enough prediagnostic information not only to judge the urgency of the situation (work in today, see tomorrow, schedule at the earliest opportunity, seek advice from the doctor) but also to estimate the amount of chair time needed to provide the service. The following Triage Form (Table 2-1) is offered as a guide; with it the receptionist should be able to accommodate the patient, keep the office on schedule, and avoid the stress and chaos associated with falling behind and making scheduled patients wait!

Table 2-1	**Sample triage form***

Question	Answer	Response
1. Are you presently in pain?	NO	The receptionist is free to make an appointment on a day that is convenient for both the patient and the doctor.
	YES	The receptionist should proceed to question 2.
2. Is the tooth sensitive to cold or heat?	YES	This indicates the pulp is most likely alive (vital), and treatment will require the use of an anesthetic. The receptionist should proceed to questions 3, 7, and 4, in that order.
	NO	This indicates the tooth is possibly necrotic, in which case the receptionist should proceed to questions 5, 6, 7, and 4, in that order.
3. On a scale of 1 to 10, with 10 being the worst, what would you judge your pain?	0–4	Being sensitive to cold or heat at this level indicates a mild pulpitis. If there is no time available on this day, an appointment within the next 24 to 72 hours should be satisfactory. The receptionist may, with the doctor's permission, recommend that the patient take two acetaminophen or ibuprofen every 6 hours.
	5–10	Being sensitive to cold or heat at this level indicates an irreversible (acute) pulpitis. It would be best for the patient to be seen that day. To determine the amount of appointment time needed, the receptionist should proceed to question 4.
		For the possibly necrotic tooth (no sensitivity to cold or heat), pain level is less important than are the responses to questions 5 and 6, and the receptionist should proceed to these questions next.

4. Is the tooth that is hurting a front or a back tooth?	FRONT	For an anterior tooth, the patient and doctor will probably need a 30- to 40-minute appointment.
	BACK	For a posterior tooth, the patient and doctor will probably need a 45- to 60-minute
5. Are you swollen and/or do you have a fever, and is the particular tooth tender when you bite on it?	YES	If the patient is swollen, a particular tooth is tender to bite on, and the patient has a fever, the patient is suffering from an active acute periapical inflammation and needs to be seen that day. The receptionist should proceed to question 6 to determine the urgency and to question 4 to determine the time needed
	NO	Indicates a chronically infected tooth and, if no time is available that day, an appointment (time to be determined by question 4) within the next 24 to 72 hours should be satisfactory.
6. Please describe exactly where you are swollen.	If the swelling is located in...	•The upper posterior part of the face in front of the ear, it could mean a maxillary molar infection that is draining into the temporal/pterygomandibular space(s), which places the brain (via the plexus) in peril (possible brain abscess). •The face around and/or under (possibly shutting) the eye, it could indicate an infraorbital-space infection caused by a diseased canine or premolar. Drainage via the unshunted angular vein is critical (possible cavernous sinus thrombosis). •Under the chin, the tongue, or the posterior part of the lower jaw, it could be caused by any mandibular tooth. Drainage into one or all of the

		deep submental, submandibular, and/or sublingual spaces could raise the tongue, close off the airway (Ludwig angina), and require an emergency tracheotomy. •If any patient calls with a swelling as described above, it is essential the receptionist advise the doctor of the infection location. The patient should be seen immediately or referred.
7: Has this tooth ever had a root canal?	NO	The receptionist may make an appointment based on the conditions previously mentioned in questions 1 through 6.
	YES	If it is a retreatment, just opening the tooth without establishing patency will be ineffective. The options are to access, negotiate a file to the apex, incise the swelling, trephine the bone, insert a wick drain, and prescribe an appropriate antibiotic (see lesson 35), or to refer the patient.

*Referral is a viable option with regard to the management and treatment of any emergency case.

Phase 2: Initial office visit

By reviewing the triage form, asking leading and meaningful questions about signs and symptoms, and listening intently to the verbal descriptors of a patient's problem in a compassionate manner, the doctor not only demonstrates personal concern for the patient's welfare and establishes a rapport that will set the tone for the balance of treatment, he or she also learns to separate differentials that help lead to a diagnosis.

Phase 3: Evaluating the patient's medical and dental history

Any health condition(s) mentioned on the medical history form that might influence the outcome of treatment should be questioned and the responses noted in the patient's record. If doubt exists with regard to health issues, the situation should be brought to the patient's attention and counseling sought

from the family physician(s) before initiating treatment. Reviewing the dental history with the patient may expose reasons for the symptoms, including a recent restorative procedure, a prior endodontic or periodontal treatment, trauma, or perhaps even a medical treatment such as a sinus scope or radiation therapy.

Phase 4: Interpreting the patient's pain—Listen, listen, listen!

The presence, location, and patient description of pain are crucial. If the pain is focused, the patient can not only pinpoint the arch but also, as a result of past and present thermal sensitivity, point directly to the offending tooth. A few specific tests can quickly and easily confirm a diagnosis.

If the inflammatory by-products of a necrotic tooth have built internal (pulpal) pressure sufficient to elevate the tooth in the socket, the patient will be able to pinpoint the offending tooth by biting down. Therefore, the diagnosis may only require the doctor to instruct the patient to bite down on a specifically placed orangewood stick or Tooth Slooth (Professional Results) to pinpoint the problem. The Tooth Slooth is an excellent instrument to test specific cusps when a coronal fracture is suspected. A few tests can quickly and easily confirm a diagnosis.

If the patient claims the pain is vague and diffuse, the doctor may be able to target only the arch. In instances of referred pain (eg, a nonodontogenic malignant metastasis, sinus inflammation, cavitational osteomyelitis), the patient must be questioned about the painful experiences and the sequences and episodes that have led to this appointment: Does the pain wake you up at night? Is there any one area in the mouth that seems to be more of a problem? How long and how often have you had this pain? Does any medication relieve the pain? Have you seen other doctors? What were their recommendations? Numerous differentials should be considered, and none should be excluded until all of the facts accumulated over the entire examination have been collated and assessed.

Since there is never any justification to initiate a treatment plan until the patient and the doctor agree on the origin of the pain, your choices are to offer the patient compassion; to admit the diagnosis cannot be confirmed at this time; and to suggest the patient return in several days or weeks to repeat the tests at which time, hopefully, the problem will have localized. You may also consider referring the patient.

Phase 5: Visual and palpation examination of intraoral soft tissue

The mucosal and facial tissues should be palpated to determine the center of the inflammation and/or the spread of infection and tenderness. All findings and differentials must be recorded. Look for bumps, lumps, enlarged lymph nodes, and so forth (Fig 2-1). The buccal and lingual mucosa and gingival tissues must be visually inspected, preferably under magnification, in search of a draining sinus tract (fistula). If a sinus tract is discovered, a No. 35 gutta-percha cone or larger should be inserted into the tract and a radiograph taken to trace and confirm the source of the infection (ie, periodontal or endodontic) (Fig 2-2).

A swollen gingival crest and papillae (hyperplastic granulation tissue) that spontaneously bleed upon touch may be indicative of long-term irritation from poor oral hygiene, periodontal pocket drainage, crown or root fracture, caries, poor restorative margins, food packing, or a more serious non-odontogenic medical problem such as anemia, leukemia, or hemophilia. The patient's facial features should be observed and evaluated for asymmetry, swelling, redness, and indications of nerve damage (eg, stroke, Bell palsy, amyotrophic lateral sclerosis, severe alcoholism) (Fig 2-3).

Periodontal pocket depths may indicate more than periodontal disease; a long narrow one-sided deep pocket could indicate a vertical root fracture or a diseased lateral canal (Fig 2-4).

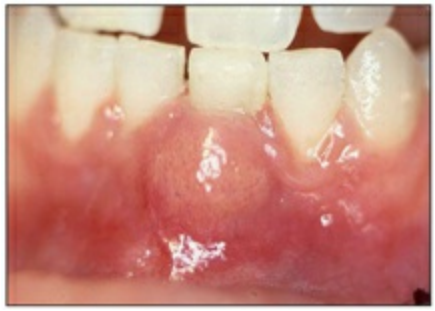


Fig 2-1 Intraoral swelling and abscess originating from a mandibular incisor.

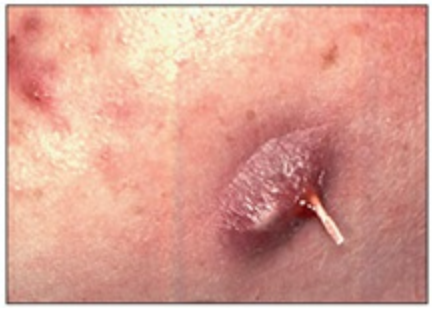


Fig 2-2 Extraoral sinus tract draining from a mandibular left molar.

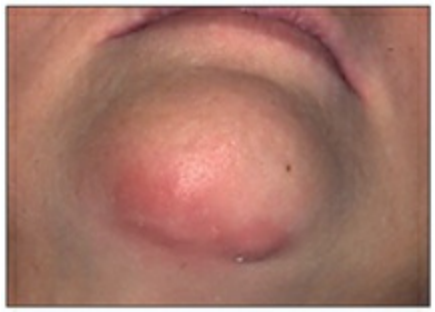


Fig 2-3 Extraoral swelling in the sub-mental area.

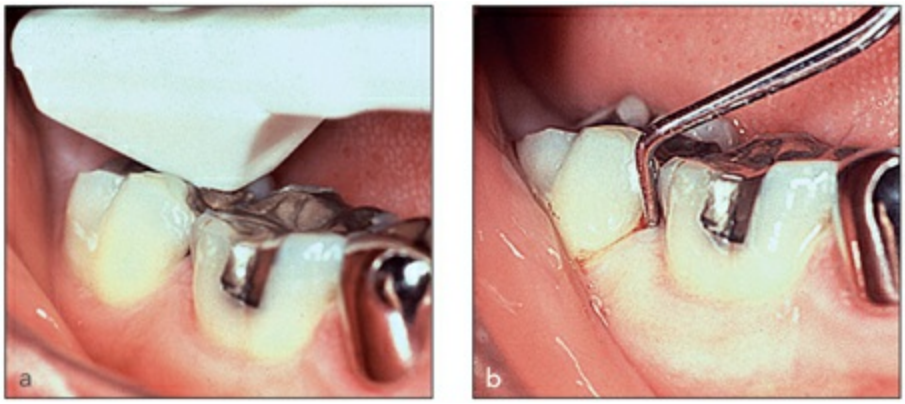


Fig 2-4 *(a)* Diagnosis of a cracked cusp in a mandibular right molar using a Tooth Slooth. *(b)* Periodontal probing confirms a deep vertical pocket associated with the tooth seen in Fig 2-4a.

Phase 6: Examination of superficial intraoral hard tissue

Each tooth within the proximity of the suspected problem tooth as well as the problem tooth itself should be examined under intense illumination and magnification to detect cracks, leaking restorations, caries, and so forth (Fig 2-5). All findings and differentials must be recorded. Painting the tooth surface with methylene blue helps define fracture lines, decay, and the defective borders of restorations. New caries detection devices help identify the presence and depth of nonvisible caries.

A deep red, rust, blue, or black discoloration of the crown is a positive indication that the microcirculation of the pulp has ruptured (probably due to trauma) and the trapped intrachamber blood is in a stage of degeneration. If such discoloration is present, the patient should be questioned about recent or past injuries. If a traumatic injury is admitted to or is suspected, the involved jawbone and dental alveoli (teeth) should be grasped and gingerly forced lingually and buccally to ascertain mobility to either confirm or eliminate reattachment.

It is always wise to check occlusion, particularly when the patient is complaining of pain in the vicinity (quadrant) of a tooth that has been recently restored.

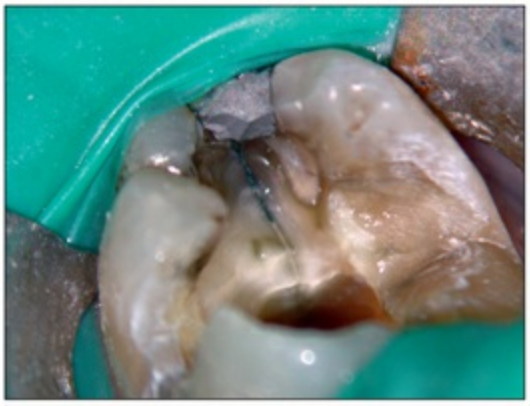


Fig 2-5 Patient presented in pain with multiple suspect teeth. Removal of the restoration in a mandibular molar revealed a crack across the floor of the chamber. Observation through a microscope showed the crack directed down the distal canal. (Image courtesy of Dr Brett A. Rosenberg, Jupiter, FL.)

Phase 7: Transillumination of the hard tissue

A gray, blue, or black color might indicate a blood infiltrate and hemostasis within the pulp chamber and the dentinal tubules or a corroding metallic restoration. A yellow or brown reflection from an unrestored crown often represents a past trauma or physiologically mineralized, nonpathologic obliteration of the root chamber and canal.

Pharmacologically affected (ie, tetracycline-stained) teeth may vary in color from yellow to black, and their drug fluorescence and etiology may be verified by using an ultraviolet light or a Wood lamp. Transillumination (in lieu of a microscope) not only exposes crazes and cracks but also aids in identifying their depths (Fig 2-6). All findings and differentials must be recorded.

Fig 2-6 Transillumination of a recently traumatized incisor demonstrating deep and superficial cracks in the enamel.

Phase 8: Clinical testing

The electric pulp test is the standard sensitivity test used to determine the presence or absence of vital pulp tissue (Fig 2-7). The electric testing systems are only reliable in determining if the tooth is vital or necrotic. The data gathered with these systems (particularly when the target tooth has been restored) are best supported with other corroborating information. However, several factors influence the tests' accuracy and reliability, such as the presence of newly and/or heavily restored teeth (large amalgams and gold or ceramic crowns), pulp-capped teeth, and recently injured (subluxated) teeth. Though the results of these tests may not always provide all the pieces of the puzzle, each patient's response is extremely relevant when added to all the other examination data collected, collated, recorded, and evaluated.

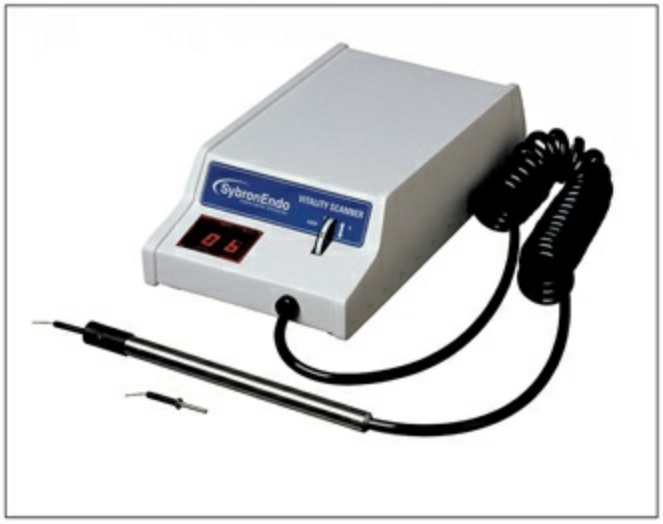


Fig 2-7a Electric pulp tester (SybronEndo).

Fig 2-7b Electrode with toothpaste as conductant.

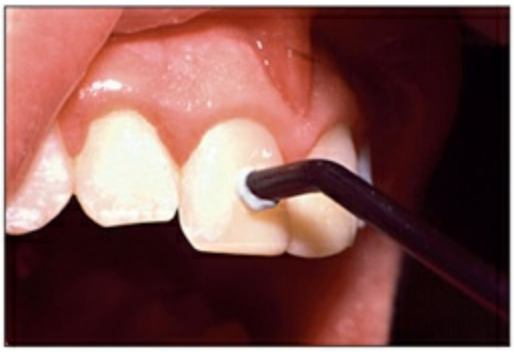


Fig 2-7c Electrode placed on the tooth.

Fig 2-7d Patient holds the electrode to complete the circuit. Release by the patient will interrupt the current, giving the patient complete control over the stimulus.

Cold test

Materials

- Endo-Ice (Coltène Whaledent) or SuperCold 134 Plus (MG Chemicals) copiously sprayed onto a cotton tip, or ice probe

Technique

For optimal results, spray the end of a cotton tip with the cryogenic liquid (Fig 2-8) or use an ice probe (Fig 2-9), and place the tip on the labial or buccal surface of the tooth at the estimated level of the pulp horn (highest density of nerve fibers). The patient's subjective response to pulp testing should be evaluated carefully to differentiate a true positive response from a false anxiety-produced response (anticipation). To ensure accuracy, one must establish a baseline and separate real results from those that are imagined. You may accomplish this by alternating different patterns (tooth sequences) throughout the test as you compare the responses of the target tooth with those of the adjacent teeth and even at times with the contralateral teeth.

Fig 2-8a Endo-Ice refrigerant liquid.

Fig 2-8b The refrigerant is sprayed on a cotton pledget.

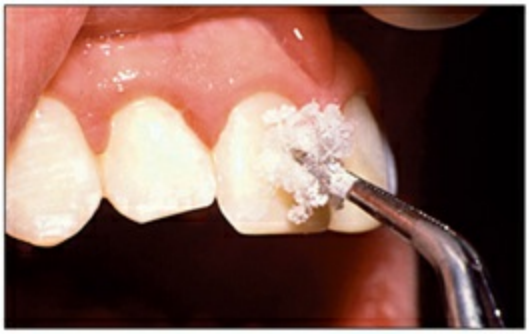


Fig 2-8c Ice crystals form, providing an extremely cold testing source.

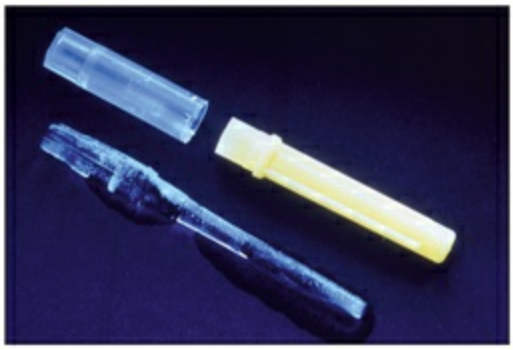


Fig 2-9a Freezing water inside a needle cover is an efficient way to make an ice probe.

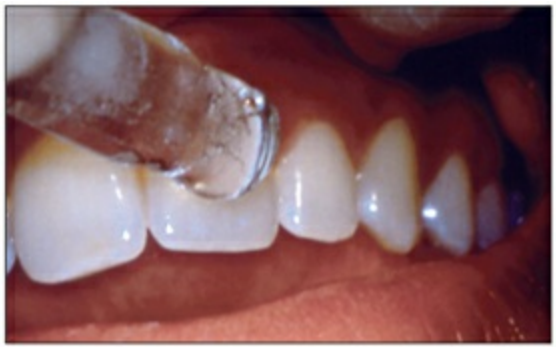


Fig 2-9b Ice probe applied to a tooth.

Interpretation

If the patient experiences slight intermittent pain, the pulp is likely healthy and/or is experiencing a potential reversible pulpitis after a recent filling or injury. The low-threshold A-δfibers of the pulp respond to acute cold. However, because the vessels of this pulp are not severely damaged (beyond repair), the sensation is gone seconds after the stimulus is removed. This tooth should be reevaluated in 30 to 60 days.

When testing patients who are experiencing pulpal pain (as in pulpitis-induced toothaches), all the main types of sensory fibers (A-β, A-δ, and C-fibers) are inflamed, and the application of cold further provokes these fibers, causing the patient to experience a sharp pain that is followed by a lingering dull pain. This tooth requires endodontic therapy.

When testing patients who are in an advanced (mixed and acute) stage of degenerative pulpitis, the tissue of the canal may be inflamed while the coronal pulp chamber may be necrotic. In such cases, cold reduces the tissue temperature and intrapulpal pressure and relieves the pain. However, within minutes of removing the cold, the temperature and pressure quickly increase (due to body temperature), and the acute pain returns. This tooth requires endodontic therapy. This form of pulpitis is representative of the so-called hot tooth, and the operator should be aware that it may be difficult to gain a working level of anesthesia.

A tooth that does not respond to thermal or electric stimuli is totally mineralized (stimulated by an injury), or its pulp is necrotic. Radiographs can reveal the true extent of the mineralization and/or periapical involvement (ie, expanded lamina dura or radiolucency).

Heat test

It is difficult to test a tooth with heat. Hot water and hot drinks have been suggested, but for those sources to be hot enough to get a reliable response, the patient's safety would be jeopardized. As an alternative, heat may be applied directly to the tooth by touching a hot (150°F to 200°F) Buchanan System B Heat Plugger (SybronEndo) to the tooth or using heated gutta-percha stopping. If there is no response, the tooth is most likely necrotic (Fig 2-10). If there is a response and it lingers after the stimulus is removed, it indicates irreversible inflammation of the high-threshold C-fibers. Either way the tooth needs endodontic therapy.

Fig 2-10a Dental Stopping (Hygenic) can be heated to provide a thermal source of heat.

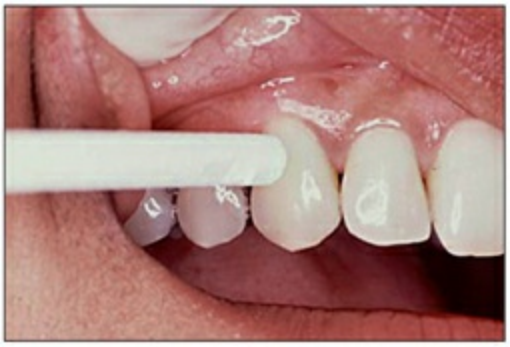


Fig 2-10b Heated gutta-percha stopping applied to a tooth.

Phase 9: Selective anesthesia

When a patient experiences pain and cannot identify which arch is involved, the use of selective anesthesia can be enormously helpful. Anesthetizing the maxillary teeth is easier as each tooth has branches from the superior alveolar nerve that can be numbed in sequence until there is an absence of pain. If the pain continues unabated, a mandibular block must be considered. With the advent of the intraosseous injection technique using X-Tips (X-Tip Technologies), it is possible to inject segments of the jaw and by so doing to anesthetize just one to three teeth at a time in the mandible (see lesson 14).

In cases where the administration of selective anesthesia in the maxilla or mandible does not relieve the pain, you must consider the possibility of referred pain of nondental origin.

Phase 10: Radiographic examination

Never make a diagnostic decision based on a single radio-graph. Always evaluate at least two views that have been taken from different angles. A quality bitewing radiograph provides the following information: *(1)* the extent and depth of caries, *(2)* the extent and depth of a restoration, and *(3)* the depth of restorative material in the pulp chamber, which may indicate a possible pulp exposure and pulp cap. In addition to confirming the information learned from a bitewing, a quality periapical radiograph reveals pulp recession and secondary dentin, alveolar bone loss (crestal, furcation, horizontal, vertical, lateral, periapical), root fractures, resorption, the number of roots and canals, canal complexity, widening of the periodontal ligament, apical or lateral radiolucencies or radiopacities, and evidence of previous endodontic treatment.

Avoid the superimposition (proximity) of roots by using the buccal object rule, or SLOB rule (same lingual, opposite buccal), to locate which root is closer to the film or sensor. When dealing with anatomic landmarks such as the mandibular canal and the sinus floor, in contrast, it is better to assess the proximity of the apices with those landmarks, which can be viewed with a panoramic radiograph or a computed tomography (CT) image.

Considering the reduction in radiation and the ability to use zoom and color for diagnosis, one must seriously contemplate investing in a digital imaging system.

The availability of three-dimensional cone beam computed tomography (CBCT) at a significantly lower radiation dose than medical CT makes it the imaging method of choice in difficult situations where anatomy or pathosis is obscure. CBCT scans are being utilized more and more by university clinicians, oral and maxillofacial surgeons, and radiologists. A detailed account of which radiographs are most appropriate and guidelines for their interpretation are available in lesson 3. The Endodontic Form (see Fig 4-1) that is currently used at the Arthur A. Dugoni School of Dentistry, University of the Pacific, is an organized method of recording diagnostic values accumulated during the examination process.

LESSON 3

Radiographic Examination and Interpretation

OBJECTIVE

To recognize, identify, and interpret anatomic structures and endodontically related pathosis.

INTRODUCTION

Preoperative radiographs are an indispensable part of the diagnosis and assessment of endodontic situations. When combined with the clinical findings, a final diagnosis is almost always assured.

Note: In multirooted teeth or teeth with obliterated root canals, it is necessary to have more than one preoperative radiograph to determine all necessary anatomic landmarks and dental morphologies. These should include a bitewing radiograph and a second periapical film taken from a different horizontal angle (either mesial or distal).

All imaging techniques and/or combinations of techniques that can assure delivery of the radiographic information needed to make an accurate diagnosis should be considered. These include bitewings, periapical radiographs, panoramic radiographs, computed tomography (CT) scans, and even rarely used methods such as Technetium-99 bone scans.

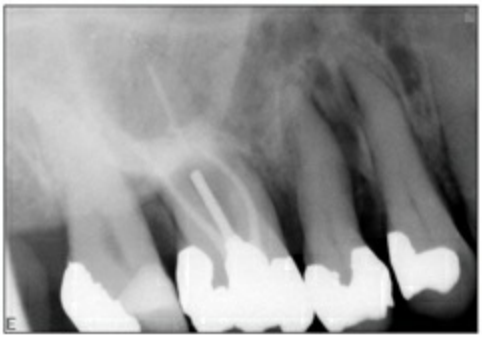


Fig 3-1a Example of a digital film in normal gray-black tones.

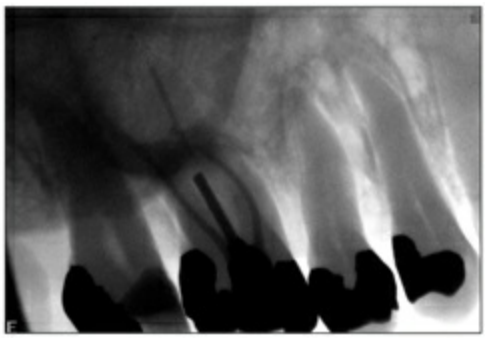


Fig 3-1b The same film demonstrating reverse contrast.

Fig 3-1c Digital image of a mandibular molar in the opaque mode.

DIGITAL RADIOGRAPHY VS CONVENTIONAL FILM RADIOGRAPHY

Studies have proven that the quality of digital images is equal to that of conventional intraoral wet-film images. In addition, recent advances, dependability, and industry support of the digital systems provide innumerable advantages over a wet-film process:

- The clarity, color, contrast, and brightness of a digital image can be easily modified, and a particular area or region can be isolated, enhanced, and magnified. This is not possible with a conventional film that has to be examined the way it was processed with no possibility of changing the image. Digital imaging often reduces the number of radiographs that have to be retaken (Fig 3-

1).

- Only one-seventieth the amount of radiation is used in making a digital image versus a conventional wet-film image, making this technique safer for the patient, the staff, and the clinician.
- A diagnostic image is provided within 3 to 4 seconds.
- The image can be used as a visual aid in describing and explaining the endodontic problems (eg, canal complexity, periapical infection) to the patient.
- The estimated length of a root can be measured prior to the insertion of a file, and any necessary adjustments can be made after insertion, via a follow-up film, within seconds.
- The image may be permanently stored in the computer for future reference and upon request can be easily copied and forwarded electronically (over the Internet) or sent by mail.

Digital computer systems require a sizable investment in equipment (eg, computer, sensors, and monitors) and a commitment to the learning curve. However, from a financial and convenience standpoint, the initial cost is quickly recaptured compared with the cost of conventional film radiography—purchasing film and processing chemicals; providing and maintaining a dark room and/or a processor; manually processing, cleaning, fixing, and drying films before they can be viewed; manually inserting and storing film holders; and losing production time at the chair, waiting for a readable image. Therefore, the majority of endodontists have incorporated a digital radiographic system in their office.

RADIOGRAPHIC IMAGING TECHNIQUES

Analyzing both a bitewing and a periapical film during the radiographic examination for a patient with an endodontic problem offers enormous advantages over relying on either of the films alone. By combining the information learned from each, a more accurate picture of both the target tooth and the surrounding teeth is gained. Identification of the painful tooth is enhanced, and the possibility of overlooking sources of pain from another nearby tooth is minimized.

Bitewing radiographs

A bitewing radiograph images the coronal portions of the maxillary and mandibular teeth of both arches on one side of the mouth, providing an accurate picture of the structural condition of as many as eight teeth. Having this information is particularly advantageous when a patient presents with a toothache and is unable to pinpoint the exact source of discomfort. Focusing on a single tooth and the information gathered from a single periapical image without knowing the condition of the adjacent or opposing teeth may lead to a situation where a patient returns with a toothache stemming from a second tooth in the same or opposing arch. This unfortunate situation can be avoided by initially taking both a bitewing and a periapical image. If the target tooth requires treatment but the bitewing reveals that other teeth in the same or opposing arch may need endodontic therapy, the patient can be informed of the situation during the case presentation. A good-quality bitewing radiograph may reveal

caries, preexisting compromised restorations, and the status of the periodontia.

Caries

A bitewing radiograph may reveal the depth of caries, its proximity to the pulp, and the number of surfaces involved.

However, the invasiveness of the decay is almost always found to be deeper than was estimated. An accompanying periapical image offers another view of the caries and divulges the presence or absence of periapical pathosis. When the information from both films is combined with the clinical data, a treatment plan can be developed, and the patient can be informed of the treatment options and fees (eg, a stepwise caries excavation procedure, indirect or direct pulp capping, endodontic therapy, or extraction) (see lesson 10).

Preexisting compromised restorations

The problem here lies with the radiographic opaqueness of the metal or resin, which can obscure underlying decay. As such, when there is a definitive translucent zone of decay on both the bitewing and the periapical films, the extent of the carious invasion can only be verified by removing the restoration. At times, it may seem enticing to be conservative and try to remove the decay without removing the restoration and clinically examining the remaining tooth structure. However, with restricted access to assess and remove infected dentin, a clinician may face criticism if the patient returns in pain after caries excavation or if the tooth is deemed nonrestorable at a future appointment. This scenario is particularly true when caries is clinically or radiographically found at or under the margin of a crown and a new crown is needed (Fig 3-2). For these reasons, patients must be informed of the excavation problem, and crown removal should be recommended as the most beneficial treatment option.

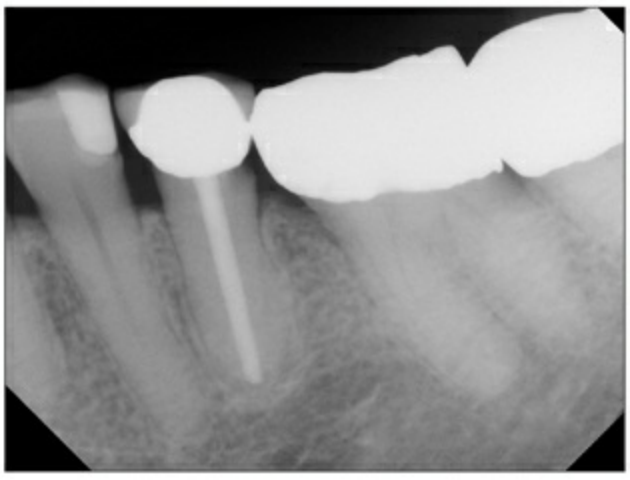


Fig 3-2 Caries is suspected at or under the margin of a crown on a mandibular left second premolar after inspection of a periapical radiograph.

Periodontal status

A bitewing image is valuable in determining the crestal level of bone. When that level is absent from

view in a bitewing radiograph, as can be seen in Fig 3-3, the extent of the periodontal disease might be the cause of the patient's complaint. This scenario requires a review and interpretation of the periodontal level on the periapical film. If the image shows alveolar bone loss along the full length of the external lateral wall of a root, there is a strong possibility the root is fractured. The current image can be compared with older radiographs to determine healing or progression of periodontal disease by comparing the crest of bone to a landmark (eg, the cementoenamel junction). Alveolar bone loss may also be detected in the furcation. In such cases, the etiology of the disease may be either endodontic or periodontal in origin, or a combination of both. If the patient is in pain, the following options, reasons, and fees associated with those options should be offered:

- If the tooth tests positive for vitality in the presence of deep periodontal probing, the patient should be referred to a periodontist for evaluation.
- If the tooth tests nonvital, it is probable that the pulpal condition is responsible for the lesion and that the overlapping periodontal problem may result from the necrotic byproducts of pulpal degeneration causing inflammation in the periodontal ligament (PDL). Furcation lesions that are solely endodontic in origin frequently heal after endodontic therapy alone. It is important to confirm that the remaining coronal tooth structure and periodontal status justify endodontic treatment versus extraction of the tooth (Fig 3-4).
- If the tooth tests nonvital, an emergency pulpectomy can be performed and the patient referred to a periodontist to evaluate the periodontal status. If the periodontal condition is treatable and there is structural justification to save the tooth, the endodontic treatment can be completed, followed by later periodontal treatment. The patient must be aware of the fees involved.

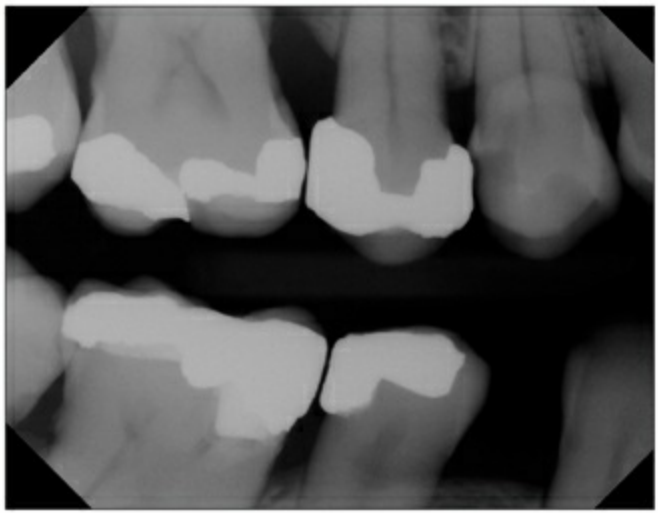


Fig 3-3 A bitewing image is a valuable diagnostic tool in determining the crestal level of bone. When this landmark is absent from view in a bitewing, the extent of the periodontal disease is advanced and might be the cause of the patient's problem. The crestal bone level is visible in the mandible. However, the crestal bone level is not visible in the maxilla adjacent to the molars.

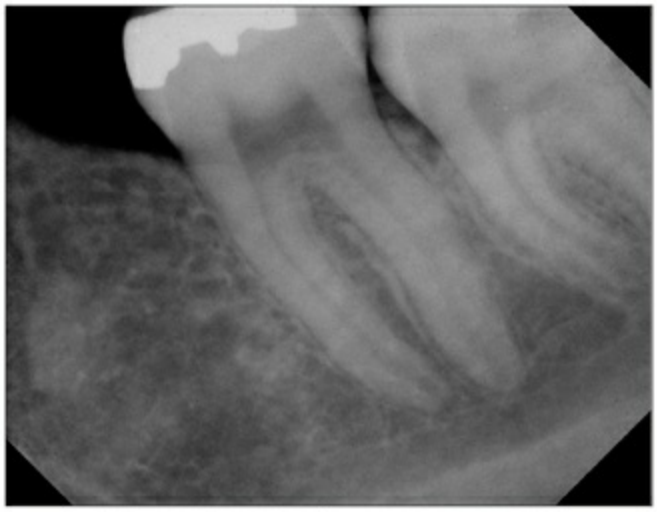


Fig 3-4 Periapical radiograph of a mandibular left molar with a healthy periodontal ligament.

Periapical radiographs

Rule 1

A periapical film or digital sensor must be placed parallel to the tooth, and the central beam must be directed at a right angle to the film or sensor. This prevents distortion (shortening or lengthening) and produces a tooth image that may be accurately measured to an estimated working length. The Rinn-type film or sensor holders not only take accurate parallel images but also provide consistent film angles that allow the clinician to compare future images with those previously taken (postoperative evaluation at the same beam angulation).

Rule 2

The image not only should show the entire tooth but also should display an area of alveolar bone around the entire root complex. For exceptionally long teeth (eg, maxillary canines), a bitewing film placed vertically will capture images from 26 to 34 mm in length. In addition, vertical bitewing radiographs can be used to concurrently view bone levels in both the maxilla and mandible.

Rule 3

No diagnostic conclusions should ever be made from a single preoperative periapical radiograph. A radiograph is a two-dimensional (2-D) image, and for that reason it is easy to superimpose roots and bone structure and obscure the presence of abnormalities, canal complexities, and periradicular pathosis. If one image is taken with a bitewing, a second image—a periapical radiograph—should be taken before treatment ensues to avoid surprises. The images should be taken from two different lateral or horizontal directions and from two different vertical angles.

Rule 4

When a mesial or distal angulation is chosen for a periapical image, it is helpful to remember the SLOB rule (Fig 3-5), which stands for "same lingual, opposite buccal." For example, if a film of an maxillary premolar is exposed by a cone angulation that is shifted to the mesial, then the two roots are seen separately on the film and do not overlap (the buccal root is projected to the distal and the lingual root, the "same lingual," is seen shifted to the mesial).

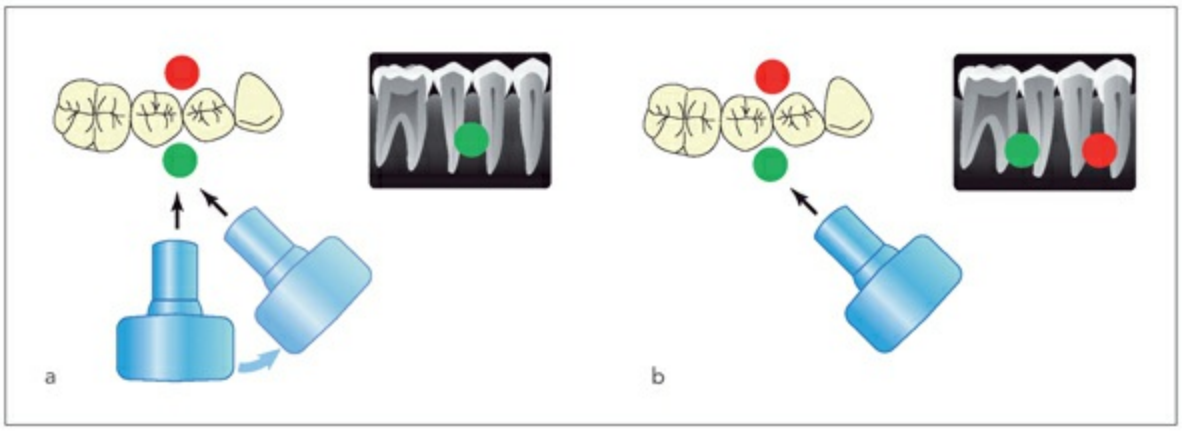


Fig 3-5 Drawing of the SLOB rule when a mesial or distal angulation is chosen for a periapical image. *(a)* The image cast on film from straight-on x-ray. The green marker on the buccal aspect is superimposed on the red lingual marker. *(b)* A mesial angulation of the x-ray separates the buccal aspect from the lingual. This horizontal change to the mesial moves the green marker to the distal and the lingual red marker stays in the same relative position to the mesial on the film.

Rule 5

Use the SLOB rule to visually separate the canals in roots with multiple canals. For example, to view the mesial root of a mandibular first molar (multiple canals in. 95% of people), the beam should be directed from the mesial. This positions the mesiobuccal (MB) canal to the distal, and the mesiolingual canal is seen to the mesial. This same system should be used on the maxillary first molar to separate the canals (greater than or equal to 70% second canals) within the MB root. With the beam angled to the distal, the MB1 canal is cast to the mesial, and the MB2 canal (lingual position) is seen on the distal aspect of the image. This variable angulation technique should also be followed when identifying which root contains a foreign object or which file is longer on a working-length radiograph (Fig 3-6).

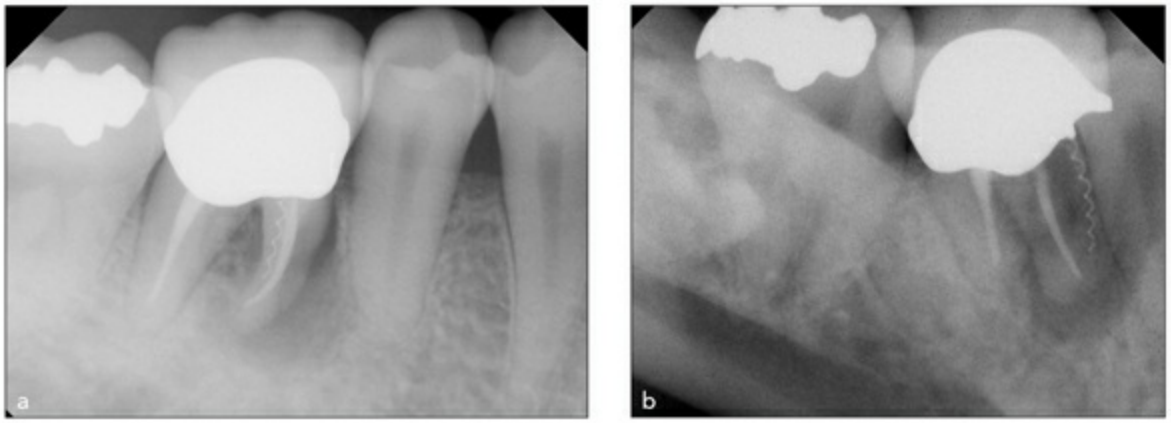


Fig 3-6 Images should be taken from different lateral or horizontal directions; in some cases two different vertical angles are necessary. This variable angulation technique should also be followed when identifying which root contains a foreign object or which instrument is longer on a working-length radiograph. The mandibular right first molar is seen with a horizontally shifted central beam to identify the location of a fractured lentulo spiral. *(a)* A mesial-angled view of a fractured lentulo spiral in the buccal canal (lentulo displaced distally). *(b)* A distal angulation of the central beam now shows the lentulo spiral displaced in the mesial direction, confirming that it is in the buccal canal.

RADIOGRAPHIC INTERPRETATIONS

Apical or lateral radiolucencies

These lesions present as dark (radiolucent) areas on a radiograph and may or may not be bordered by a white line. The PDL is disrupted in the area of the lesion. This can be verified by visually tracing the PDL, starting from the cervical area (Fig 3-7). A developing pathosis can initially present as a widening of the PDL, which means that the uniform thickness of the PDL changes and becomes wider at a certain location in the periradicular region compared to that seen in a healthy tooth. A developing pathosis can also be visible as a denser, more radiopaque area, often termed *osteosclerosis* or *condensing osteitis*, on a periapical radiograph. This radiodense zone, which indicates low-grade pulpal inflammation, may eventually develop into a periapical radiolucency over time as the pulp degenerates (Fig 3-8). Chronic lesions are often dark areas that are well demarcated from the surrounding bone, whereas expanding lesions are frequently less defined and commonly demonstrate a hazy border.

Care must be taken not to initiate endodontic therapy purely on the basis of a single radiolucency (see Rule 3) as certain other diseases may mimic lesions of dental origin. A large range of nonodontogenic lesions can manifest themselves in maxillofacial bone structures.

Note: Many anatomic structures and radiolucencies may lie on, over, or under root ends and can be misinterpreted as periradicular pathoses. Common examples include the mental foramen and the incisive foramen. Varying the beam direction, as in the SLOB rule, shifts these anatomic landmarks and clarifies the overlap.

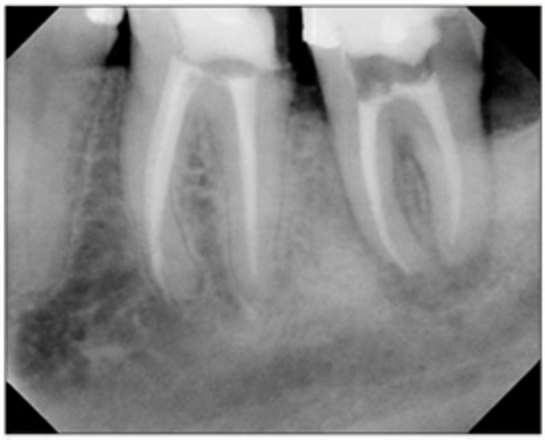


Fig 3-7 Periapical radiograph of a mandibular left second molar with a chronic apical lesion and the loss of a normal configuration of the periodontal ligament. Note the apical transportation of the mesial root canal on both the second molar and the adjacent first molar.

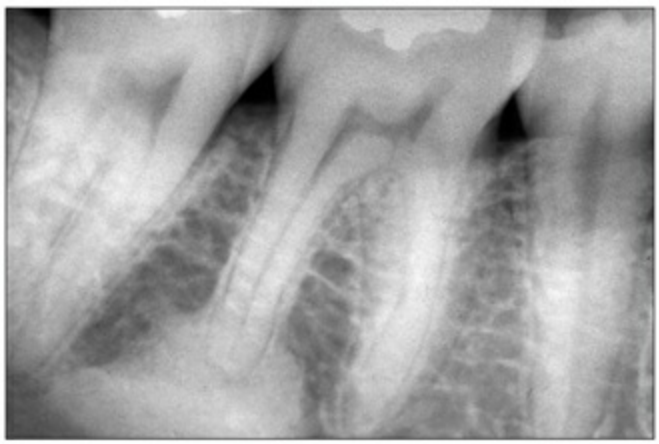


Fig 3-8 Osteosclerosis (radiopacity) associated with the distal root of a mandibular right first molar. (Image courtesy of Dr Ralan Wong, San Francisco.)

Periapical cemental dysplasia

This commonly misinterpreted lesion can be found in the tooth-bearing jaw area, and it may be projected over a root tip (Fig 3-9). Clinically, this condition affects women more frequently than men, and the incidence is particularly high among women of African descent in their forties. The mandibular anterior teeth are more frequently affected than are the maxillary teeth, with the lesion generally occurring in two or more teeth. To avoid confusing such a rarefaction as being of endodontic origin, the PDL must be closely studied, and the vitality of the teeth must be confirmed through pulp testing. Various other systemic conditions can occasionally mimic periapical lesions. The reader is encouraged to consult an oral pathology textbook when such conditions are suspected.

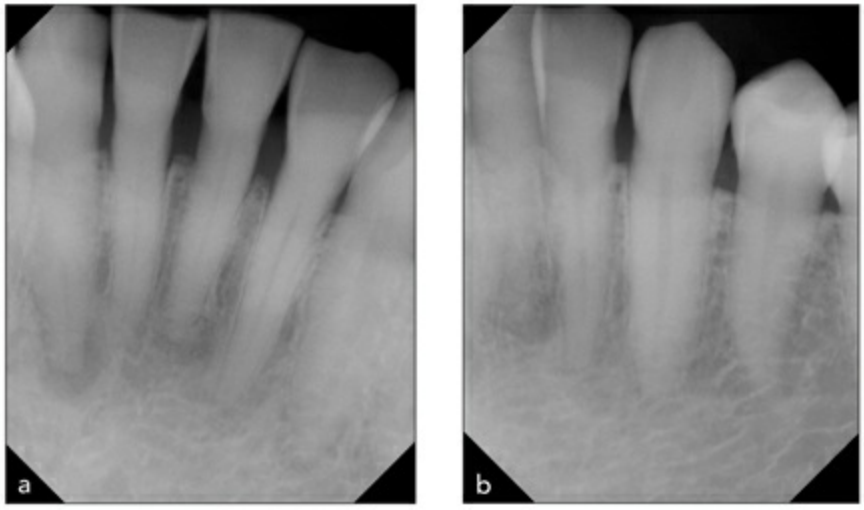


Fig 3-9 Periapical cemental dysplasia is one example of a commonly misinterpreted lesion. It may be projected over a root tip. Vitality of the pulp is a critical consideration in the differential diagnosis. *(a)* Straight-on x-ray angle showing lesions adjacent to the mandibular anterior teeth. *(b)* A horizontal shift in the angulation of the radiograph demonstrates the lesions' move away from the periodontal ligaments.

Fractures

Horizontal or vertical fractures are clearly visible on radiographs if the fragments are spaced widely enough or the x-ray beam is aligned with the plane of the fracture (Fig 3-10). In many instances, fractures appear as faint dark lines or as double lines (horizontal fractures), since the beam casts both the buccal and lingual aspects of the fracture on the film. In some cases, the fracture cannot be seen, or its presence may only be suggested by a thickened PDL space surrounding the portion of the root with the concealed fracture.

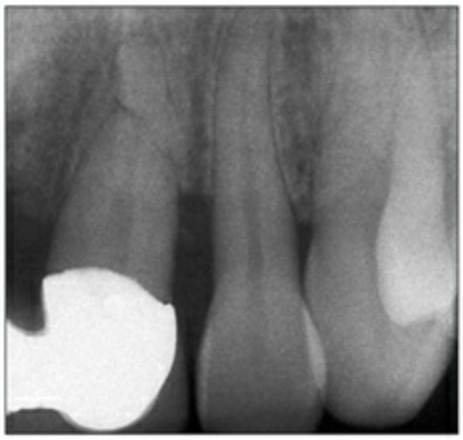


Fig 3-10 Root fractures may appear as faint dark lines on periapical radiographs. In this case, the maxillary right central incisor has suffered a trauma that resulted in root fracture.

Number of roots and canals

Multirooted teeth or roots with more than one canal can often be identified when comparing periapical radiographs from two different angulations (see the SLOB rule) (Fig 3-11). Evidence indicating the presence of another root in endo-dontically treated teeth includes double PDL lines (superimposition) or abruptly disappearing canals (bifurcation).

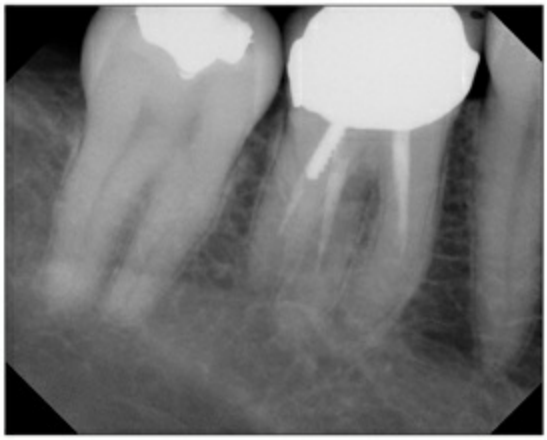


Fig 3-11 An example of a three-rooted mandibular molar. In this case a distal x-ray angulation demonstrates the third root and the short root canal fillings.

Mineralizations

With advancing age, more and more tertiary dentin is laid down, and the pulp and canal spaces become narrower. Mineralized canals may only be visible as faint dark lines or not at all. Mineralization increases the difficulty in finding, recognizing, and negotiating root canals. In addition, pulp stones may fill a pulp chamber and block access to the canal orifices (Fig 3-12). The strategy for treatment and access preparation can be planned accordingly when highly mineralized canals or pulp stones are visible.

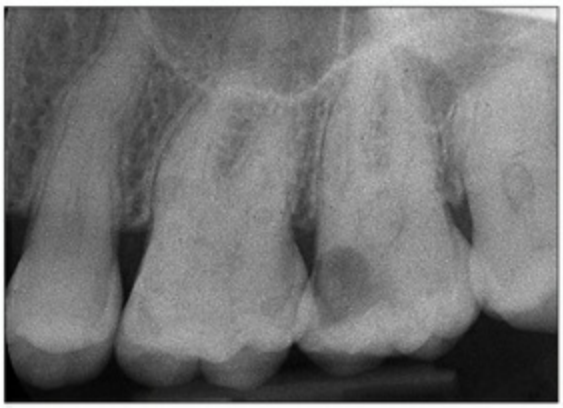


Fig 3-12 Pulp stones may fill a pulp chamber and block access to the canal orifices. In this example, the pulp chamber of the maxillary left second molar is filled with a large pulp stone that requires removal to access the root canals. The first molar is almost completely mineralized.

Resorptions

Multinucleated giant cells that resorb dentin (dentinoclasts) are the cause of internal and external root resorption. While this may be a natural process in the exfoliation of primary teeth, resorptions in permanent teeth need to be identified and treated.

Internal resorption

This process occurs when the coronal pulp has become necrotic or chronically inflamed and the tissue apical to the resorption zone is still vital. The root canal is clearly widened in the resorptive area (Fig 3-13a), and a perforation into the PDL may exist in advanced cases. Radiographic appearance shows the resorptive defect to be a continuous part of the pulpal space in all radiographic angulations.

External resorption

This process is often a sequela to traumatic injury such as orthodontic movement and root planing and begins in an area where the root is denuded of cementum. It can also occur at the cervical area of a tooth because of an incomplete fusion of enamel to cementum, making the exposed dentin (which is less mineralized) vulnerable to resorptive cells. This defect is superimposed on the root canal, but a distinctive root canal space with dentin borders is visible in the radiograph (Fig 3-13b). These defects usually do not penetrate into the pulp because the pulp is surrounded by a protective layer of unmineralized predentin that is not susceptible to resorption by dentinoclasts.

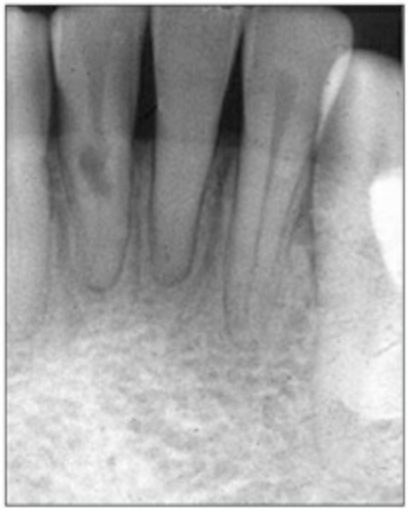


Fig 3-13a Internal root resorption in a mandibular right central incisor. The resorption is a continuation of the canal space, indicating pulpal origin of the resorption.

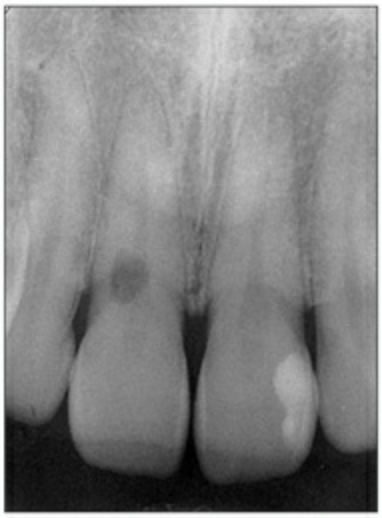


Fig 3-13b External root resorption in a maxillary right central incisor. Note that the canal shadow is still visible.

Pulpotomy

A successful pulpotomy (see lesson 37) may be identified by a visible hard tissue "bridge" sealing the root canal space apical to the cement or restoration and the lack of any periradicular pathosis.

Apical radiopacity

In certain cases, the bone surrounding a tooth with low-grade inflammation of the pulp can become denser (whiter) than the surrounding bone. Usually this finding manifests into a periapical lesion over time. The phenomenon of bone presenting as markedly denser than adjacent alveolar bone is termed *condensing osteitis* and is indicative of a low-grade pulpal inflammation (see Fig 3-8).

Sinus tract tracing with gutta-percha

A sinus tract is a manifestation of a chronic periapical abscess with intermittent discharge of pus from the inflamed periradicular tissues into the oral cavity. In the clinical assessment of a sinus tract, a gutta-percha cone size 35 or larger is gently introduced into the tract and advanced. A radiograph can confirm a periodontal or endodontic source (see Fig 4-2). Vitality testing is necessary to confirm the diagnosis.

Changes in the trabecular bone pattern

Comparisons of previous radiographic surveys with current radiographs allow for observation of changes in the trabecular bone pattern. Often a diagnosis or culprit tooth can be identified by these radiographic changes in bone appearance.

Hypercementosis

A thickening of the cementum layer and consequently an altered "club-shaped" appearance of the roots can be identified on periapical radiographs. There is no correlation between hypercementosis of the roots and pathosis (see Fig 7-4).

Ankylosis

Disappearance of the periodontal ligament space may be an indication of tooth ankylosis (replacement resorption), which indicates the loss of the PDL and the "fusion" of root and bone. Percussion of the tooth in question can confirm this finding. These teeth sound very different from normal teeth supported by a vital healthy attachment. This is a common sequela of trauma to the attachment and tooth (see lesson 40).

Evidence of previous endodontic treatment

Most root canal filling materials contain radiopacifiers such as barium sulfate that make them appear white on a radiograph. These materials permit the density and completeness of obturation to be inspected and quantified.

Perforations

Interruption in the lateral continuity of root dentin or excessive thinning of dentin in the furcation area may indicate a perforation. Lesions in the PDL space associated with the suspected area of perforation would corroborate the diagnosis. Visual inspection, often by reentering the root canal space or by surgical exposure of the defect, is absolute confirmation.

Fragments of separated instruments

Separation of hand or engine-driven instruments is an occasional mishap. Radiopaque metal fragments can be seen superimposed onto the canal space. The buccal or lingual position of such a fragment may be determined using the SLOB rule.

Evaluation after treatment

When evaluating the quality of obturation, it is customary to judge periapical radiographs for homogeneous fillings, obturation voids, gaps (lateral seal), and fillings that are overextended and underfilled or short of the apical foramen. To determine as accurately as possible the quality of the lateral seal of a root canal filling, use a set of radiographs taken with mesial or distal angulations to detect unfilled spaces. Dark lines parallel to the root canal filling indicate a gap between filling material and canal wall. Crimped patterns in the gutta-percha indicate deficiencies in cone fitting and condensation techniques (Fig 3-14).

Note: The measured length of the root filling on a 2-D image is more accurate than is the detection of voids in the obturation. Fillings should not be more than 2 mm short of the root apex. Teeth with irreversible pulpitis contain sterile tissue in the apical portions of the root canal and heal even with fillings that are short. In cases with apical radiolucencies, the root canal filling should extend to the full working length—0.5 mm short of the root apex (ie, the cementodentinal junction).

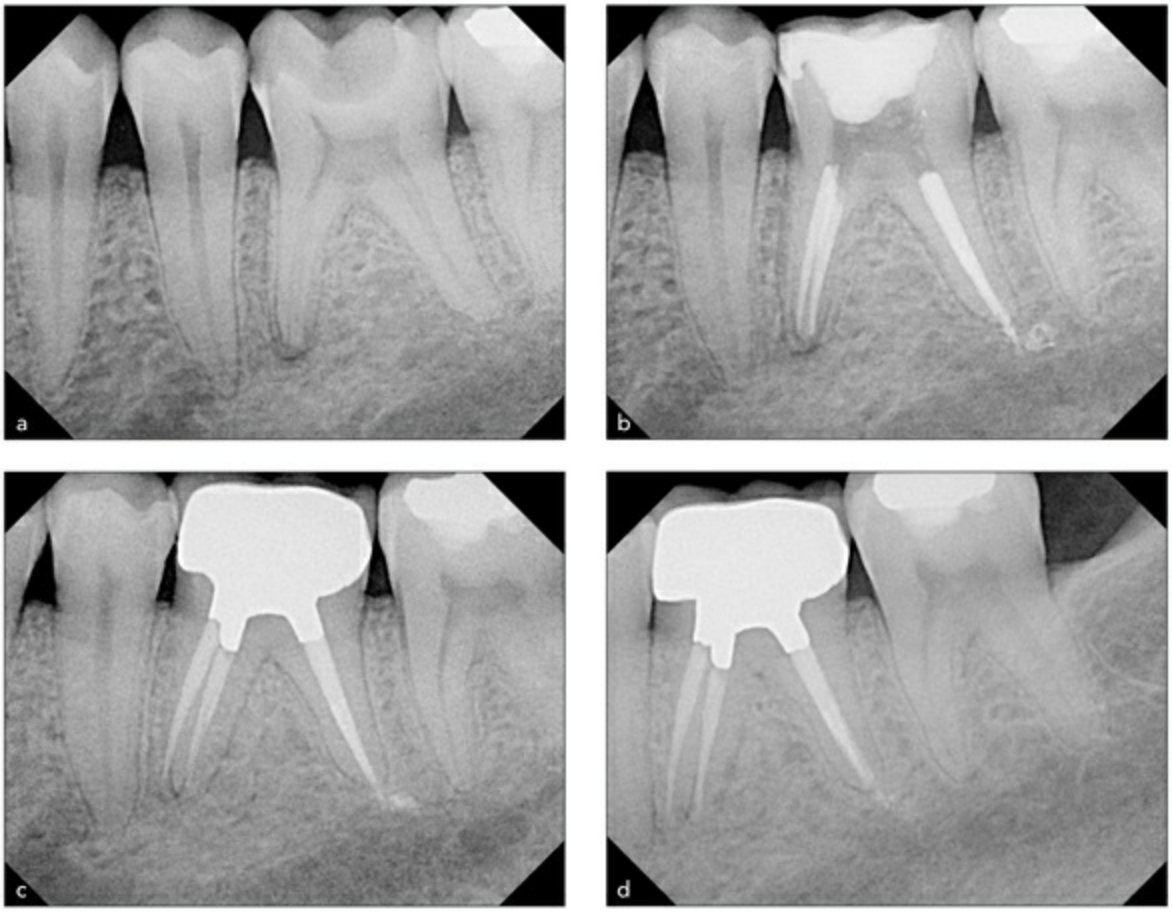


Fig 3-14 The course of periradicular repair after root canal therapy. *(a)* Carious exposure of a mandibular molar. *(b)* Immediately after endodontic therapy. *(c)* Six months postoperatively, the periradicular tissues are repairing as excess sealer is absorbed. The tooth is restored. *(d)* One year postoperatively, healing is complete. (Images courtesy of Dr Ralan Wong, San Francisco, CA.)

Persistent radiolucencies

After endodontic treatment, persistent infections are often easily identified on conventional and digital periapical radiographs, especially when the cortical plate has eroded. However, it is impossible to make a definitive diagnosis of a pathosis that does not heal after conventional retreatment without enucleating and histopathologically processing the tissue. In the future, it may be possible to diagnose a dental granuloma versus a cyst by comparing the grayscale values in radiographs and histograms. Ultrasound imaging and color power Doppler are technologies that can help diagnose periapical lesions and the quality of their vascularization, but these methods are not commonly used in dental practices.

ALTERNATIVE RADIOGRAPHIC TECHNIQUES

Panoramic images

These films provide information about the entire maxilla and mandible, including the temporomandibular joints. They produce a symmetric display of the anatomic structures on both sides of the patient's jaws. This panoramic view is extremely helpful in detecting abnormal structural formations (anomalies) and the presence of benign and malignant tumors. Of great value for endodontics is the fact that these films permit the accurate measurement of the proximity of the root tips in posterior teeth to the major vital structures (Fig 3-15). A number of court cases in recent years have been ruled in favor of the patient when endodontic filling material has been inadvertently forced into the maxillary sinus or mandibular canal. For that reason when a periapical image shows the root tips at, near, or possibly in these structures, you should take a panoramic radiograph and be particularly careful about determining and maintaining working length.

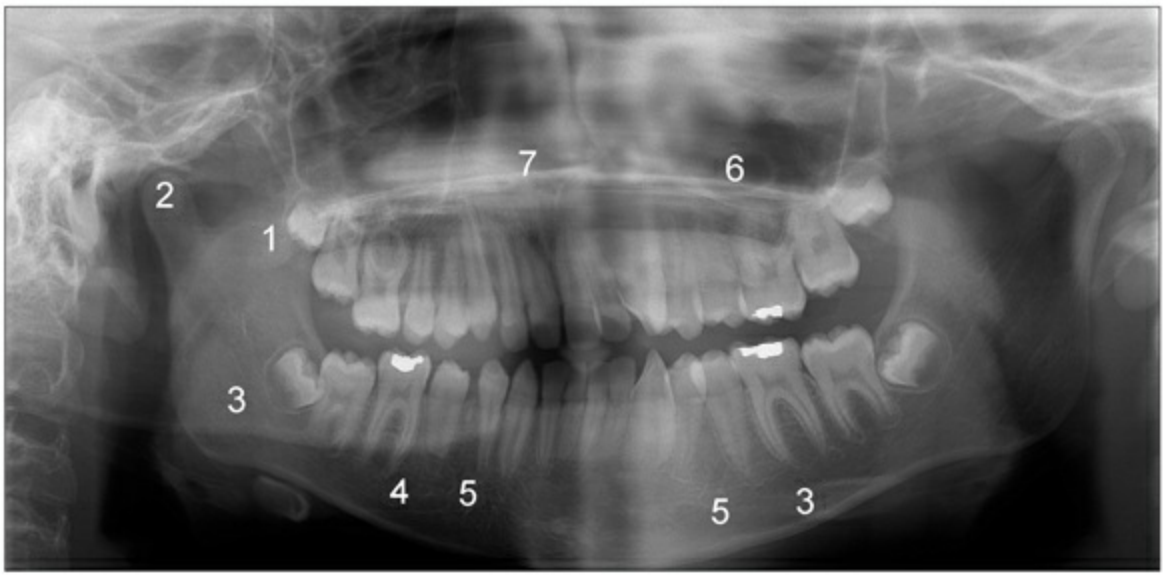


Fig 3-15 Numerous anatomic landmarks can be seen on a panoramic radiograph, including (1) coronoid process, (2) mandibular condyle and condylar neck, (3) mandibular ramus and body, (4) mandibular canal, (5) mental foramen, (6) inferior border of the maxillary sinus, and (7) hard palate.

Occlusal images

These are particularly valuable in providing a horizontal view of a lesion, such as a benign or malignant tumor or a cyst, that is located in the palate. The size of the lesion can be estimated, and if the lesion is found to be tooth related, its origin is usually an infected tooth (often a lateral incisor), and the pathosis is often a cyst (Fig 3-16).

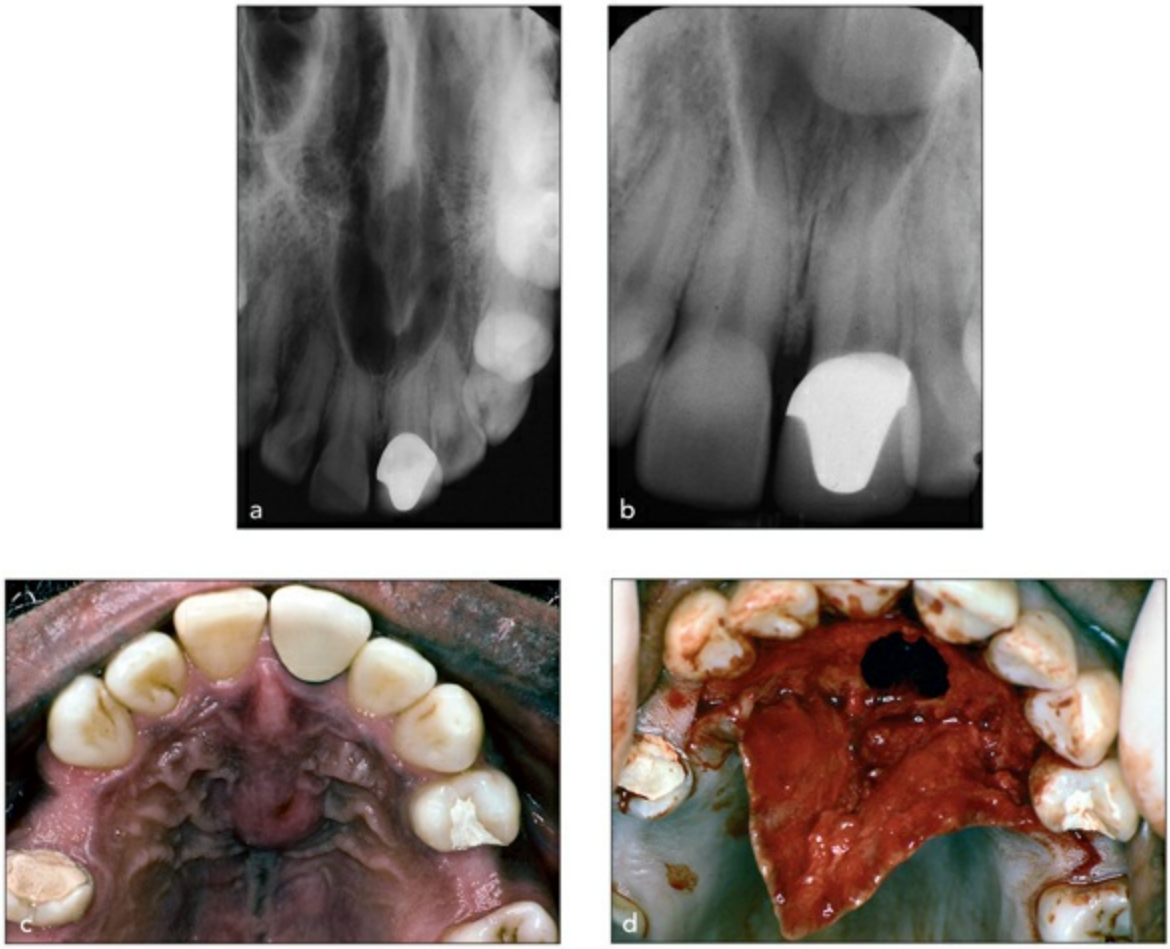


Fig 3-16 Occlusal images provide a horizontal view of objects and pathoses that are located in the palate. These images show a large lesion diagnosed as a giant cell granuloma originating from a maxillary left central incisor. *(a)* Occlusal radiograph. *(b)* Periapical radiograph. *(c)* Intraoral photograph of the anterior maxillary jaw showing swelling in the apical area of maxillary left central incisor. *(d)* Situation after raising a palatal surgical flap.

Digital cone beam computed tomography scans

Cone beam computed tomography (CBCT) has become extremely useful when dealing with implants, and its value has particularly increased in endodontic therapy. These systems allow a clinician to evaluate a certain area of interest without distortion or artifacts. The images may be displayed as three-dimensional (3-D) volumes or as 2-D slices in different planes. While the resolution is slightly less than that of conventional radiographs, the availability of 3-D information and the significantly lower radiation dose than medical CT scans makes CBCT the imaging method of choice where anatomy or pathosis is obscured by other anatomic structures. CBCT scans are particularly valuable in presurgical planning with optimized visualization of important anatomic structures such as the sinus or mandibular canal. In addition, they are of important assistance in cases where lesions or other pathologies cannot be accurately visualized in 2-D radiographs. Figure 3-7 demonstrates a periapical radiograph of a mandibular left second molar with a chronic lesion. A CBCT scan of the same tooth can be seen in Fig 3-17.

The scanning devices responsible for these "limited-field" 3-D images have greatly advanced clinicians' understanding of the anatomic complexities faced in any given case (Fig 3-18). The field of interest can be limited to several teeth, and the resulting scans can produce images with voxel sizes down to 0.08 mm for viewing (Fig 3-19). In difficult instances of diagnosis such as an internal or external resorption, which often superimposes itself over pulpal anatomy as in Fig 3-13, a 3-D image defines very accurately the extent of the disease and the amount of resorptive invasion (Fig 3-20).

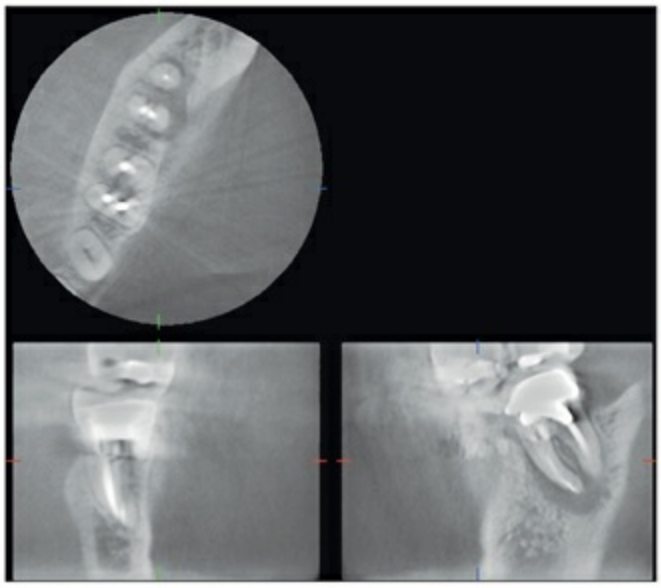


Fig 3-17 CBCT scan of the molar seen in Fig 3-7. The tooth, the periapical lesion, and other anatomic structures may be viewed in horizontal *(upper left)*, vertical *(lower left)*, and sagittal *(lower right)* sections.

Fig 3-18 The 3D Accuitomo 80 CBCT (J Morita).

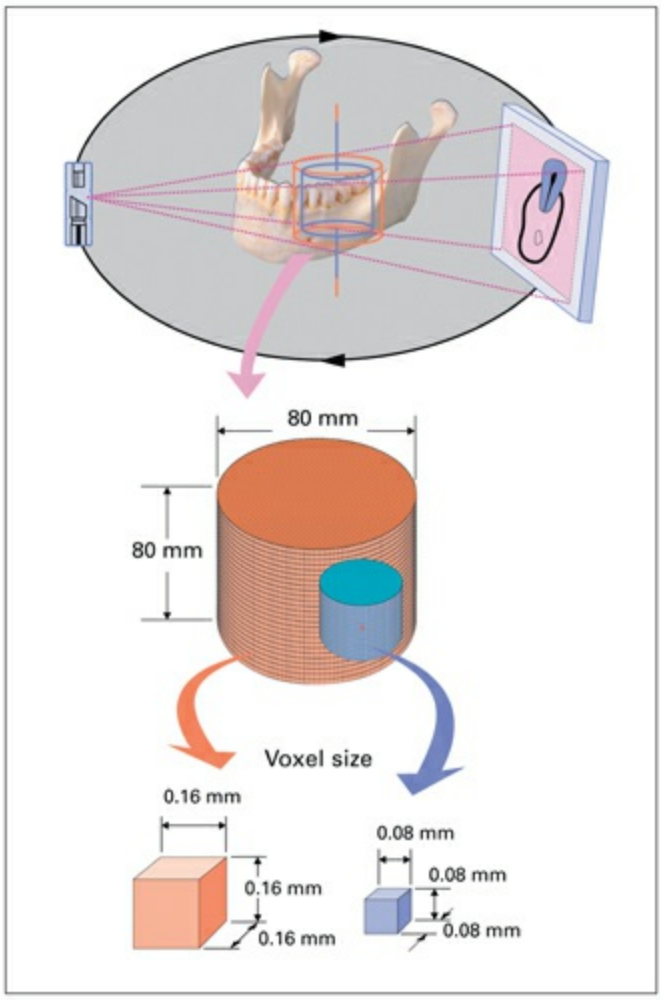


Fig 3-19 A representation of the CBCT scan by the 3D Accuitomo 80. The field of interest incorporates 80 mm.

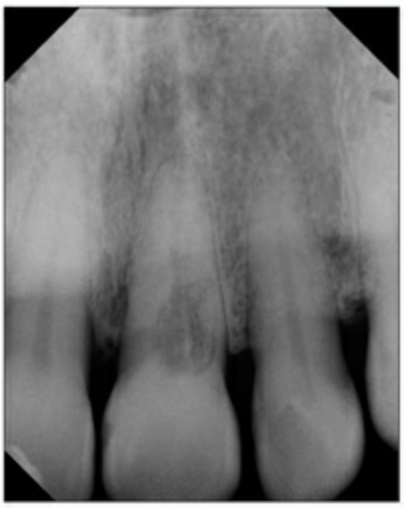
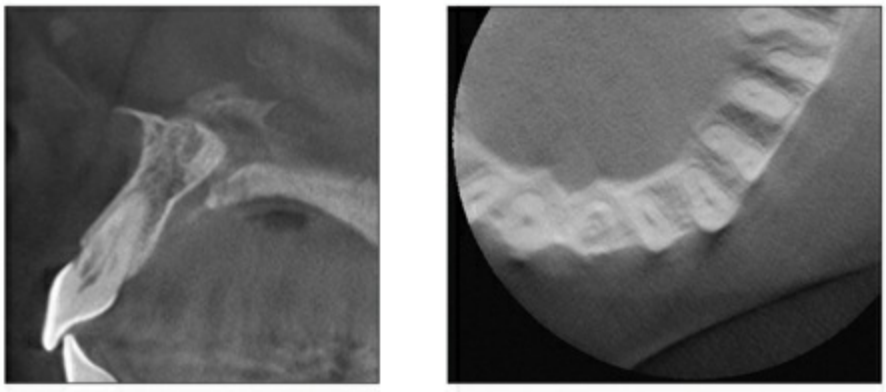


Fig 3-20a A traditional periapical image showing resorption of indistinguishable etiology on the maxillary left central incisor. Is it internal or external resorption?



Figs 3-20b and 3-20c Two slices from a 3D Accuitomo 80 CBCT scan show the extent of cervical (external) resorption that invades the maxillary left central incisor. The process is highly destructive, yet it has not invaded the predentin surrounding the pulp.

PRESURGICAL IMAGING

Surgical treatment of nonhealing cases requires a detailed knowledge of anatomic relationships involving structures such as the mandibular canal and the maxillary sinus and their relationship to proximate root apices. CBCT has significant value in presurgical diagnostics. Large bone lesions can be imaged to their true extent. Assessing periradicular lesions in multirooted teeth, differentiating such lesions from nonodontogenic cysts and cementoma, and understanding size and distances are now predictably possible. In addition to the spatial relationships of root apices to anatomic structures, other features can be viewed such as accessory canals, the location of root canals, and canal obstructions. The follow-up of healing events and repair of pathoses after endodontic surgery can be observed conclusively.

Scintography

The use of Technetium-99 to identify bone lesions has been a standard in medicine (bone cancer detection) for quite some time. Though rarely used in dentistry, it is useful in detecting multiple lesions throughout the maxilla and mandible. For the most part, this technique has been found valuable when treating patients with cavitational bone cysts, also termed *neuralgia-inducing cavitational osteomyelitis*.

LESSON 4

Diagnosis

OBJECTIVE

To make a pulpal and periradicular diagnosis based on data gathered from a patient's history, verbal description of symptoms, disease signs, radiographs, and responses to a variety of diagnostic questions and tests.

INTRODUCTION

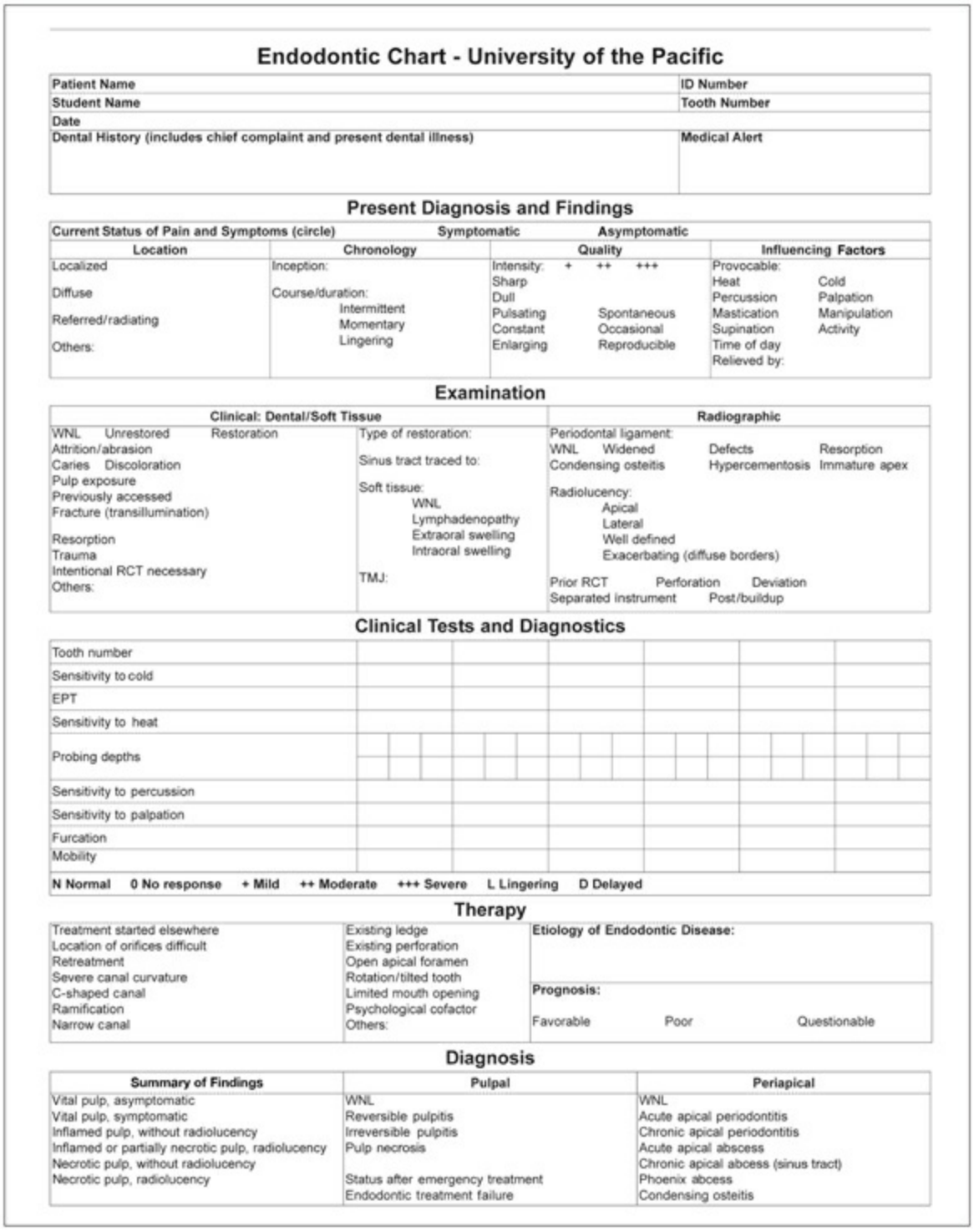
The purpose of a diagnosis is to establish a valid reason to initiate, postpone, or refer appropriate endodontic treatment. A diagnosis must become part of the patient's treatment record.

To reach a diagnosis and decide on a treatment plan, you must determine:

- If the symptoms described by the patient are odontogenic in nature, do not stem from other sources, and indicate the need for endodontic treatment
- Which tooth is the true source of the problem
- The condition and pulpal status of the suspect (identified) tooth
- If, after being informed of the alternatives, the patient wishes to be treated endodontically and is willing to commit to the financial cost and maintenance of the teeth in question
- Which cases due to their complexity are better referred to an endodontic specialist

MEDICAL AND DENTAL HISTORY

Health status and dental history provide important information essential tomaking a diagnosis (see lesson 2). Figure 4-1 shows an example of an Endodontic Diagnosis Form used for examination and diagnosis.



Endodontic Chart - University of the Pacific

Patient Name	**ID Number**
Student Name	**Tooth Number**
Date	
Dental History (includes chief complaint and present dental illness)	**Medical Alert**

Present Diagnosis and Findings

Current Status of Pain and Symptoms (circle) Symptomatic Asymptomatic

Location	Chronology	Quality	Influencing Factors
Localized	Inception:	Intensity: + ++ +++	Provocable:
Diffuse	Course/duration:	Sharp	Heat Cold
Referred/radiating	Intermittent	Dull	Percussion Palpation
Others:	Momentary	Pulsating Spontaneous	Mastication Manipulation
	Lingering	Constant Occasional	Supination Activity
		Enlarging Reproducible	Time of day
			Relieved by:

Examination

Clinical: Dental/Soft Tissue		Radiographic
WNL Unrestored Restoration Attrition/abrasion Caries Discoloration Pulp exposure Previously accessed Fracture (transillumination) Resorption Trauma Intentional RCT necessary Others:	Type of restoration: Sinus tract traced to: Soft tissue: WNL Lymphadenopathy Extraoral swelling Intraoral swelling TMJ:	Periodontal ligament: WNL Widened Defects Resorption Condensing osteitis Hypercementosis Immature apex Radiolucency: Apical Lateral Well defined Exacerbating (diffuse borders) Prior RCT Perforation Deviation Separated instrument Post/buildup

Clinical Tests and Diagnostics

Tooth number						
Sensitivity to cold						
EPT						
Sensitivity to heat						
Probing depths						
Sensitivity to percussion						
Sensitivity to palpation						
Furcation						
Mobility						

N Normal 0 No response + Mild ++ Moderate +++ Severe L Lingering D Delayed

Therapy

Treatment started elsewhere Location of orifices difficult Retreatment Severe canal curvature C-shaped canal Ramification Narrow canal	Existing ledge Existing perforation Open apical foramen Rotation/tilted tooth Limited mouth opening Psychological cofactor Others:	**Etiology of Endodontic Disease:** **Prognosis:** Favorable Poor Questionable

Diagnosis

Summary of Findings	Pulpal	Periapical
Vital pulp, asymptomatic	WNL	WNL
Vital pulp, symptomatic	Reversible pulpitis	Acute apical periodontitis
Inflamed pulp, without radiolucency	Irreversible pulpitis	Chronic apical periodontitis
Inflamed or partially necrotic pulp, radiolucency	Pulp necrosis	Acute apical abscess
Necrotic pulp, without radiolucency		Chronic apical abcess (sinus tract)
Necrotic pulp, radiolucency	Status after emergency treatment	Phoenix abcess
	Endodontic treatment failure	Condensing osteitis

Fig 4-1 Endodontic Diagnosis Form currently used at the Arthur A. Dugoni School of Dentistry, University of the Pacific.

Patient interview

The patient should be asked about the intensity of the pain: Do you have any pain? If so, what is your pain level on a scale of 1 to 10? (High intensity may indicate irreversible pulpal disease and the need for endodontic therapy.) Are your symptoms influenced by factors such as heat, cold, pressure, time of day, or posture? For example, a sharp lingering pain lasting more than 30 seconds after cold provocation may be a sign of irreversible pulpitis and indicate the need for endodontic therapy. However, if the symptoms are mild and relief is almost immediate, it is better to take a "wait and see" approach and schedule the patient for another appointment in 30 to 60 days. At this follow-up visit, you should repeat the test and compare the results. The treatment decision depends on whether or not the problem has pointed or has subsided. The clinical information regarding further patient interrogation is described in detail in lesson 2.

Extraoral examination

Palpation and visual inspection of a patient's face and neck can detect swelling or asymmetry from infection and abscess formation. Deep space infections associated with fever and multiple space invasions may require the patient to be referred to an oral and maxillofacial surgeon or hospital emergency room. The clinical information is described in detail in lesson 2.

Intraoral examination

Examination of the teeth and oral tissues includes tissue inspection, assessment of occlusion, palpation, mobility, and percussion, as well as thermal and electric assessment. It is often wise to test the whole quadrant in question and the contralateral teeth and to compare the results with those of healthy teeth. The details of an intraoral examination and the condition of the clinical crown are discussed in lesson 2.

A detailed soft tissue mucosal examination (buccally and palatally) at times reveals a draining sinus tract (fistula) that could direct one to the immediate site of an infection. By inserting a gutta-percha cone (whatever size and length the tract will accommodate) into the sinus tract entrance and taking a periapical film of its path, you will generally be led to the origin of the infection (Fig 4-2). Clinical testing to determine the vitality of the suspected tooth (teeth) as well as that of the adjacent teeth should confirm a diagnosis. In the case depicted in Fig 4-2, the pulp of the canine was necrotic, and a subsequent apical periodontitis had developed.

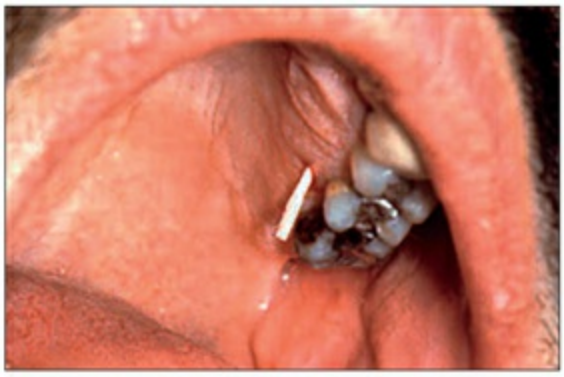


Fig 4-2a A gutta-percha cone is inserted into a palatal sinus tract adjacent to a maxillary left first molar that is suspected to be the problem.

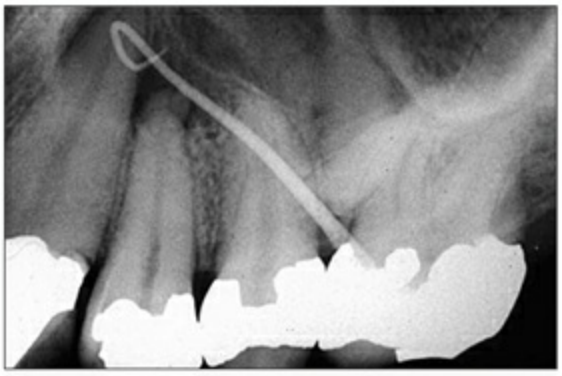


Fig 4-2b The radiograph proves the molar is not the culprit, as the gutta-percha cone was traced to a large periapical lesion in the area of the maxillary left canine. Cold testing revealed that the canine contained a necrotic pulp.

Clinical testing

Pulpal sensitivity tests consist of electric pulp tests and thermal (heat or cold) tests. Though a tooth's reaction to thermal stimuli is useful in determining the relative degree of pulpal involvement in a disease state, electric pulp testers merely indicate the presence or absence of vital pulp tissue (life or death). The readings on these devices do not measure the relative health of a tooth nor specifically designate the stages of pulpal disease. (Clinical testing devices and selective anesthesia techniques are described in lesson 2.) The patient's subjective response to pulp testing should be evaluated carefully to differentiate a true positive response from a false one that might represent the anticipation of pain. It should be compared with the response of contralateral and adjacent teeth to ensure accuracy.

Many clinicians assume that the presence of nerve fibers correlates with a viable blood supply to the pulp. However, some types of nerve fibers can tolerate a lack of oxygen for a certain amount of time. As such, sensitivity and vitality are not mutually inclusive. A nonsensitive tooth with no innervation can still be vital and blood-perfused (eg, after luxation injuries). Clinically, this means that for some time after the loss of a blood supply, teeth can still respond to testing and thereby lead

one to an incorrect diagnosis.

An accurate clinical diagnosis in endodontics is a difficult competency to master. All tests that provoke a response need to be carefully assessed along with history, symptoms, and signs of disease for a clinician to have a thorough understanding of the underlying biologic implications. Thus, evaluating all the data from other tests is important in making the correct diagnosis.

Diagnostic tips

- Spontaneous pain to cold and a history of previous pain episodes in the same tooth (ie, high-intensity toothaches) usually indicate the presence of severe and irreversible pulp pathosis and the need for endodontic therapy.
- Odontogenic pain rarely, if ever, crosses the midline of the face.

Radiographic examination

A diagnosis and treatment plan cannot be defined without identifying important structural, anatomic, and tooth-related landmarks such as tooth position relative to the sinus and inferior alveolar nerve (IAN), location of the mental canal, the length and number of roots of multirooted teeth, and the extent of mineralization of a root canal. To accomplish this goal, it is advantageous to use multiple radiographic techniques and varied angulations. As such, a comprehensive radiographic examination might include the following:

- Bitewing radiographs provide the most accurate portrayal of the depth of decay and the size of the existing pulp space.
- Periapical radiographs taken from different horizontal angles (either mesial or distal) expose the degree of periodontal bone loss, the expanse of the lesion, and additional roots and root canals to identify the degree of case difficulty (Fig 4-3).
- Occlusal plane and/or panoramic radiographic images depict with accuracy the estimated span between root tips and strategic anatomic structures (maxillary sinus and IAN). More detailed clinical and radiographic examination information is described in lessons 2 and 3.

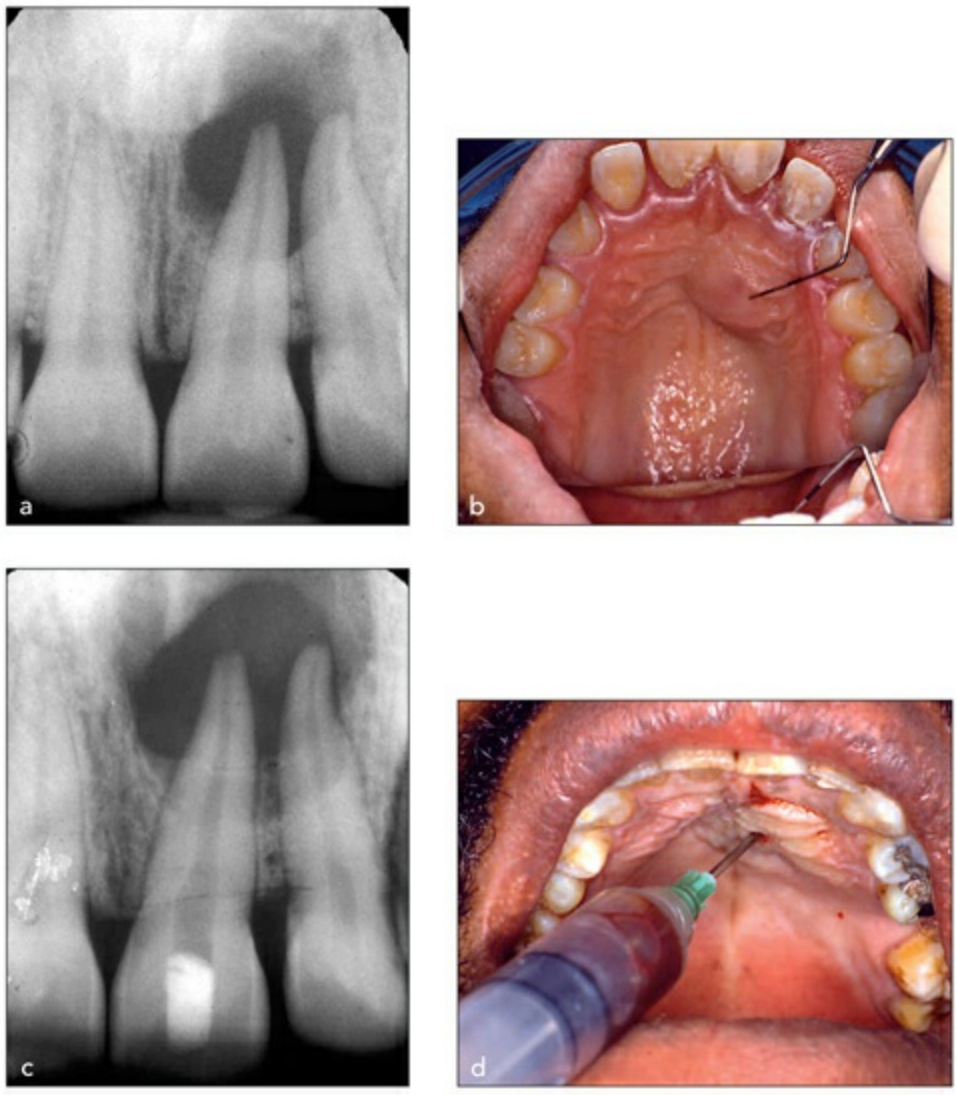


Fig 4-3 *(a)* Periapical film demonstrating a very large and acutely inflamed lesion associated with the maxillary left central incisor. *(b)* Notice the associated palatal swelling. *(c)* The tooth was accessed to disinfect the pulpal space. *(d)* Drainage and decompression were achieved by needle aspiration.

PULP AND PERIAPICAL CONDITIONS, DISEASES, AND DIAGNOSTIC INDICATORS

A healthy pulp is a pulp that is symptom free and responds normally to vitality testing. This pulp is free of inflammation. Moderate responses to thermal and electric stimuli may occur, but there are neither spontaneous symptoms nor a history of pain (toothache).

Pulpitis

The pulp tissue is vital and depending on the degree of inflammation may or may not have symptoms.

Reversible pulpitis

A tooth with reversible pulpitis may exhibit a sharp hypersensitive response to thermal provocation or electric pulp testing that subsides immediately after removal of the stimulus. Other than that, the tooth is asymptomatic.

The fact that the patient's response to cold is moderate (short and transitory) and to percussion tests is negative indicates that the inflammation should resolve itself and the pulp should quickly return to its normal state. However, one must suspect hidden signs of trouble and carefully examine the tooth for caries that might exist beneath a faulty or cracked and leaking restoration or for a vertical crack that involves a pulp horn. If left to time, these situations will ultimately lead to a bacterial invasion of the pulp, and the reversible pulpitis can quickly become an irreversible pulpitis or necrosis.

Beyond the examination, when deemed necessary due to the severity of the patient's complaint, interceptive vital pulp therapy may be indicated. For instance, the patient may need to use a surface fluoride treatment or a desensitizing toothpaste if the origin of the problem appears to be erosion of the enamel and subsequent exposure of the root and dentin. When a possible pulp exposure (under a restoration) is suspected, removal of the restoration and placement of a sedative dressing at the floor of the pulp chamber is warranted.

Irreversible pulpitis

The diagnostic signs and symptoms of irreversible pulpitis encompass a wide range of situations, all of which suggest the pulp is inflamed to a degree that cannot revert to normal. That is, subjective and objective findings signify that the vital pulp is inflamed to such a degree that it is unable to reverse the inflammatory response and thereby heal. This condition may be characterized as *symptomatic* or *asymptomatic*.

Symptomatic

Spontaneous acute pain that lingers after thermal stimulation and refers pain to other sites is characteristic of symptomatic irreversible pulpitis (Fig 4-4). A patient with this condition usually experiences prolonged (constant) stimulated episodes of spontaneous intense pain, which may be local or referred. The pulp may be partially or totally inflamed and possibly even hyperplastic (through a large carious exposure, trauma, or tooth structure resorption).

Electric pulp testing may be of questionable value, since the pulp is vital and the radiographs usually provide only indirect evidence of trouble, such as deep caries or an extensive restoration.

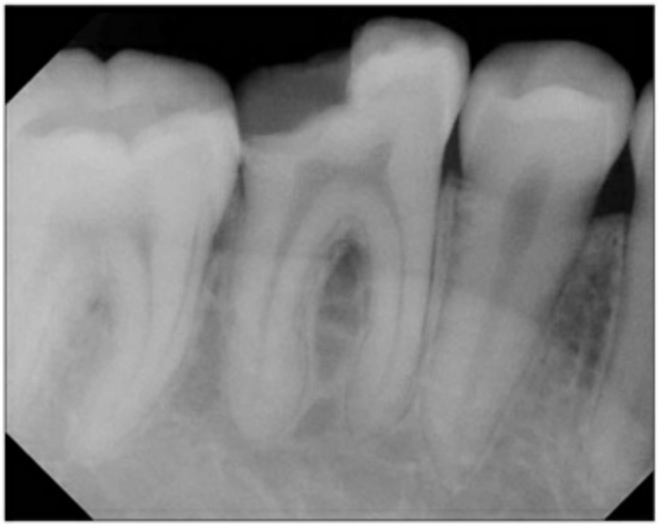


Fig 4-4 Typical endodontics case demonstrating irreversible pulpitis in a mandibular right first molar.

Asymptomatic

Chronically inflamed pulp tissue that produces no (sporadic) clinical pain symptoms is characteristic of asymptomatic irreversible pulpitis. The signs of this condition are vague, and though they are periodically apparent to the patient, they may not be present at the time the patient presents for the examination. As such, it may be extremely difficult to diagnose which tooth is the cause of the problem. Since one cannot injudiciously initiate treatment without a confirmation of the diagnosis, it is incumbent upon the clinician to inform the patient of the treatment conundrum.

The patient should be seen again in 30 to 60 days, at which time the examination and tests should be repeated and the results compared. Hopefully, the signs and symptoms will escalate enough to determine the true cause.

Pulpal necrosis

The clinical diagnosis of this condition specifies death of the dental pulp tissue. The pulp is nonvital to testing and may be partially or totally necrotic. The necrotic tooth is often asymptomatic, and in most cases it will not respond to any sensitivity test other than percussion. Depending on the degree of involvement of the pulp space, the crown of the tooth may be discolored (red to black) from hemoglobin degradation.

The apical area may appear relatively normal, or a periapical pathosis (eg, an expanded lamina dura or extended periradicular lesion) may be radiographically apparent. Much depends on whether the entire canal tissue is necrotic and the length of time bacteria from the canal have been proliferating in the periapical tissues.

Endodontic failure and retreatment

In this clinical diagnostic category, the pulp chamber of the tooth in question has been endodontically treated to some degree, as in pulp capping or pulpotomy without definite treatment, or the canal has been extirpated, as in pulpectomy. The root canal has been instrumented and filled with some form of canal filling material.

PERIAPICAL AND APICAL DIAGNOSES

Normal apical tissues

In this category, teeth display normal periradicular tissues without heightened sensitivity to percussion or palpation testing. The white line representing the lamina dura around the root is intact, and the periodontal ligament space is of the same width.

Symptomatic apical periodontitis

The apical periodontium is inflamed and painful, producing clinical symptoms such as pain on biting, pressure, and percussion. An apical radiolucent area may or may not be visible. This stage may occur in such a short period of time that no periapical changes are apparent on the radiograph on the day the patient presents.

Acute apical periodontitis

Acute apical periodontitis can be an inflammation of short duration within healthy periapical tissues. A newly placed maloccluding filling will produce this response. However, the usual signs and symptoms are extreme tenderness to occlusal percussion and palpation. Slight to pronounced swelling, moderate to severe pain, and mobility may also be present. A sudden change of minor symptoms to an acute apical periodontitis may be diagnostic for endodontic intervention.

Exacerbation of chronic apical periodontitis

This long-standing condition may be characterized by its sudden onset (ie, spontaneous pain, sensitivity to pressure, pus accumulation, and possibly a large swelling of the surrounding soft tissues [abscess]). When referred to as a *phoenix abscess*, the condition is recognized as a large pathosis (appears identical to an acute apical abscess due to swelling) with its distinguishing characteristic being the presence of a defined apical radiolucency on the radiograph.

- Open an access cavity and instrument the canals to size.
- Place a calcium hydroxide dressing to the working length and seal the access cavity.
- Call this patient on the day of and the day after the procedure to follow the patient's recovery.
- If the patient's condition worsens, he or she must be seen immediately, the tooth must be re-instrumented and redressed, and the patient placed on an appropriate antibiotic.
- Incision and drainage of the soft tissue may be necessary.

Asymptomatic apical periodontitis

The apical periodontium is inflamed, but no clinical symptoms can be verified (revisit the phoenix abscess). The patient may be unaware that there is a periapical lesion (Fig 4-5a).

Tip: The clinical examination and radiographic confirmation of loss of attachment must include a differential diagnosis of a lateral periodontal abscess associated with a vital, sensitive tooth.

Acute apical abscess

This diagnosis exhibits rapid development, spontaneous pain, tenderness of the tooth to pressure, pus accumulation, and swelling of surrounding tissues. Although manifested clinically by swelling and pain, radiographically the tooth may appear normal or may only have a slightly thickened periodontal ligament (Fig 4-5b). This condition may be the sequela of an advanced stage of acute apical periodontitis or the result of endodontic procedures that contribute to an acute flare-up. It may also be caused by a foreign body reaction.

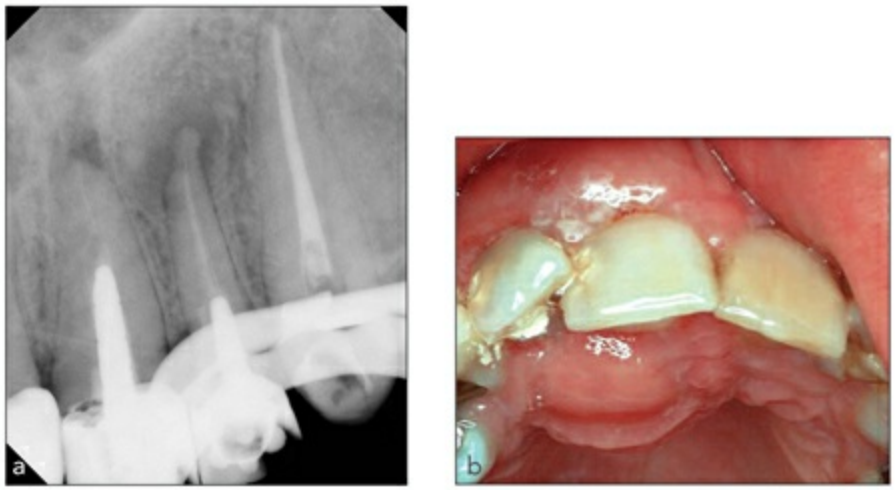


Fig 4-5 Typical clinical cases presenting for endodontic diagnosis. *(a)* Chronic apical periodontitis in maxillary central and lateral incisors. The teeth in question are asymptomatic. Both have poor-quality root canal therapy. *(b)* Acute apical abscess on the palate in a maxillary right central incisor.

Chronic apical abscess

A chronic apical abscess is caused by an infected pulp space and necrotic pulp tissue. It is distinguished by a gradual onset and little or no discomfort (asymptomatic), though slight tenderness to palpation and sensitivity to percussion may be present. Because it is a chronic apical abscess, a draining sinus tract is often present, which intermittently discharges pus. Due to the presence of granulomatous tissue (eg, lymphocytes, plasma cells, and macrophages), it is also referred to as *periapical granuloma*.

Typically, this type of periapical inflammation has existed for a prolonged period of time. It is often diagnosed by the presence of an unexpected apical rarefaction on routine radiographs.

Condensing apical periodontitis and osteosclerosis

This represents a state of chronic pulpal inflammation that is associated with reactive bone tissue formation. Untreated, this condition usually progresses into a chronic apical periodontitis. A characteristic sign is a periapical radiopacity associated with a tooth that responds within normal range to sensitivity testing. The most common pulpal and periapical diagnoses are listed in Table 4-1.

Endodontic-periodontal lesions

Sensitivity testing can distinguish between a purely periodontal lesion, where the tooth reacts to cold or another provocation, and an endodontic lesion, which involves a necrotic nonsensitive pulp. Lesions of endodontic origin may cause secondary periodontal involvement due to the longstanding drainage of pus through a narrow periodontal pocket. On the other hand, periodontal pockets that remain untreated may lead to secondary endodontic involvement through portals of communication between the periodontal ligament and the pulp space. In rare instances, true combined lesions resulting in the communication of both endodontic and periodontal pathoses may be diagnosed.

Tip: In teeth that require endodontic treatment and show furcation involvement or lateral periodontal lesions, the root canal treatment should be performed first and the tooth reevaluated for periodontal healing later. This avoids unnecessary surgical intervention of the periodontium as many periradicular lesions resolve after successful endodontic therapy.

Trauma

For teeth that have suffered a traumatic injury, it is necessary to determine how extensive or

complicated the injury is. Uncomplicated crown fractures (no pulp expsorue) can often be restored and the tooth (pulp) periodically evaluated. In contrast, a complicated crown fracture that involves the pulp necessitates vital pulp therapy or requires a pulpectomy and concomitant endodontic therapy. Teeth with luxation injuries are often severed from both vascular and neural structures passing through the apical foramen. In immature teeth, revascularization is possible, but teeth with complete, mature root formation require endodontic therapy. (A more detailed account of recommended treatment steps in cases of severe traumatic injury can be found in lesson 40.)

Tip: Due to the trauma of the tooth's innervation, traumatized teeth often retain their vitality even though the tooth may test negative to cold and/or electric pulp testing. To avoid unnecessary therapy, these teeth must be carefully appraised over time.

Pain of nonodontogenic origin

A variety of diseases can cause pain that is felt in a tooth but is not caused by pulpal disease. These include dentin hypersensitivity, sinus infections, cysts, metastatic cancer, referred pain from neurologic disorders, psychiatric disorders, cardiac sources, myofacial pain, and an array of other diseases and conditions.

Although the vast majority of toothaches are the result of pulpal or periapical pathoses, in some cases patients report to a dentist with pain that cannot be verified through clinical examination, clinical diagnostic tests, or radiographs.

Tip: It is wise not to commence treatment if the responsible tooth or the origin of the pain cannot be identified. It sometimes takes months for a periapical lesion to develop, and in rare inconclusive cases, this might be the only verification of pulpal disease.

Such non–tooth-related pain scenarios are difficult to diagnose and isolate. As such, the following symptoms of nondental pain and pain that mimics toothache have been described:

- Spontaneous pain in multiple teeth, poorly localized
- Changing locations or crossing the midline
- No apparent local dental cause for the pain
- Burning, nonpulsatile or shock-like toothaches
- Constant, chronic toothaches that simulate sinus problems
- Unrelenting, recurrent toothaches without localization
- Local anesthesia of the suspect tooth or arch that does not relieve the pain
- No response of the toothache to adequate dental therapy

Caution: If a nondental pathosis is suspected, no treatment should be initiated, and the patient should be referred to an appropriate clinic or clinician (eg, an orofacial pain clinic, neurologist, oral surgeon, or physician). The records should reflect the tests, the results of the tests, and the patient and doctor discussions.

CONCLUSION

Many cases can be diagnosed with a minimum of evaluation and testing because of their obvious etiology (eg, a clinically observed pulp exposure or a radiographically detected area of periapical rarefaction). In less obvious cases, however, the use of endodontic sensitivity testing can often provoke undemonstrative symptoms and reactions that are critical for an accurate diagnosis (Table 4-1 and Fig 4-6).

Table 4-1 **Common pulpal and periapical diagnoses**

	Sensitivity	Pain	Radiolucency	Sinus tract
Healthy pulp	Yes	No	No	No
Reversible pulpitis	Yes	Yes/No	No	No
Irreversible pulpitis	Yes	Yes/No	No	No
Condensing osteitis	Yes	No	Radiopacity	No
Necrosis	No	No	No	No
Symptomatic apical periodontitis	No	Yes	Yes/No	No
Asymptomatic apical periodontitis	No	No	Yes	No
Acute apical abscess	No	Yes	Yes/No	No
Chronic apical abscess	No	No	Yes	Yes/No

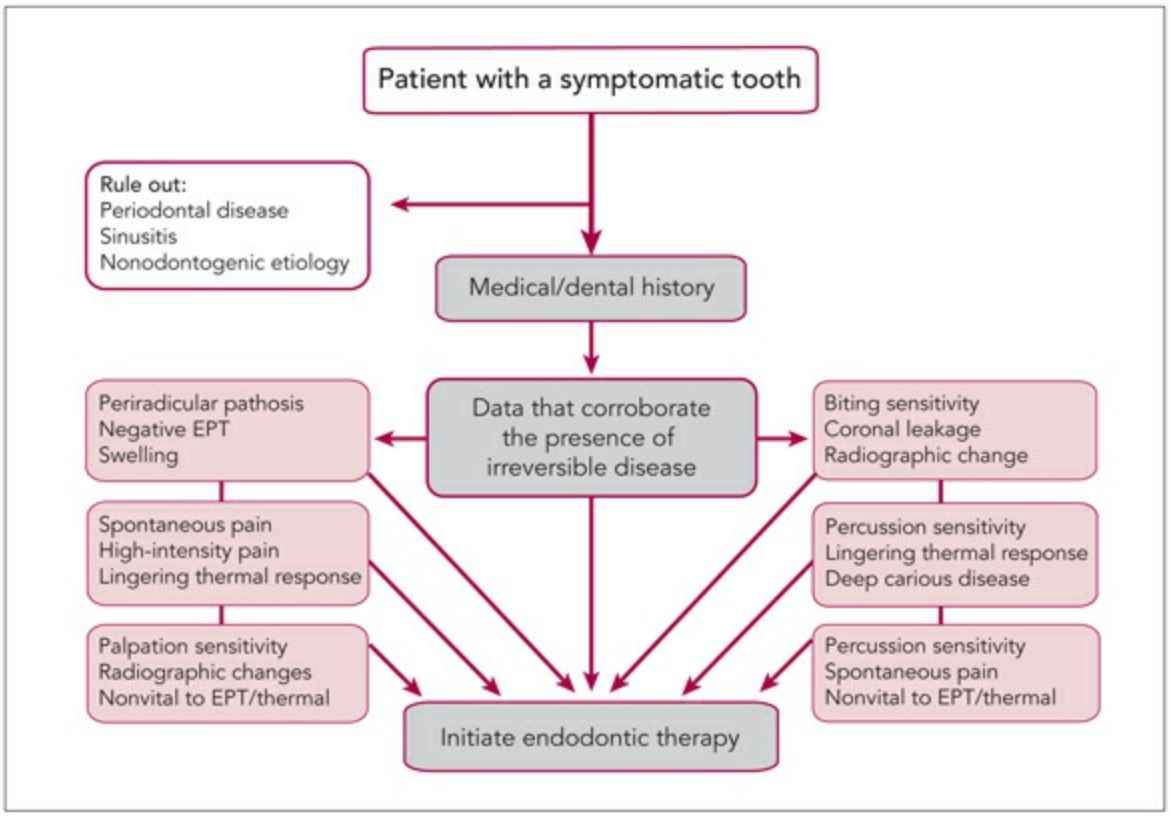


Fig 4-6 Algorithm demonstrating typical signs and symptoms that dictate the clinician choose endodontic therapy. Scenarios are only possibilities and are not inclusive. EPT = electric pulp test.

LESSON 5

Treatment Documentation and Record Keeping

OBJECTIVE

To keep impeccable professional, legal, and ethical records of the planning and documentation of a patient's care.

INTRODUCTION

Of the multiple reasons for keeping accurate patient records, the following are the most important:

- Remain current with the health status of the patient.
- Verify the treatment options that were offered and treatment that was provided to the patient.
- Be able to provide legal documentation on behalf of the patient to the courts, third-party payers, or the patient's heirs.
- Be able to provide legal documentation in the defense of a legal claim made against yourself (as the providing dentist).
- Fulfill the laws that regulate an ethical professional practice.
- Contribute and provide quality assurance assessments to dental research centers.
- Improve communications among health practitioners.
- Assist in identifying the victims of massive injuries.

QUALITY DOCUMENTS

Quality documents should do the following:

- Provide an accurate history of the patient's consultation including medical history, differential diagnosis, treatment plan, and prescribed treatment in clear understandable language.
- Enable anyone reading the documents to readily discern patients' problem(s) at the time they presented and how the dentist logically and systematically managed the problem(s).
- Recreate the course of treatment from beginning to end. That is, a complete, detailed dental record stands as the most reliable evidence that a dentist followed the standard of care, offered the patient alternatives and treatment options, discussed and accepted the patient's decision, and provided the patient with informed consent.

Note: From a risk management perspective, quality documentation of clinical care is the single most important deterrent to a plaintiff attorney's acceptance of a patient's claim for malpractice. Poor charting and record keeping is the most common reason that liability insurers must seek to settle claims—there simply is no credible record to defend against the patient's allegations. A significant point to remember is that if it is not written in the record, it was not done.

BASELINE ESSENTIALS OF RECORD KEEPING

- Accurate patient information, such as name, address, and phone number.
- Complete medical and dental history with updates, including blood pressure readings.
- Precise description of conditions that are present, to include stating "within normal limits" if appropriate.
- Record of significant findings of supporting diagnostic aids such as tests (eg, pulp tests, percussion, palpation, Tooth Slooth [Professional Results]) and radiographs and digital images.
- Reports from, as well as to, medical referrals or dental specialists.
- Diagnosis and treatment plan.
- Informed consent obtained in writing; a copy of the form should be given to the patient and noted in the record.
- Description of all treatment provided, materials and drugs prescribed and used, treatment prognosis, and outcome assessment.
- Financial records must be accurate and separate from the treatment records.
- Records should be retained indefinitely; *never destroy records*.
- Health Insurance Portability and Accountability Act (HIPAA): The confidentiality of the information gathered must be protected.

Additional aspects of routine record keeping

All patient information, forms, radiographs, written comments, and so forth should be objective and kept in a methodical and consistently organized manner in a single "patient folder." Anything found in the patient record is discoverable in a lawsuit:

- The names and reports of any other providers involved in a patient's care should be part of the record included in the patient folder.
- The patient's signature must be on all pertinent forms. These include a current medical history (within a year of treatment), updated consent forms for each new treatment proposal, and authorization(s) (eg, HIPAA disclosure forms) to release information to insurers and financial institutions such as banks and credit unions.
- It should be noted if the patient understands the proposed treatment plan but does not accept it; the patient should sign an informed refusal of care form.

To avoid a legal challenge, be specific on correcting entry errors:

- Draw a single line through the incorrect text without making it unreadable.
- Do not use liquid paper or obliterate the entry with felt pen.
- Elaborate on any findings that might justify the reason for correcting the entry.
- Mark the change "corrected entry for [date of the error]." Enter the date you are making the change, and sign (name and initials) in the nearest open space.

RECORD KEEPING SPECIFICS FOR ENDODONTIC THERAPY

- Record any history of temporomandibular joint disorders—this protects the clinician in case a patient claims that the endodontic treatment initiated the problem.
- All radiograph and digital images must be of diagnostic quality; avoid making a diagnosis based strictly upon another person's (referred) radiograph. Always take two radiographs or digital images at slightly different angles and from different directions prior to making an endodontic diagnosis.
- Record both a pulpal and a periapical diagnosis for the tooth in question as well as for adjacent teeth.
- If performing "prophylactic" endodontics on a healthy tooth, it is important to provide a reasonable rationale to prevent accusation of fraudulent treatment.
- Use of rubber dam is the standard of care in endodontics and must be documented.
- Record lengths of root canals including reference points for each canal; lengths obtained from electronic apex locators are acceptable.
- Record types, sizes, and tapers of the files and instrumentation technique used.
- Include type and amount of irrigant and medicament used during the filing.
- Record type of obturation materials used including technique and how the access was restored.
- A postoperative radiograph or digital image must be taken, and an interpretation of the result should be documented.

• Indicate any adverse events that occurred during treatment (eg, fractured file, overfill), and indicate that the patient was informed about the event and possible sequelae, treatment options, and prognosis. Have the patient sign the notes to acknowledge that she or he has been informed.

Document the fact that written and oral postoperative instructions were given and recall dates were offered or secured.

Electronic records

There is a considerable movement towards electronic record keeping, especially in endodontic practice. Electronic records provide an accurate visual display of recorded information, capable of being retrieved and printed in a timely manner. A significant advantage is that the electronic record maintains a continuous audit trail, which can preserve the original content of information and indicate changes in the recorded information. From a legal standpoint, the electronic record produces a legible "business" record that is admissible in court and significantly reduces many of the problems associated with written records such as record loss, security issues, and cumbersome data retrieval. It is anticipated that electronic dental records will eventually become a standard of practice.

Legal audits

What does a plaintiff's expert witness look for when reviewing a doctor's records?

Organization of data

Are the progress notes, treatment notes, and records disorganized and inadequate? Documentation of the medical and dental history must be comprehensive and questioned for accuracy. Medical issues must be discussed and risk issue questions appropriately responded to (ie, medication, physician consult, and referral):

• Preoperative radiographs must be clean, clear, focused, and of diagnostic quality.

• Tests used during the examination and their results must be described, a diagnosis made, and a treatment plan designed and delivered in clear, concise understandable language.

• Treatment options and their benefits, rewards, prognosis, and fees must be disclosed.

• The patient must sign an Informed Consent Form before treatment is initiated (see lesson 10).

Record of anesthetics and sedative use

Were local anesthetics, analgesics, conscious sedation techniques, sedatives, hypnotics, or nitrous oxide used?

• There must be a running record of the use of nitrous oxide and of oxygen flow with a recording of

vital signs at appropriate intervals, and the names of the sedative or hypnotic drugs used, the concentration, and the method of administration. The patient's reaction to these drugs must also be accounted for.

- The record must include the name of the local anesthetics used, the presence and concentration of a vasoconstrictor (or note its absence), the method of administration, and whether it provided adequate anesthesia or if it was necessary to reinject. At the conclusion of treatment the amount of anesthetic solution used should be recorded.
- The status of the patient at the conclusion of anesthesia or sedation must be described. If there was any problem with a patient's recovery at the end of the procedure, its management and the patient's condition at the time of dismissal should be noted. Contacting the patient from 24 to 72 hours after the procedure displays concern and is always a positive element of care for the jury.

Treatment narrative

Are the progress notes a running contemporary narrative detailing treatment as it is performed and completed, including objective observations made while treatment is in progress? Can any person pick up the chart and trace the sequence of care without any of the steps of the endodontic process being questioned? There must be a complete, comprehensive, and continuous recording of the endodontic treatment as it progresses. These include the following:

- Placement of rubber dam
- Access opening (bur)
- A description of the tissue found in the chamber and canal (hemorrhage or odor)
- Tentative clinical diagnosis
- Instrument(s) used to negotiate the canal (ie, type, size, and method of navigation)
- Canal measurement (electronic or quality radiograph)
- Canal size and length enlargement (type and sizing sequence)
- Irrigation method and solution(s) used
- Types of materials (sealer) and compaction technique(s) used to obturate
- Material used to restore the coronal access opening

Unexpected incidents

Did any unusual occurrences or incidents take place during the treatment process?

- If anything unusual occurred, the facts should be recorded without misrepresentation in simple language that reasonably reflects what actually happened. Records should be serious, and the description of the event should be limited to what happened. Resist the temptation to explain, rationalize, or argue your case in the records.
- Reread all statements, and avoid complex words and terms that are vague. Be certain that what you record does not have several different meanings that would be subject to interpretation in more than one way.

- If the incident was an injury (eg, a stick), do not make statements in the record about how careful you were prior to the injury, and do not convey in the records your opinion that someone else was negligent. Record your response(s) to the injury.
- Document any acts of patient noncompliance or legal threats and complaints about the quality of your care. The account may be briefly documented in the patient records in a judgmentally neutral manner, but expressions that imply disapproval or a negative value judgment of the patient must be avoided.

CONCLUSION

The following is a summary of recommended "dos and don'ts":

- Fill in all blanks and spaces. Record negatives as well as positives.
- Use standardized abbreviations but use them sparingly.
- Chart precise amounts.
- Date and sign any additions or corrections (see Additional aspects of routine record keeping) on the chart.
- Record an emergency contact mechanism for the patient and next of kin.
- Document and date all contact or attempted contact with the patient, such as phone calls; messages left (who they were left with); missed, cancelled, and late appointments; services rendered; and dosages and refills of all prescriptions (record the pharmacy phone number and the name of the pharmacist who took the call if the medication was called in).
- Chart all information immediately. Delay leads to inaccuracies and/or missing information.
- Document plans for future care or follow-up.
- Record the complete date (day/month/year), and sign each and every chart entry.
- Use black ink (pens only, no pencil entries), which is best for photocopying purposes.
- *Do not* chart subjective comments about the patient (eg, your opinion about a patient's mental status). Record such subjective observations on a separate sheet marked "confidential" or "personal notes." Confidential and personal notes can be withheld from the patient and are not discoverable by the patient's attorney.
- *Do not* chart names without describing how these people function in relation to the patient's present or future care.
- *Do not* chart information that is not pertinent to the care of the patient.
- *Do not* chart financial or insurance data in a clinical record; use a separate form and folder.
- *Do not* file a chart until it has been checked for completeness.
- *Do not* alter records after a suit has been filed; do not attempt to clarify, add, change, or modify an existing entry in any way.
- *Do not* use liquid paper, scribble over, cut off, or in any way obliterate a chart entry that has been made (see Additional aspects of routine record keeping).

PART TWO

Treatment Strategies and Decision-Making

LESSON 6

Managing the Apprehensive Patient

OBJECTIVE

To gain the patient's trust, address and allay fears and anxieties, and keep the therapy free of stress and pain.

INTRODUCTION

In today's society, the public is far more educated and health conscious than were preceding generations and is less likely to accept an extraction as the only alternative. However, a treatment plan that includes root canal therapy is often met with reluctance. Because of the perception that pain and discomfort are associated with root canals, dentists must recognize the extent and clinical significance of a patient's apprehension and make a conscious effort to resolve or eliminate those fears. Though every patient should be treated equally, the techniques and suggestions in this lesson are directed at managing the anxious patient with compassion.

EARNING A PATIENT'S TRUST

The overall professional demeanor of the doctor, the caring manner in which the patient is examined, the proficiency demonstrated by the attending staff, and the clarity of the case presentation all influence the patient-doctor relationship. There is no better placebo than being treated with sensitivity and compassion, and every effort should be made during the examination and consultation

appointment to convey that care and concern. During this time you must reinforce patients' confidence and trust by:

1. Making them feel comfortable in the presence of you and your staff. Instigate and conduct normal conversation, adjust the chair and headrest to their satisfaction, suggest they loosen any tight clothing around their neck or wrists, ask and answer questions about their medical and dental history with sincerity and concern, and do all of this as if they were the only patient you were seeing that day.
2. Efficiently and confidently examining, identifying, and discussing the diagnostic differentials of their case.
3. Informing them of the need to separate the differentials and to confirm a diagnosis by taking diagnostic radiographs and performing percussion and thermal pulp tests.
4. Describing and explaining what they should expect as you carefully and slowly carry out the tests (apprehensive patients do not tolerate surprises).
5. Clearly and succinctly discussing the results of the tests and the final diagnosis. Explain what the treatment will be and why it is needed, and respond to any concerns (see lesson 10).
6. Assuring them that you have treated similar cases and have had a success rate equal to those published in studies of root canal therapy (92% to 98%).

Note: Your examination behavior should give patients every reason to believe their treatment will be managed painlessly and successfully. That kind of trust is a tangible goal of considerable importance.

PATIENT OBSTACLES

Regardless of how well some patients are treated in your office, they may hesitate to accept your treatment proposal. You must identify (question and discover) the underlying reasons for their resistance to treatment (eg, indifference, restricted finances, lack of time, fear). Most of the time these issues can be resolved when appropriate solutions are proposed.

Indifference

If the patient does not see the need for the treatment, you must be able to turn a "no need" into a "want." Greater time must be given to further educate the patient with regard to the value of the tooth, the consequences of losing the tooth, and the limited and expensive options that are available once the tooth is gone:

1. The patient can be offered endodontic education materials (published by the American Association of Endodontists [AAE]) that clearly identify why root canal therapy should be the treatment of choice when a tooth is in peril.
2. The patient should be given time to read the AAE literature at home and to reconsider the proposed treatment plan.
3. Follow-up the visit with a phone call (3 to 4 days later) to show concern for the patient's welfare,

to offer further advice if asked, and to get a concluding decision.

4. All communication must be recorded, and if the patient is referred by you for a second opinion, inform the second doctor of the situation, the diagnosis, and the patient's decision.

Limited finances

Though "cash up front" is the simplest way to conduct business, the fee for endodontic treatment is substantial, and some financially stressed patients may not see a way to pay (lump sum) for the treatment regardless of their need or want. The following suggestions are offered:

1. If the patient has insurance, every effort should be made to assure the patient the proper insurance codes will be filed (the endodontic insurance code system is available from the AAE) to maximize coverage.
2. What is not covered in the dental insurance plan or a patient's co-pay plan can be calculated to give the patient a more realistic and acceptable idea of what will be the "out-of-pocket" cost.
3. To assist the patient in paying the portion of the fee not met by insurance plans, the office should be in a position to offer a reasonable payment method (ie, credit card).
4. If the patient has no insurance and chooses not to use a credit card, suggest that a loan be made with one of the local banks. Some banks have established payment plans for patients of dentists whose office accounts are in that bank.
5. The least favorable scenario is to suggest that the patient pay a percentage of the fee prior to the treatment and establish a short-term in-house payment schedule (maximum 30 to 60 days) for the balance.

Time constraints

Some patients who work in demanding high-level jobs as well as hourly workers who lose wages when they are "off the clock" find it difficult to make and keep dental appointments. Though inconvenient, try to make arrangements that fit the time frames of the patient and the office schedule—perhaps an hour earlier or later in the day, for example. This adjustment is particularly important if the patient has been referred. Complete the treatment plan, if possible, in one appointment (see lesson 27).

Fear, apprehension, and anxiety

Fifty percent of the population does not visit the dentist regularly because of the fear of getting a shot (needle) and the media perception that root canal therapy is painful. A doctor must recognize the extent of a patient's anxiety and be able to respond to those emotions by offering appropriate conscious and unconscious sedation and alternative anesthetic techniques. Underestimating a patient's apprehension could lead to an unexpected mid-treatment episode, such as syncope, a claustrophobic spasm, a convulsion, and/or vomiting, when rubber dam is still in place. Such an event would force

the treatment and, possibly, the entire treatment plan to be terminated. Conscious sedation treatment options should be offered to avoid these unexpected and unwanted experiences.

ANALGESIC, ANESTHETIC, AND SEDATIVE MEDICATIONS

Oral analgesics

Ingesting one of the following oral medications (presented in the order of preference) 30 to 60 minutes prior to the endodontic procedure has been shown to significantly raise a patient's pain threshold during and after treatment:

- Ibuprofen, 600 to 800 mg (Advil, Wyeth Consumer Healthcare) or 400 to 800 mg (Motrin, Pfizer)
- Hydrocodone bitartrate, 5 mg, and acetaminophen, 500 mg (Vicodin, Abbott Laboratories)
- Meperidine hydrochloride (Demerol, Sanofi-Aventis), 50 mg

Since analgesics do not provide anesthesia, an injection of a local anesthetic solution must accompany their use.

Oral sedatives

Oral sedatives have a slow onset, and their effectiveness is somewhat unpredictable. Single doses of the following drugs can be highly effective when they are ingested the night before the appointment to help the patient have restful sleep and again an hour before the actual treatment to help the patient relax during the procedure:

- Diazepam (Valium, Roche Laboratories), 5 to 10 mg, 60-minute onset, duration of 6 to 7 hours
- Alprazolam (Xanax, Pfizer), 0.25 to 0.50 mg, rapid 30-minute onset, duration of 4 to 8 hours
- Lorazepam (Ativan, Biovail Pharmaceuticals and Baxter Healthcare), 2 to 4 mg, slow onset, long-acting amnesiac

Since sedatives do not provide anesthesia, an injection of a local anesthetic must accompany their use. When sedatives are administered at the appointment time, you must be certain that patients are accompanied by a person capable of driving them home at the time the procedure is finished.

Oral hypnotics

Oral hypnotics have a very slow onset, and their effectiveness is somewhat unpredictable. Ingesting single doses of one of the following oral medications the night before the appointment, to help the patient have restful sleep, and again an hour prior to the actual treatment, to help the patient relax during the procedure, is highly effective:

- Triazolam (Halcion, Pfizer), 0.125 to 0.25 mg, individualized to the patient's body weight, produces varied levels of drowsiness

- Pentobarbital (Nembutal, Ovation Pharmaceuticals), 80 to 100 mg, medium onset, duration of 3 to 6 hours
- Secobarbitol (Seconal, Ranbaxy) 80 to 100 mg; depresses the sensory cortex, decreases motor activity, and produces drowsiness, sedation, and hypnosis; can be very effective as a relaxant when administered in capsule form in doses of 50 to 100 mg

Patients should be forewarned that the recovery period for hypnotics may be long, and dizziness, light-headedness, and sleepiness may be temporary side effects. Since hypnotics provide no anesthesia, an injection of a local anesthetic must accompany their use. When hypnotics are administered, you must be certain that patients are accompanied by a person capable of driving them home at the time the procedure is finished.

Oral antihistamines

The following drugs are safe, have rapid onsets and medium durations, and are particularly popular and effectively in pediatric dentistry:

- Promethazine (Phenergan [Baxter Healthcare]), 10 to 25 mg, individualized to the patient's body weight, produces varied levels of drowsiness, duration of 2 to 8 hours
- Hydroxyzine (Atarax and Vistaril, Pfizer), 50 to 100 mg, individualized to the patient's body weight, produces varied levels of drowsiness, duration of 4 to 6 hours

Inhalation anesthesia

Nitrous oxide is an effective sedative and hypnotic. It has a rapid onset, effectively raises the pain threshold, produces a comfortable euphoria, and is safe for all ages when used at controlled (subanesthetic) oxygen levels of 20% to 50%. Below these oxygen levels, nitrous oxide is classified as a general anesthetic and changes both the safety value and the cost of medical protective insurance. The use of nitrous oxide requires a sizable investment in both equipment and training. At safe levels, nitrous oxide provides no anesthesia. Therefore, an injection of a local anesthetic must accompany its use.

Intravenous sedation

Intravenous sedation (IVS) is the most effective means of attaining conscious sedation, deep sedation, and general anesthesia. With IVS, the drug is administered directly into the bloodstream. As such, the sedative onset is immediate. Because the effect of the drug can be measured based on patient response, level of anesthesia, and recovery, it can be controlled:

- Diazapam (Valium), sedation
- Triazolam (Halcion), amnesia
- Midazolam (Versed, Roche Laboratories), anxiolysis

Since these drugs are effective for sedation and amnesia but do not provide anesthesia, an injection of a local anesthetic must accompany their use.

The use of IVS requires a sizable investment in technical monitoring equipment, and the increased safety risk is reflected in elevated malpractice insurance rates. Most states require IVS certification (perhaps annually) by a state board of dental examiners.

Dental anesthesiologists are becoming more available throughout the country, and though they prefer that the patient be brought to their office, they will come to your office to provide this service for an additional fee, charged to the patient. When submitted properly, a patient's medical insurance often covers the additional cost.

General anesthesia

A general anesthetic removes a patient's ability to voluntarily and involuntarily respond. For that reason this service should be reserved for cases that require a hospital or surgical center setting and a qualified dental or medical anesthesiologist. The use of general anesthesia has decreased dramatically as the concepts and agents for conscious techniques have become safer, more reliable, more effective, and less expensive.

USE OF LOCAL ANESTHETIC TO CONTROL ACUTE PULPAL PAIN

Though no patient appreciates pain during a dental procedure, an apprehensive patient considers the slightest amount of pain a crisis. For that reason, when a highly emotional patient has a tooth diagnosed with a pulpitis, one must not assume that the normal local anesthetic approaches meet the depth of anesthesia required to penetrate and extirpate the pulp of an acutely inflamed tooth, even when the signs of anesthesia are evident following an injection (ie, facial, gingival, chin, and lip numbness). To continue accessing the pulp under those conditions would only exacerbate the patient's anxiety, raise frustration, possibly force the termination of the treatment procedure, and cause the patient to seek help elsewhere (a public relations disaster for the practice). The balance of this lesson suggests and describes anesthetic techniques directed toward anesthetizing the uncooperative "hot tooth" (see lesson 14) using the normal anesthetic drugs, routes, and techniques.

Basis of deep anesthesia

The needle must be positioned close to the appropriate target nerve, and a volume of anesthetic solution that will provide at least 1 hour of deep anesthesia (eg, 2% lidocaine with 1:100,000 epinephrine solution) must be delivered. To extend the anesthesia working time from 2 to 4 hours and ward off the pain rebound effect, use 1.5% bupivacaine hydrochloride (Marcaine, Abbott Laboratories) with 1:200,000 epinephrine solution during the procedure or just prior to releasing the pa tient (provides 2 to 5 hours of controlled postoperative pain relief).

Anesthetic techniques

For the mandible

The routine anesthetic injection technique for the teeth of the mandible is normally a Division III lingual block. This injection provides anesthesia to the third division of the trigeminal nerve and to none of the other peripheral nerves. According to studies, it is only successful from 65% to 77% of the time. This may be inadequate when facing a difficult acute pulpitis (hot tooth). The Gow-Gates mandibular block technique is a recommended alternative to an unsuccessful inferior alveolar nerve block. According to studies, it offers a 96% to 98% success rate and anesthetizes not only the major branch of the third division of the trigeminal nerve but also all ancillary nerves associated with the mandible (see lesson 14).

For the maxilla

The routine anesthetic injection technique to anesthetize the teeth in the maxilla is via buccal infiltration. However, the maxillary teeth are often innervated by more than one branch of the maxillary superior division and, consequently, may require multiple injections before a working level of anesthesia is gained on the target tooth. For instance, a first permanent molar might require a posterior, middle, and anterior superior alveolar injection as well as an anterior and posterior palatal injection before the tooth is adequately anesthetized for the pulp to be approached. Suggested alternatives include the maxillary division II posterior tuberosity injection (preferred) or the greater palatine injection. Both successfully anesthetize the entire maxillary superior division of the trigeminal nerve.

For either the mandible or the maxilla

Each tooth is supplied with a single dental nerve that branches from the inferior or superior alveolar nerve and passes through the cancellous bone until it enters the tooth at the apex. Regardless of the technique used to anesthetize a tooth, preparing a path through the lamellar layer of the jawbone and flooding the cancellous bone at, near, or around the apex of the offending tooth with anesthetic solution makes sense.

A recent study of 51 patients with irreversible pulpitis in a posterior tooth concluded that a supplemental intraosseous injection (IO) was successful in achieving complete pulpal anesthesia in 88% of cases where conventional regional anesthesia had failed. A recent study effectively used the IO system on 33 of 37 patients (89%) diagnosed with irreversible pulpitis who felt pain during canal access. Since the IO technique is not routinely taught in dental schools, see lesson 14 for a description of the technique.

CONCLUSION

• A decrease in treatment quality is directly proportional to a decrease in patient cooperation and an

elevation of stress for the doctor.

- Do not use oral sedation techniques unless you are comfortable with them. That is, you must be knowledgeable and current with regard to the pharmacodynamics of the drugs you are planning to use.
- Never overestimate your ability, and always respect your limitations.
- The treatment plan consultation with the patient must be clear and comprehensive with regard to the reasons for and the risks of the oral sedation technique you are planning to use.
- The patient must accept the conscious sedation proposal and any additional fees for the service by signing a consent form.

Final cautions

The apprehensive patient is subject to losing consciousness and postural tone (syncope) as a result of a dramatic change in the amount of oxygen and glucose that is being delivered to the brain. Fainting is most common between the ages of 18 and 35 and occurs more often in the morning than in the afternoon. If fainting occurs, the patient should be positioned so the abdomen and legs are raised to a level above that of the heart and brain. Gravity quickly forces the blood to return to the heart, and oxygen to the brain is ensured. All tight clothing must be loosened, and ice packs should be applied to the neck and brow. Once the patient is conscious, a lemon-flavored glucose drink (Glutol, Paddock Laboratories) has been found to be very effective in preventing further episodes of syncope.

The office staff should be trained in crisis management. Each member of the staff should be qualified to administer cardiopulmonary resuscitation, trained to use a portable defibrillator, and assigned to a particular emergency responsibility, such as getting the oxygen tank, calling 911, or applying the ice.

Note: When everything has been done to provide the necessary treatment in a painless and judicious fashion and the patient is still uncooperative, it is best, for all concerned, to refer the patient.

LESSON 7

Endodontic Treatment Planning: Tooth-related Considerations

OBJECTIVE

To develop a course of action that will eliminate the cause and positively influence the prognosis and long-term outcome once an endodontic problem has been confirmed.

INTRODUCTION

From a legal standpoint, the treatment plan proposed to a patient during the case presentation must include the benefits and deficiencies of all reasonable treatment options including extraction. For each proposed plan, however, the doctor should clearly explain the most likely outcome and which he or she believes to offer the greatest benefit and to be in the patient's best interest.

TREATMENT PLAN BASICS

Prior to offering a patient endodontic therapy, the doctor must be certain that the following conditions are met:

- The suspect tooth has strategic value and is restorable.
- The treatment prognosis and outcome will be positive.

• The complexity of the root canal anatomy is negotiable.
• The patient's best interest is served by retaining the tooth.

Once the clinician is satisfied that there are no contraindications to therapy, treatment planning becomes a simple exercise of choosing the right components. Fortunately, there are times when the signs, symptoms, verbal descriptors, test results, and radiographs are so clear that you can instinctively diagnose the situation and effortlessly design the appropriate treatment plan. For example, when a tooth tests nonvital, is tender to percussion, and reveals a periapical radiolucency on radiographic examination, the signs and symptoms clearly indicate that the tooth is irreversibly inflamed and a root canal is indicated. In this case, the patient's options include conventional endodontic therapy with or without apical surgery, or extraction.

When the signs and symptoms are vague or equivocal, the due diligence must be intensified by asking leading questions, listening to the patient's responses, testing and retesting the suspect tooth and adjacent teeth, reviewing new radiographs (taken at different angles), and even resorting to anesthetizing selective teeth (at times even the arch). After this information has been gathered, you must call upon your knowledge, diagnostic skills, past experiences, and intuition to collate the new information and separate the distractors from the diagnostic keys. Hopefully, a commonality will surface, and the cause of the problem and the corresponding treatment options will become obvious. However, when the true cause of a severe toothache cannot be determined, it is an ethical duty to tell the patient that the diagnosis is not conclusive and to offer the following treatment options:

• *Option A:* Suggest that endodontic therapy be performed on the suspect tooth as the best way to relieve pain and resolve the problem. The patient must understand that the procedure may not be successful and agree to it. The patient's depth of pain will likely decide if the patient accepts this uncertainty.
• *Option B:* If the patient's pain is tolerable, suggest that the patient wait a few days or weeks until the diffuse pain and/or swelling localizes. To ease the decision, you might assure patients they will be seen immediately if symptoms worsen.
• *Option C:* Referring the patient is always an option.

Regardless of the option chosen, the decision must be put in writing and signed by the patient and the dentist (see lesson 10).

THE DOCTOR ALWAYS HAS TREATMENT OPTIONS

• *Accepting or refusing:* The responsibility for treatment depends on the clinician's ability, confidence, and prior experience in treating similar situations.
• *Referral:* Referral is a shared accountability between the general dentist and a specialist. It is an ethical and moral indication that the dentist is doing what he or she feels is in the best interest of the patient. A referral could be based on a number of factors.
  – *The degree of difficulty:* Cases that are judged to be *high difficulty* may exceed your technical or skill level. Were you to treat such a case and the outcome turn out to be unfavorable, the patient could initiate a legal challenge for not being referred to a skilled specialist.

  - *Certain medical risks:* Life-threatening medical risks (eg, blood dyscrasias, hemophilia, major management cases) should not be treated in a normal dental office.
  - *Personal reasons:* There are valid personal reasons to refer a patient. These include having insufficient time to see the patient, being uncomfortable treating a family member or close friend, not enjoying to perform root canals, and not wanting to treat a difficult or uncooperative patient.
- *Extraction:* Though it is difficult to tell a person motivated to save a tooth that it must be extracted, this is the ethical and moral choice when the tooth:
  - Has no esthetic, masticatory, or space-maintaining function
  - Lacks adequate periodontal support
  - Has insufficient tooth structure to restore
  - Shows signs of rejection (eg, severe external resorption)

DIAGNOSTIC DETERMINANTS

A number of dental conditions do not have simple answers. It is imperative that a patient's treatment options, both certain and tenuous, be clearly explained and understood. For example, if a conservative approach fails to resolve a problem, the patient might think that the treatment decision was wrong. The following examples represent true situations where the authors were called upon as expert witnesses and found that the defendant dentists, though they knew the litany of treatment options (see examples), failed to offer and/or record appropriate alternatives to the patient. Thus when the doctor's treatment had a poor outcome, the patient filed suit, and the plaintiff's attorney filed a grievance of omission. As mentioned in lesson 5, "if it is not written in the record, it was never done."

Periodontal considerations

An acute and painful mucosal abscess that elicits symptoms that are both periodontal and pulpal can confuse even the most careful diagnostician.

Treatment challenge

A patient presents with a mucobuccal abscess and severe pain with symptoms that are pulpal (ie, thermal sensitivity, tender to percussion). However, probing and radiographic examination reveal a significant periodontal condition (ie, deep pockets, severe bone loss) (Fig 7-1). Though the doctor feels certain that the pulp is involved and that endodontic therapy would relieve the patient's pain, long-term retention of the tooth may rely more on resolving the periodontal problem. If the doctor makes a definitive decision to initiate endodontic therapy to relieve the pain and the periodontal problem worsens or the patient is later referred to a periodontist and told the tooth must be extracted, the patient-doctor relationship would be seriously threatened (eg, loss of confidence and trust, fee challenges). This situation requires that all treatment options be clearly described and explained in understandable language prior to initiating any treatment. Once an agreement is made, an informed

consent document must be signed (see lesson 10), and only then should treatment proceed.

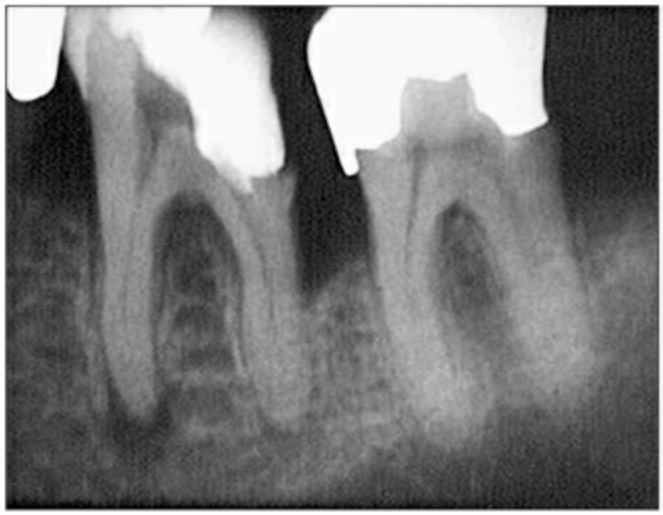


Fig 7-1 Carious exposure of a mandibular molar with severe distal bone loss compromises long-term retention of the tooth and makes extraction and replacement a more viable alternative.

Treatment option A

The periodontal condition is discussed, and the patient is advised to see a periodontist. The patient agrees, and since the patient is in severe pain, the doctor as a courtesy calls the periodontist. The periodontist agrees to see the patient immediately, and the periodontal referral and the discussions are recorded in the chart.

Treatment option B

If the periodontist is unavailable but will see the patient in 24 to 48 hours, the referring doctor is obliged to respond to the patient's pain. Ask the patient to rate the pain on a scale of 1 to 10 (mild to severe, respectively). If the score is from 1 to 5, prescribe an analgesic. If it is from 6 to 10, explain to the patient that, because there are reasons to suspect a pulpal involvement, the pain might be relieved for the 24 to 48 hours by initiating a root canal therapy (ie, accessing the pulp and extirpating the canal). Before initiating root canal therapy, make sure the patient is fully informed of the following:

- If the patient accepts the proposed endodontic procedure and the periodontal verdict is positive, the root canal therapy will be completed at a later date.
- If the periodontist declares the periodontal condition to be beyond repair and recommends extraction, the patient is responsible for the fee for the partial root canal therapy.
- The fee for both the partial and the complete root canal therapy must be disclosed during the presentation, and an informed consent document must be signed.
- The presentation discussions and the periodontist's report, when received, must be included in the patient's chart.

Treatment option C

If the pain is of endodontic origin but the doctor thinks there is inadequate epithelial attachment and insufficient evidence to guarantee the success of endodontic therapy, the appropriate treatment plan would be to suggest the patient see a periodontist (for legal purposes) but recommend (with a reasonable explanation) an extraction. The patient must decide on the course of action, the discussions must be recorded, and an informed consent document must be signed.

Dentinal considerations

Probably the most common kind of nonurgent odontogenic pain is the brief but sharp pain related to the exposure of dentinal tubules to outside stimuli. Causes include dentin exposure by caries, cervical erosion, and trauma, among others.

Treatment challenge

The overriding question for the clinician is whether the brief sharp pain is a "normal" response of a healthy pulp or a sign of pulpal inflammation (possibly irreversible). Again, a definitive treatment leaves the doctor vulnerable to criticism if the procedure fails. Though it may seem time-consuming and academic to the doctor, the patient must be given all of the valid options. The following benefits and risks of each option should be discussed and explained (with bias toward the best treatment), and the course of action decided by the patient:

- Conservatively protecting and insulating exposed dentin (indirect dentinal therapy) in a healthy pulp typically results in complete resolution of the dentinal symptoms.
- A pulp cap may be placed if the pulp is exposed or if the remaining dentin, after caries excavation, is estimated to be less than or equal to 0.2-mm thick (see lesson 36).
- Root canal therapy.

Restorative considerations

Pain

One of the more difficult conditions to evaluate with precision is the pain that follows and lingers after a recent restoration. Again, a definitive treatment leaves the doctor vulnerable to criticism if the procedure fails. Explain and discuss the following options with the patient:

- Allow time (2 to 4 weeks) for the pulp to respond favorably to the trauma of the operative procedure.
- Remove the filling material and place a sedative dressing of zinc oxide and eugenol.
- Root canal therapy.

If the restoration is quite old, a leak or crack should be suspected. In such a case, the restoration must be removed, and the cusps and pulp chamber roof should be examined under magnification.

Restorability

When considering the future restorability of a tooth before endodontic or periodontal intervention, the dentist must *(1)* assess whether he or she has the requisite skills to meet the restorative challenge(s) without creating an unhealthy periodontal situation and *(2)* determine whether an extraction and replacement would serve the patient's best interest when structural or functional considerations make the prognosis questionable (Fig 7-2).

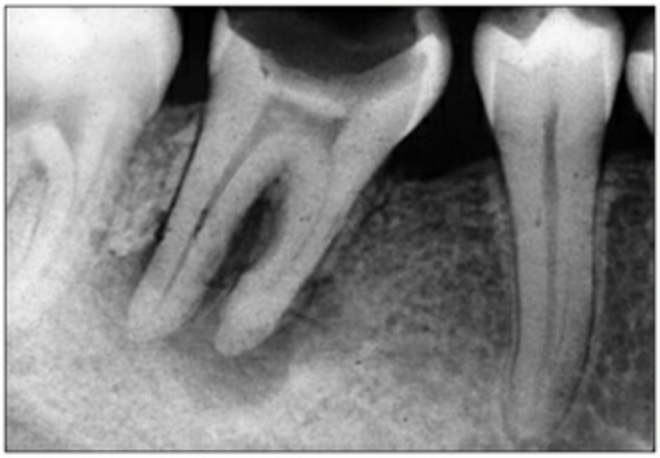


Fig 7-2 Extreme caries and the weakened structural integrity of this mandibular molar create a poor prognosis for long-term retention.

Endodontic involvement

Once a periradicular endodontic lesion is diagnosed, the dentist must confirm the location and delineate the specific nature of that problem. The tooth or teeth involved must be tested for vitality to determine if the problem is of odontogenic origin before the options are discussed and offered to the patient. If the etiology is nonodontogenic, a referral is the best option. If the source is odontogenic, teeth with a history of deep caries, pulp caps, large and/or multiple restorations, trauma, or previous painful episodes should be suspected immediately. The periodontal ligament of such teeth exhibits referred pain because the lack of proprioceptors in the pulp proper may simulate nonodontogenic pain. Pulp and percussion tests almost always expose the culprit:

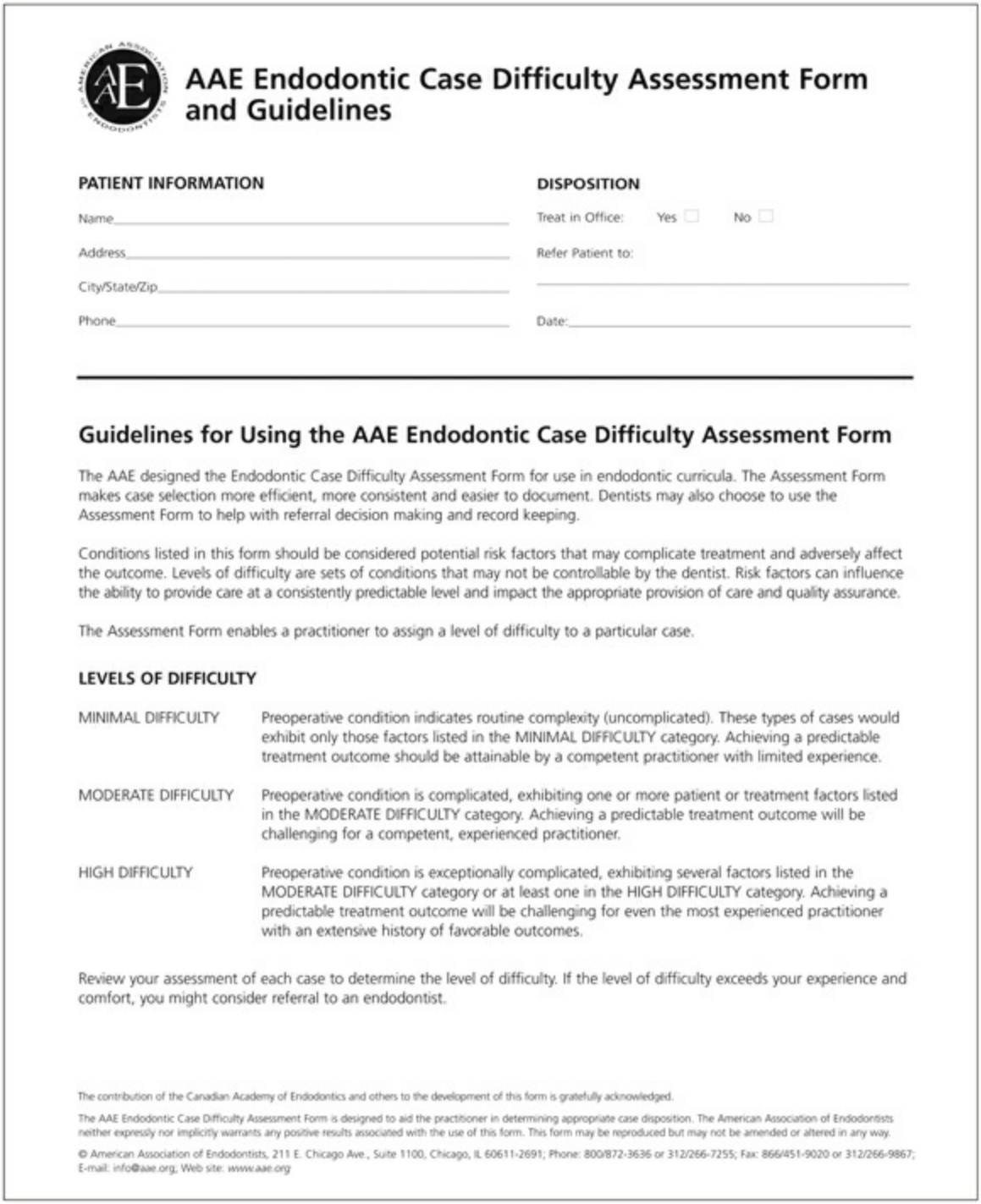
- Endodontic therapy with the need for concomitant or later apical surgery is the prime option.
- Extraction is indicated if the suspect tooth has no strategic value, is not restorable, and/or the prognosis and outcome are questionable.

Case selection and treatment considerations

The American Association of Endodontists (AAE) has developed a practical tool that makes case selection efficient, consistent, and easy to document. The Endodontic Case Difficulty Assessment Form (Fig 7-3) is intended to assist practitioners with endodontic treatment planning (Fig 7-4), and it is also helpful with referral decisions and specific recordkeeping demands. The assessment form clearly and comprehensively identifies:

- Patient considerations

- Diagnostic and treatment considerations (Figs 7-5)
- Additional considerations (Fig 7-6)
- Levels of difficulty in each category and their potential complexities and risks
- Guidelines to aid the dentist in determining whether the complexity of the case is appropriate for her or his experience and/or skill level



AAE Endodontic Case Difficulty Assessment Form and Guidelines

PATIENT INFORMATION

Name_____

Address_____

City/State/Zip_____

Phone_____

DISPOSITION

Treat in Office: Yes ☐ No ☐

Refer Patient to:

_____

Date:_____

Guidelines for Using the AAE Endodontic Case Difficulty Assessment Form

The AAE designed the Endodontic Case Difficulty Assessment Form for use in endodontic curricula. The Assessment Form makes case selection more efficient, more consistent and easier to document. Dentists may also choose to use the Assessment Form to help with referral decision making and record keeping.

Conditions listed in this form should be considered potential risk factors that may complicate treatment and adversely affect the outcome. Levels of difficulty are sets of conditions that may not be controllable by the dentist. Risk factors can influence the ability to provide care at a consistently predictable level and impact the appropriate provision of care and quality assurance.

The Assessment Form enables a practitioner to assign a level of difficulty to a particular case.

LEVELS OF DIFFICULTY

MINIMAL DIFFICULTY	Preoperative condition indicates routine complexity (uncomplicated). These types of cases would exhibit only those factors listed in the MINIMAL DIFFICULTY category. Achieving a predictable treatment outcome should be attainable by a competent practitioner with limited experience.
MODERATE DIFFICULTY	Preoperative condition is complicated, exhibiting one or more patient or treatment factors listed in the MODERATE DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for a competent, experienced practitioner.
HIGH DIFFICULTY	Preoperative condition is exceptionally complicated, exhibiting several factors listed in the MODERATE DIFFICULTY category or at least one in the HIGH DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for even the most experienced practitioner with an extensive history of favorable outcomes.

Review your assessment of each case to determine the level of difficulty. If the level of difficulty exceeds your experience and comfort, you might consider referral to an endodontist.

The contribution of the Canadian Academy of Endodontics and others to the development of this form is gratefully acknowledged.

Fig 7-3 Endodontic Case Difficulty Assessment Form. (Reprinted with permission from the AAE.)

AAE Endodontic Case Difficulty Assessment Form

Criteria and Subcriteria	Minimal Difficulty	Moderate Difficulty	High Difficulty
A. PATIENT CONSIDERATIONS			
Medical history	☐ No medical problem (ASA Class 1*)	☐ One or more medical problems (ASA Class 2*)	☐ Complex medical history/serious illness/disability (ASA Classes 3-5*)
Anesthesia	☐ No history of anesthesia problems	☐ Vasoconstrictor intolerance	☐ Difficulty achieving anesthesia
Patient disposition	☐ Cooperative and compliant	☐ Anxious but cooperative	☐ Uncooperative
Ability to open mouth	☐ No limitation	☐ Slight limitation in opening	☐ Significant limitation in opening
Gag reflex	☐ None	☐ Gags occasionally with radiographs/treatment	☐ Extreme gag reflex which has compromised past dental care
Emergency condition	☐ Minimum pain or swelling	☐ Moderate pain or swelling	☐ Severe pain or swelling
B. DIAGNOSTIC AND TREATMENT CONSIDERATIONS			
Diagnosis	☐ Signs and symptoms consistent with recognized pulpal and periapical conditions	☐ Extensive differential diagnosis of usual signs and symptoms required	☐ Confusing and complex signs and symptoms: difficult diagnosis ☐ History of chronic oral/facial pain
Radiographic difficulties	☐ Minimal difficulty obtaining/interpreting radiographs	☐ Moderate difficulty obtaining/interpreting radiographs (e.g., high floor of mouth, narrow or low palatal vault, presence of tori)	☐ Extreme difficulty obtaining/interpreting radiographs (e.g., superimposed anatomical structures)
Position in the arch	☐ Anterior/premolar ☐ Slight inclination (<10°) ☐ Slight rotation (<10°)	☐ 1st molar ☐ Moderate inclination (10-30°) ☐ Moderate rotation (10-30°)	☐ 2nd or 3rd molar ☐ Extreme inclination (>30°) ☐ Extreme rotation (>30°)
Tooth isolation	☐ Routine rubber dam placement	☐ Simple pretreatment modification required for rubber dam isolation	☐ Extensive pretreatment modification required for rubber dam isolation
Morphologic aberrations of crown	☐ Normal original crown morphology	☐ Full coverage restoration ☐ Porcelain restoration ☐ Bridge abutment ☐ Moderate deviation from normal tooth/root form (e.g., taurodontism, microdens) ☐ Teeth with extensive coronal destruction	☐ Restoration does not reflect original anatomy/alignment ☐ Significant deviation from normal tooth/root form (e.g., fusion, dens in dente)
Canal and root morphology	☐ Slight or no curvature (<10°) ☐ Closed apex (<1 mm in diameter)	☐ Moderate curvature (10-30°) ☐ Crown axis differs moderately from root axis. Apical opening 1-1.5 mm in diameter	☐ Extreme curvature (>30°) or S-shaped curve ☐ Mandibular premolar or anterior with 2 roots ☐ Maxillary premolar with 3 roots ☐ Canal divides in the middle or apical third ☐ Very long tooth (>25 mm) ☐ Open apex (>1.5 mm in diameter)
Radiographic appearance of canal(s)	☐ Canal(s) visible and not reduced in size	☐ Canal(s) and chamber visible but reduced in size ☐ Pulp stones	☐ Indistinct canal path ☐ Canal(s) not visible
Resorption	☐ No resorption evident	☐ Minimal apical resorption	☐ Extensive apical resorption ☐ Internal resorption ☐ External resorption
C. ADDITIONAL CONSIDERATIONS			
Trauma history	☐ Uncomplicated crown fracture of mature or immature teeth	☐ Complicated crown fracture of mature teeth ☐ Subluxation	☐ Complicated crown fracture of immature teeth ☐ Horizontal root fracture ☐ Alveolar fracture ☐ Intrusive, extrusive or lateral luxation ☐ Avulsion
Endodontic treatment history	☐ No previous treatment	☐ Previous access without complications	☐ Previous access with complications (e.g., perforation, non-negotiated canal, ledge, separated instrument) ☐ Previous surgical or nonsurgical endodontic treatment completed
Periodontal-endodontic condition	☐ None or mild periodontal disease	☐ Concurrent moderate periodontal disease	☐ Concurrent severe periodontal disease ☐ Cracked teeth with periodontal complications ☐ Combined endodontic/periodontic lesion ☐ Root amputation prior to endodontic treatment

*American Society of Anesthesiologists (ASA) Classification System

Class 1: No systemic illness. Patient healthy.
Class 2: Patient with mild degree of systemic illness, but without functional restrictions, e.g., well-controlled hypertension.
Class 3: Patient with severe degree of systemic illness which limits activities, but does not immobilize the patient.
Class 4: Patient with severe systemic illness that immobilizes and is sometimes life threatening.
Class 5: Patient will not survive more than 24 hours whether or not surgical intervention takes place.

www.asahq.org/clinical/physicalstatus.htm

Fig 7-3 *(cont)*

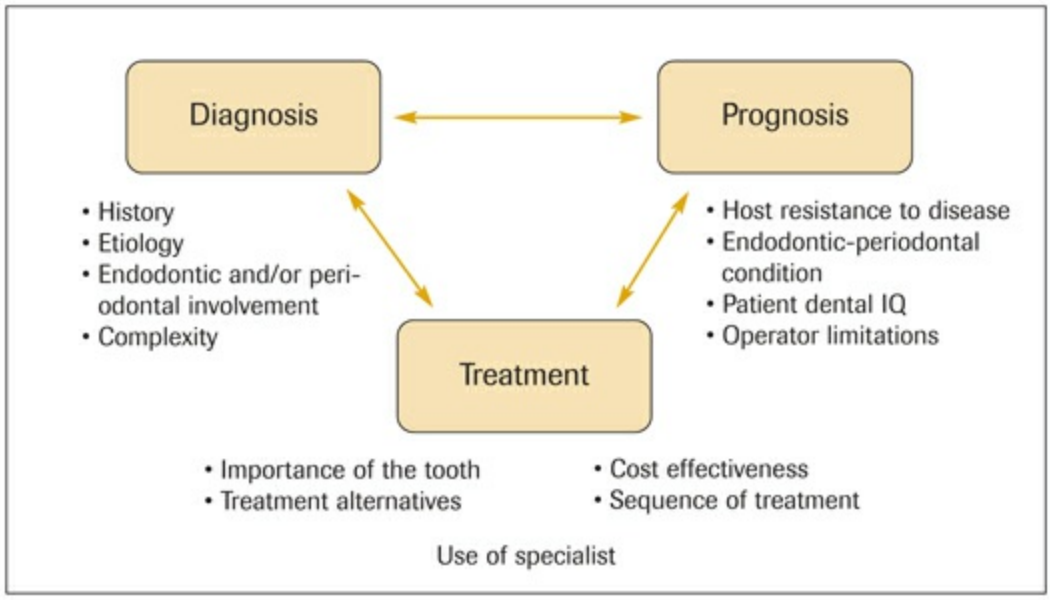


Fig 7-4 Decision-making tree identifying key considerations in treatment planning for endodontics.

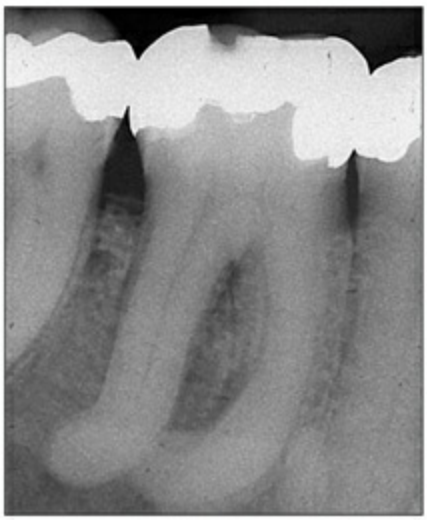


Fig 7-5 A very long tooth, in combination with acute curvature in the apical third and a highly mineralized pulp chamber, conspire to make this molar a case with very high difficulty that should be carefully considered in treatment planning and treated by an expert clinician.

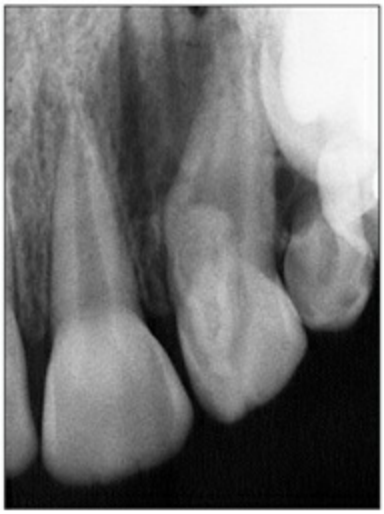


Fig 7-6 A dens in dente and a dilacerated root with a large periradicular infection make this lateral incisor a tooth that should be categorized as high difficulty.

LESSON 8

Endodontic vs Implant Therapy for a Single Tooth

OBJECTIVE

To understand the decision-making process on whether to maintain or replace a natural tooth.

INTRODUCTION

At no time should a doctor recommend treatment other than what is beneficial for the patient. *Do no harm.* Appropriate treatment of a dental condition, be it periodontal, endodontic, prosthetic, or surgical, should be dictated by a patient's needs. There are definitive indications and contraindications for every treatment, and those issues alone should be the deciding factors.

Though the final decision rests with the patient, the case presentation must include all treatment options, be presented in language the patient understands, show valid reasons (based on the conditions) as to which option is best, explain how the procedure will be done, predict how long the procedure will take, identify the expected prognosis, and estimate how much the treatment will cost. The manner in which a case is presented should always be designed toward what is best for the patient and only the patient (see lesson 10).

ENDODONTIC THERAPY

Indications

- A tooth that is necessary, functioning, and restorable.
- A tooth that is periodontally sound (eg, healthy periodontal ligament and surrounding alveolar bone).
- In trauma cases where esthetics and arch stabilization are a concern. If the tooth and the alveolar bone are fractured and displaced, immediate endodontic treatment and a splint help to stabilize the arch and preserve alveolar bone. A final diagnosis and treatment plan can take place after initial healing.
- In patients with high-risk medical conditions (eg, high-risk heart problems, bisphosphonate-associated osteonecrosis, severe osteoporosis, hemophilia, uncontrollable diabetes) that contraindicate surgery (extraction). Endodontic therapy can be of great value as a noninvasive delaying approach.

Contraindications

- In teeth that are unnecessary (eg, non-occluding third molar, severely angled or positioned tooth out of buccal or lingual arch alignment).
- In teeth that are nonrestorable (eg, severely decayed or vertically fractured teeth with the cervical border below the crest of bone).
- In teeth displaying severe periodontitis with extensive pocket depths, spontaneous bleeding, and/or level 3 or higher mobility.
- In teeth with severe injury to the roots and the alveolar ridge (eg, shattered or vertically fractured). However, retaining the tooth temporarily is still better than immediately extracting the tooth. The added trauma of the extraction would surely cause the loss of alveolar dimension and bone volume, both of which would complicate a future implant placement.

Patient considerations for saving teeth

- *Emotional:* The emotional aspects of losing a tooth and the fear and apprehension of having surgery can be difficult for patients to accept.
- *Financial:* Based on insurance codes, implants cost from 75% to 80% higher than does endodontic therapy. Insurance plans often cover endodontic therapy but not implants.
- *Satisfaction:* The Delta Dental insurance records of 1,126,288 patients revealed patient satisfaction to be 97% after 8 years following endodontic treatment.

Advantages

- *Time frame:* From 80% to 90% of endodontic cases can be accomplished in one appointment.
- *Convenience:* General dentists perform the majority of endodontic cases in their own office in one appointment.

- *Esthetics:* The restoration margins may be placed beneath the gingival crest without fear of recession.
- *Physical sensation:* An endodontically treated tooth has a normal and healthy periodontal ligament (PDL) that gives the patient a natural sensory nerve response when biting, chewing, and eating.
- *Success rate:* Advances in the understanding of endodontic pathosis, aseptic technique, and principles of canal preparation and obturation have significantly increased the rates of predictable healing and retention—95% and higher under ideal conditions.

IMPLANT THERAPY

Indications

- When endodontic therapy is not indicated (Fig 8-1)
- When the edentulous alveolar (lamellar) bone volume is sufficient to support placement and stabilization of an implant
- When an extraction site can be restored via a bone graft to support placement and stabilization of an implant
- When a patient's health can manage the surgery without risk
- When major maxillofacial trauma makes extensive oral reconstruction necessary

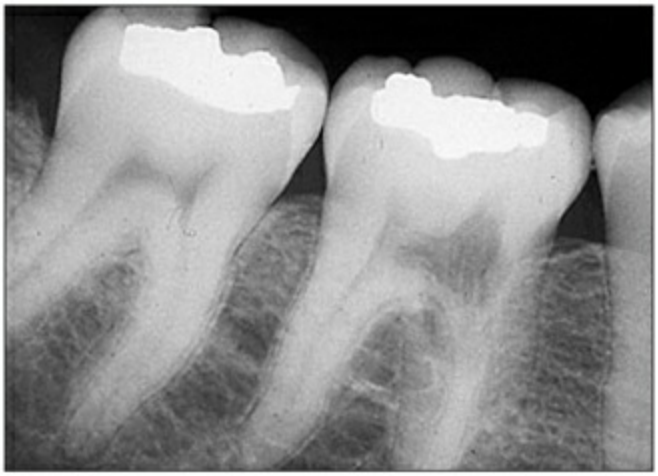


Fig 8-1a External resorption has structurally weakened the mandibular molar. The tooth's long-term prognosis is significantly compromised by the structural weakening.

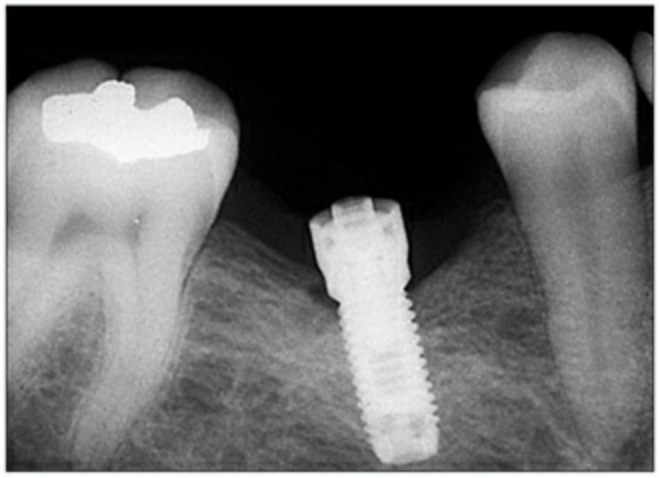


Fig 8-1b After extraction and healing of the socket, an implant is placed and covered during healing and integration.

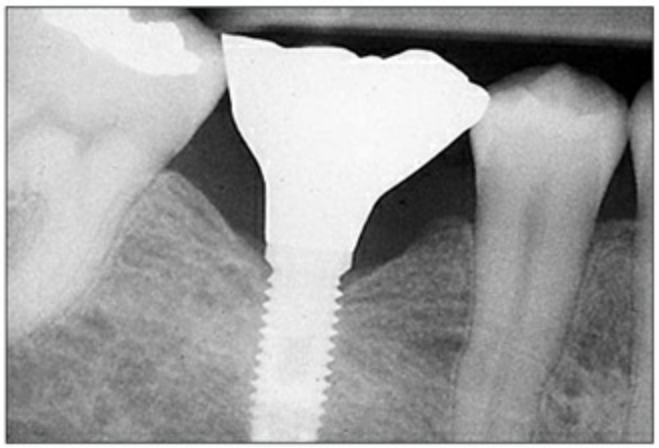


Fig 8-1c The implant is loaded with placement of the restoration.

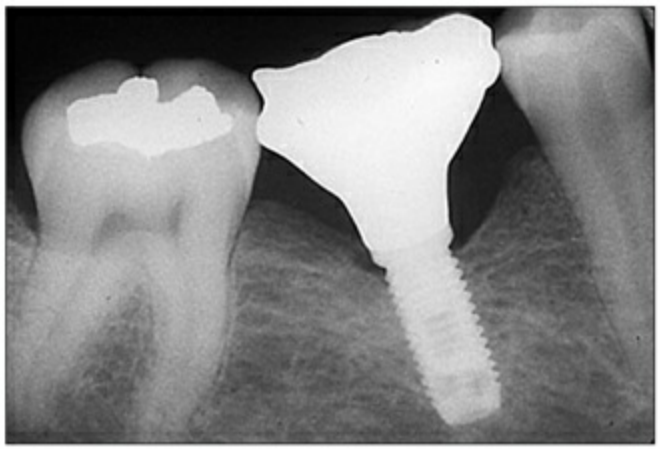


Fig 8-1d Function is restored. The 1 year follow-up demonstrates a healthy prosthesis.

Advantages and disadvantages

• *Time frame:* Implant therapy requires a minimum of 5 to 8 appointments over a period of 3 to 6

months. The patient must be referred to a specialist for extraction and implant placement; return to the general dental office following the extraction for a provisional restoration (partial denture or resin-bonded bridge); return to the specialist for either implant placement (if not done at time of extraction), or verification of osseointegration, and/or removal of the healing cap; and again return to the general dentist for restoration delivery and adjustments.

- *Esthetics:* There is always the fear that bone will regress and that the corresponding gingival recession will expose the metal implant.
- *Physical sensation:* Implants are osseointegrated and are without a natural and healthy PDL. As such, there is no sensory response when biting, chewing, and eating.

ENDODONTIC AND IMPLANT OUTCOMES

Studies have shown that endodontic and implant therapies have equally successful outcomes.

- A retrospective study of 196 root canal–treated cases and 196 implant cases reported a 94% success rate for both groups.
- The Delta Dental insurance records of 1,126,288 patients from 50 US states were evaluated. Of 1,462,936 initially nonsurgical endodontic treatments performed by both general practitioners and specialists, the success rate was 97% after 8 years, and patient satisfaction was high.
- In one study of 32 titanium alloy implants placed immediately after the extraction of teeth diagnosed during endodontic surgery as having root fractures, perforations, or endodontic-periodontal complications, 31 were fully integrated within 6 months.
- The records of 2,000 teeth that were endodontically treated by a specialist over a period of 30 years were examined clinically and radiographically, and the results were analyzed statistically by the Pearson chi-square test or the Fisher exact test and multivariate logistic regression. The overall endodontic success rate was 91.45%.
- The Academy of Osseointegration developed a database that included 57 studies of 12,000 single-tooth implants and 13 studies of 23,000 endodontic cases. The outcomes were equivalent. No difference was noted in the success rates between the two procedures in any of the observation periods. Researchers concluded that the decision to employ endodontic therapy or implant therapy must be made based on parameters other than treatment outcome.

CONCLUSION

The treatment options offered by saving teeth should be dictated by the circumstances the patient is experiencing, the condition of the tooth or teeth involved, the skill and experience of the doctor, and the potential for success. The therapy must be delivered in a predictable manner with the greatest chance of success and benefit to the patient.

There is a troubling trend in dentistry where patients are being denied their informed rights by those who favor the placement of an implant and do not offer the endodontic alternatives of appropriate retreatment, apical surgery, or crown-lengthening surgery.

The following quote from *Inside Dentistry* demeans the trust of the patients who place their faith in dentists to do no harm. “Implant surgery is actually easier to learn than a root canal . . . Instead of trying to negotiate canals that are tortuous and fill pulp chambers with moldable materials, with dental implants you are drilling a round hole with a round drill and filling it with a round implant.”

It is a concern to see a mind-set that recommends the extraction of teeth that could be saved by alternative and more judicious endodontic procedures. Heroic efforts to save teeth “at all costs” are no longer recommended. However, neither should the expediency and panacea of the implant therapy promised above be believed.

LESSON 9

Infection and Success Rates

OBJECTIVE

To identify the role that infection of the root canal system has on the success of an endodontic case.

INTRODUCTION

An effective antimicrobial treatment strategy is required to promote the successful healing of an infected root canal. The eradication of bacteria from the canal space relies on *(1)* careful preparation (instrumentation) of the canals to an adequate length and size, *(2)* cleaning and disinfecting the walls and dentinal tubules with a chemical agent (eg, 0.5% to 6% sodium hypochlorite or chlorhexidine gluconate) delivered via a fine gauge needle throughout the chemomechanical root canal preparation, and *(3)* hermetically sealing the canals with a solid filling material (gutta-percha). For grossly infected (weeping, putrescent) cases that cannot be completed in one visit, a mixture of calcium hydroxide paste can be placed as an interappointment dressing; its ability to dissolve tissue remnants and its high alkalinity (pH 11+) effectively eliminate the residual bacteria.

FACTORS INFLUENCING SUCCESS

How much of the canal system is treated?

Vast areas of the infected canal wall surface of teeth with periapical radiolucencies are neither touched by an instrument nor affected by any disinfecting irrigation solution. For this reason, a certain number of cases fail to heal even when the most meticulous chemomechanical protocols are carried out. Root canals are complex anatomic structures with lateral canals, isthmuses, connecting channels, junctions, fins, and extensions that cannot always be reached with the repertoire of instruments and irrigants currently available. Studies estimate that roughly 40% of a canal wall surface is left untreated, and that deficiency offers microorganisms a place to harbor and multiply.

Infection and periapical inflammation

The majority of nonhealing periradicular radiolucencies have a bacterial etiology. Failure of the coronal seal (leaking restorations) permits an ingress of microorganisms, and the number and resistance of the remaining bacteria from the original infection (as a result of an inadequate root canal cleaning and shaping process) are the primary reasons for continuing failure (Fig 9-1). In rare cases, factors located outside the tooth, such as true cysts, may cause a lesion to persist and even grow (ie, a nonhealing expanding apical periodontitis).

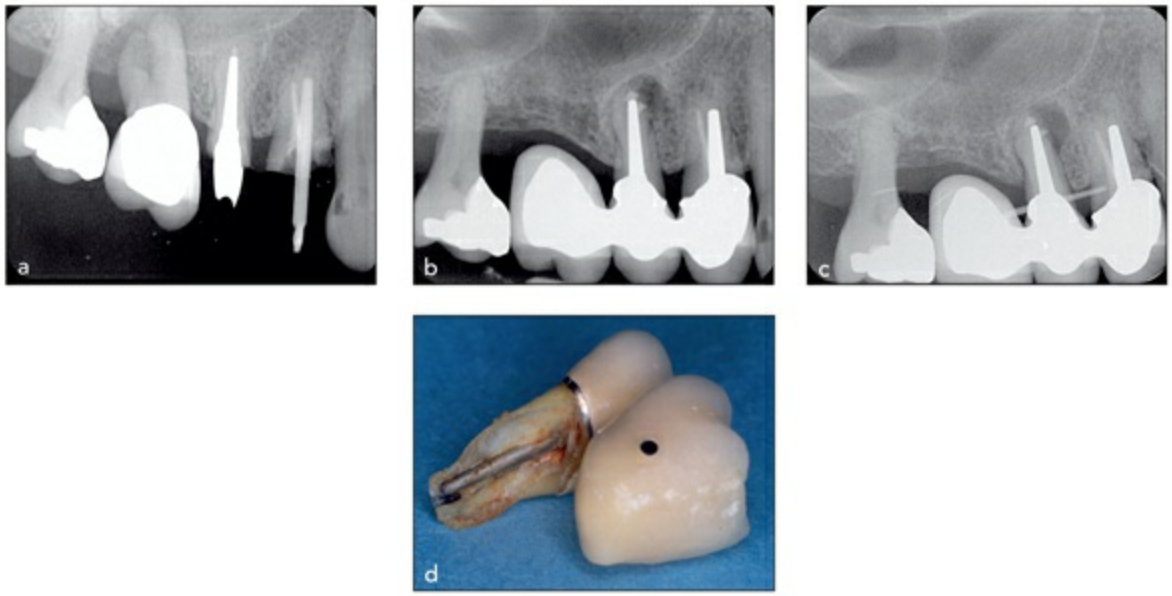


Fig 9-1 An example of poor treatment planning. *(a)* Maxillary right premolar be fore placement of a fixed partial denture. *(b and c)* Three years following endodontic therapy. *(d)* Nonhealing failure due to vertical root fracture. The posts of this cantilever case are too long and too wide.

Success of endodontic treatment in teeth with periapical lesions

Apical periodontitis, visible as a periapical rarefaction on a radiograph, has a negative influence (reduced prognosis) on the success rate of endodontic treatment or retreatment. Yet the healing rate of teeth with periapical lesions is still known to be high (Fig 9-2). Friedman and Mor collected data from follow-up studies and stated that the chance of teeth with apical periodontitis fully healing after nonsurgical endodontic treatment or retreatment is 74% to 86% and the likelihood that those teeth will remain functional over time is 91% to 97%.

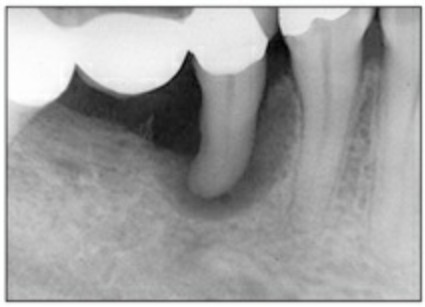


Fig 9-2a Periapical and lateral bone lesion associated with a mandibular right second premolar.

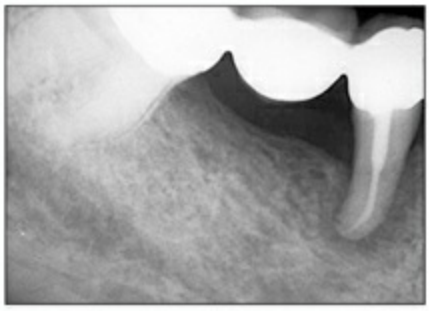


Fig 9-2b The same tooth 6 months after endodontic therapy. Repair is obvious.

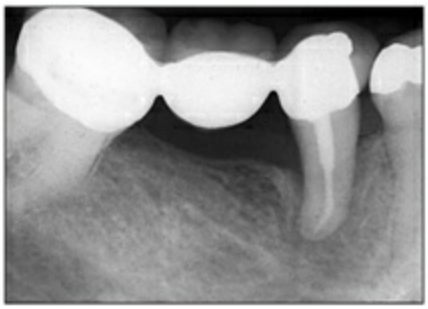


Fig 9-2c The same tooth 12 months after endodontic therapy was completed. Complete repair is somewhat compromised because of the original chronicity and size of the lesion.

Probability of healing

The chances of successful healing are influenced by *(1)* lesion size (large), *(2)* the presence of a true cyst, *(3)* retreatment of previous endodontic therapy, *(4)* too short or too long a working length, and *(5)* obturation shorter than 2 mm from or beyond the root apex (Fig 9-3). Interestingly, the absence of an infection prior to completion is more important for the healing process than is the quality of the root filling.

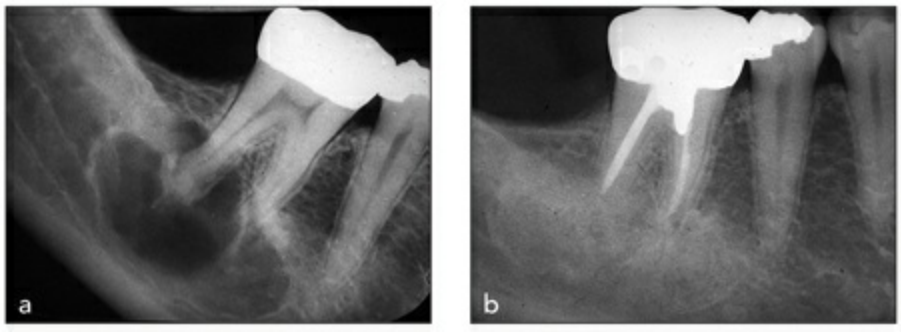


Fig 9-3 *(a)* A traumatic cyst located under a mandibular molar. *(b)* The cyst healed following quality endodontic treatment and a graft in the area. The outline and the proximity of the inferior alveolar nerve can be seen on the preoperative radiograph. (Images courtesy of Dr Carl Newton, Indianapolis, IN.)

Leaking temporary or permanent fillings

Coronal leakage is an important risk factor! The best endodontic treatment will fail if the root canal system is recontaminated by microorganisms from the oral cavity. The temporary filling must create an impermeable seal during the interappointment phase of treatment, and the time frame between the appointments should be kept as short as possible (1 to 4 weeks). The permanent restoration following the completion of the root canal therapy (preferably a crown) should also be placed as quickly as possible (1 to 2 weeks), and the margins of the restoration should be impervious to leakage. An example can be seen in Fig 9-4. Studies state that a quality endodontic treatment and a quality restoration offer a 92% or higher success rate, whereas the success rate of a quality root canal treatment with a poorly fabricated restoration ranges from 50% to 70%; when both the root canal and the restoration are poorly done, the success rate drops still further to 20% to 30%.

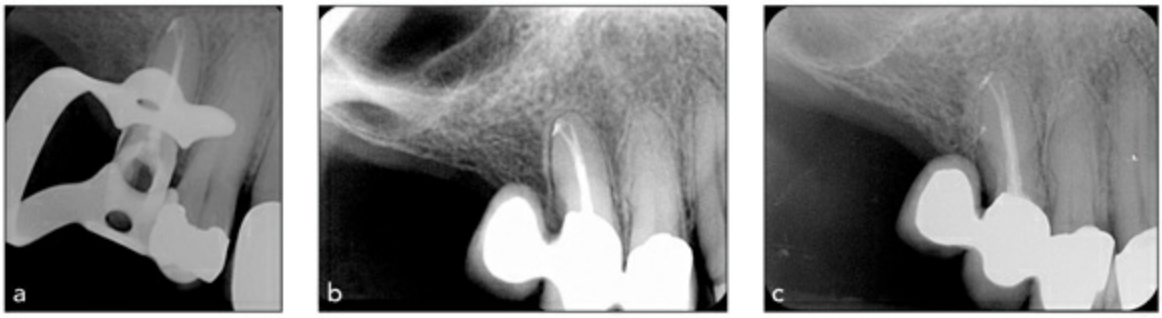


Fig 9-4 Maxillary right premolar after completion of endodontic treatment *(a)* and 2 years postoperatively *(b and c)*. This cantilever case demonstrates intact dentinal structure, and the periodontium has remained healthy.

Immune status of the patient

Conditions leading to impairment of nonspecific immune responses lend themselves to unfavorable results. However, human immunodeficiency virus (HIV) infections do not have a negative impact on treatment prognosis. Even in cases when the root canal filling(s) is not ideal, endodontic treatment is

highly successful in the majority of HIV/AIDS patients. The rate of healing is obviously independent of the clinical symptoms, the medications taken, or the viral load.

Healing time

Ørstavik examined the amount of time necessary for the development and healing of apical lesions. He found that in endodontically treated teeth, most cases of apical periodontitis develop within 1 year, but healing continues for more than 4 years.

PROBLEMS: WHAT TO AVOID

Never leave canals empty between appointments after the cleaning and shaping process. Though the number of microorganisms is reduced, they have not been eliminated. Studies of root canals that have been left empty between visits show the empty canal space is quickly recolonized by bacteria that feed on debris and fluids from the periradicular area. This problem can be easily managed by spinning a dressing of calcium hydroxide into the root canal with a rotating lentulo spiral. The dressing not only dissolves necrotic tissue but also, due to its high alkalinity, reduces the number and virulence of the bacteria hidden in the canal irregularities. Advantageously, the dressing has an ongoing effect and will continue to disinfect the root canal for several weeks. A quality coronal temporary filling (impervious to leakage) must be placed and, ultimately, replaced by a permanent restoration as soon after final obturation as possible.

CONCLUSION

Ideally, all root canals should be prepared to their electronic working length and appropriate size, carefully rinsed with antimicrobial solutions during the mechanical process, densely obturated, and effectively temporized in one appointment. For emergency visits (work ins) where time is short, two visits may be required. During the initial visit, the canal should be quickly accessed; its length determined with an electronic apex locator; and the canal instrumented sufficiently to remove the majority of tissue, debris, and bacteria along the full length of the root canal (maximal reduction of microbes in the root canal system is important at this visit). Calcium hydroxide is then spun into the canal, and the access is effectively sealed. The patient is reappointed for a second visit, at which final instrumentation and obturation are completed.

To reinforce the chemomechanical goals, residual sodium hypochlorite and ethylenediamine tetraacetic acid (EDTA) should be flushed from the canal with saline. This is a particularly important step if a bonded resin core will be fabricated.

LESSON 10

Presenting a Treatment Plan to a Patient

OBJECTIVE

To acquire unequivocal and indisputable permission to perform endodontic therapy on a patient.

INTRODUCTION

A treatment plan should be a summary of the tangible and intangible issues revealed in the medical and dental history and the diagnostic observations recorded during a comprehensive clinical examination. It should be designed toward what is in the best interest of the patient and what will provide the best long-term outcome. If there are conditions that may compromise endodontic treatment, they must be discussed, addressed, resolved, and, when necessary, referred.

GENERAL GUIDELINES

Purpose of a presentation

Prior to getting legally binding permission to initiate endodontic treatment, a patient must be informed and advised in clear, precise, and understandable language about the reasons, benefits, risks, expected prognosis and outcome, and fees associated with the treatment. To a lesser degree, but of equal importance, the actual endodontic process should also be described—the use of an anesthetic;

the purpose and placement of rubber dam; reasons for the cleaning, shaping, and filling of a canal; the degree of difficulty; the technology and materials involved; and the ultimate need for a final restoration.

Once the patient and the doctor agree to the treatment proposal, a formal informed consent contract should be drawn, signed, and witnessed. If for any reason that treatment procedure is altered after the patient has approved the treatment plan, the original informed consent agreement is no longer valid. As such, the changes, reasons, benefits, and fees for the modification(s) must be discussed, permission to continue treatment must be agreed upon, and a new informed consent contract must be signed and witnessed.

Establishing trust

"Unless a person likes and trusts you they will not coherently listen to you" (Decker B, *You've Got to Be Believed to Be Heard*, 2008). This statement refers to studies showing that a person who does not like or trust a narrator will not focus on (listen to) what is being said. Correspondingly, without a patient's trust, issues regarding procedure, degree of difficulty, fee, prognosis, posttreatment restorations, and so forth will often be misunderstood when presented and later challenged: "I was never told how involved a root canal really was." "I would never have agreed to a fee that high." "No one ever told me I would need a crown after the root canal." "I thought the crown was included in the fee." "The doctor told me the tooth would last forever."

Most patients schedule an appointment with a new doctor as a result of positive comments made by someone they trust. They usually rely on a friend or family member who is or has been a patient in that office, or they trust the judgment of their regular dentist when being referred. These patients arrive in the office somewhat preconditioned to trust you. However, that trust is not guaranteed, and it is up to the doctor and his or her entire staff to earn, foster, and nurture it. There are a number of subtle factors that influence (improve) a patient-doctor relationship:

- The decor, cleanliness, and organization of the office communicate a lot about the quality of the dentistry that can be expected.
- The welcoming interpersonal impression of the first person the patient meets in the office establishes a rapport that speaks for the personality of the entire office.
- The professionalism, proficiency, sensitivity, compassion, and caring manner (tender loving care) the doctor and the auxiliary staff display during the preclinical and clinical examination exhibit competence, and with that comes belief.
- The assuring manner in which the doctor addresses, discusses, and responds to the patient's problem(s) will set the tone for the entire treatment.

Consultation room

Although most consultations take place at the dental chair, a patient will be less distracted and intimidated by the clinical surroundings of an operating room and will be far more receptive to a

well-documented treatment plan when it is presented in a well-lit consultation room that is comfortable, private, and out of the listening range of other patients.

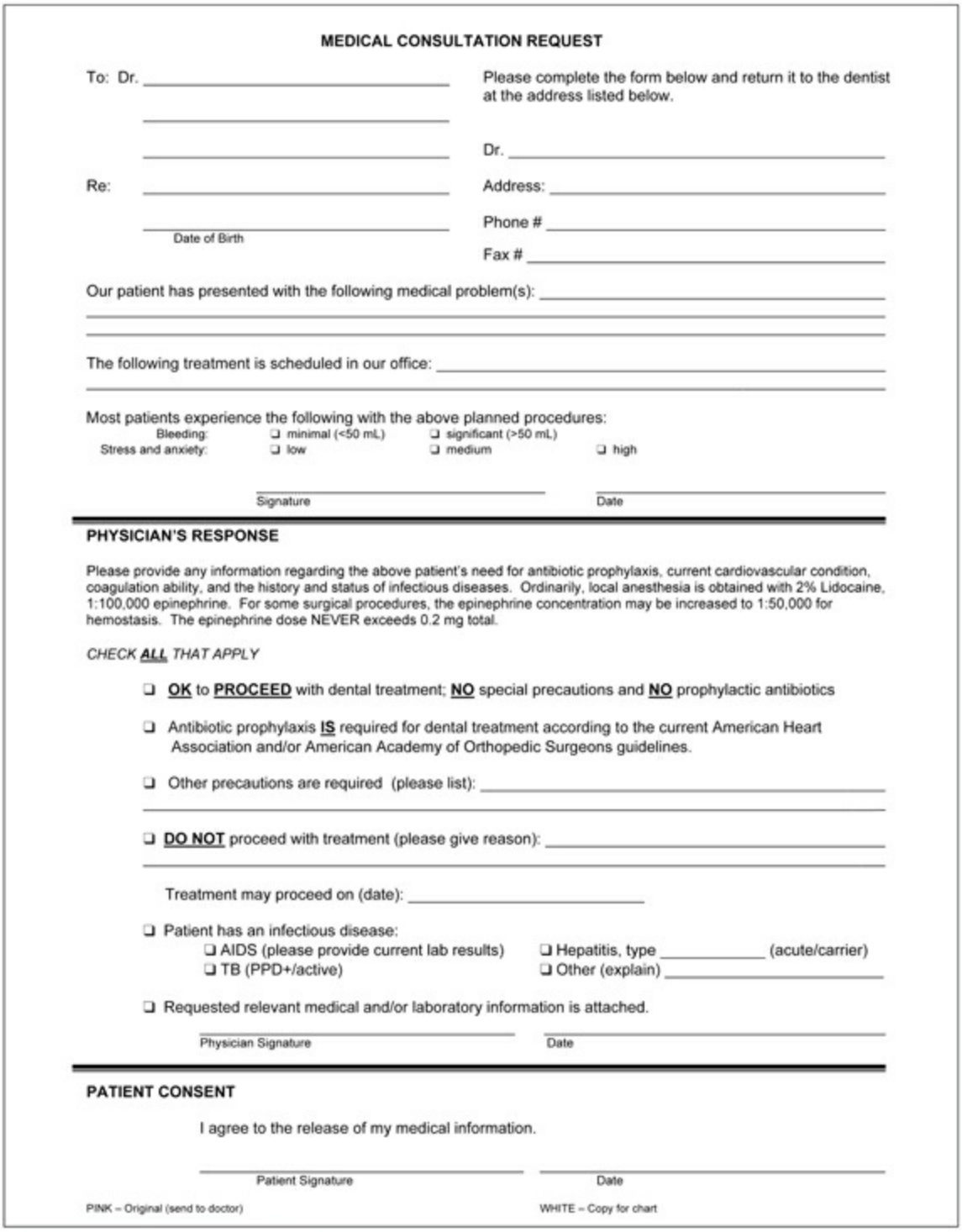
ENDODONTICS-SPECIFIC GUIDELINES

Though the scientific aspects of endodontic therapy and the technology employed to instrument, disinfect, and obturate a canal are important, the actual presentation should focus on the rationale, features, benefits, problems, and solutions of the proposed treatment. Since most people learn by seeing, hearing, and doing, it is advantageous to personalize the proposed treatment plan by sketching and tracing the patient's individual problems, risks, solutions, and prognosis on a carbonless Presentation Form. By this point, sufficient diagnostic information should have been gathered to respond to all questions and objections. Nevertheless, the illustrated educational material published by the American Association of Endodontists (AAE) is excellent in describing endodontic procedures and discussing and supporting the advantages of endodontic therapy. In addition, dental supply houses offer a number of visual aides (eg, models and posters) that are extremely helpful in describing and demonstrating the endodontic process.

Complications

Though a potential treatment plan may be superficially outlined and discussed with a patient, any health issue(s) that places that patient in a concerned risk category is a priority and must be addressed before any treatment is formally proposed or initiated.

Patients should be informed of the relevance of the health problem to endodontic therapy and why a referral to their personal physician is not only indicated but also in their best interest. The doctor should also inform patients that the endodontic treatment may necessitate a referral, based on the advice of the physician with regard to the use of prophylactic antibiotics and treatment care (Fig 10-1).



MEDICAL CONSULTATION REQUEST

To: Dr. _____

_____

_____

Re: _____

_____
Date of Birth

Please complete the form below and return it to the dentist at the address listed below.

Dr. _____

Address: _____

Phone # _____

Fax # _____

Our patient has presented with the following medical problem(s): _____

_____

_____

The following treatment is scheduled in our office: _____

_____

Most patients experience the following with the above planned procedures:

Bleeding: ❑ minimal (<50 mL) ❑ significant (>50 mL)

Stress and anxiety: ❑ low ❑ medium ❑ high

_____ _____
Signature Date

PHYSICIAN'S RESPONSE

Please provide any information regarding the above patient's need for antibiotic prophylaxis, current cardiovascular condition, coagulation ability, and the history and status of infectious diseases. Ordinarily, local anesthesia is obtained with 2% Lidocaine, 1:100,000 epinephrine. For some surgical procedures, the epinephrine concentration may be increased to 1:50,000 for hemostasis. The epinephrine dose NEVER exceeds 0.2 mg total.

*CHECK **ALL** THAT APPLY*

❑ **OK** to **PROCEED** with dental treatment; **NO** special precautions and **NO** prophylactic antibiotics

❑ Antibiotic prophylaxis **IS** required for dental treatment according to the current American Heart Association and/or American Academy of Orthopedic Surgeons guidelines.

❑ Other precautions are required (please list): _____

_____

❑ **DO NOT** proceed with treatment (please give reason): _____

_____

Treatment may proceed on (date): _____

❑ Patient has an infectious disease:

❑ AIDS (please provide current lab results) ❑ Hepatitis, type _____ (acute/carrier)

❑ TB (PPD+/active) ❑ Other (explain) _____

❑ Requested relevant medical and/or laboratory information is attached.

_____ _____
Physician Signature Date

PATIENT CONSENT

I agree to the release of my medical information.

_____ _____
Patient Signature Date

PINK – Original (send to doctor) WHITE – Copy for chart

Fig 10-1 A Physician Release Form, which is recommended for requesting a medical consultation.

Closure

Once the patient agrees with the proposed plan, he or she must be asked to sign a legally binding informed consent form (Fig 10-2). If the patient is under the age of 18, incapacitated, or impaired and is being represented by a parent, guardian, or trustee, the doctor must identify that person's legal right to make health decisions for the patient (all statements must be noted, signed, and witnessed). Once the representative understands and agrees to the proposed treatment plan, he or she must sign the legally binding informed consent form.

Patient Name: _____ Patient ID: _____

INFORMED CONSENT FOR ENDODONTIC THERAPY

I understand that root canal treatment is a procedure to retain a tooth which may otherwise require extraction. Although root canal therapy has a very high degree of clinical success, it is a biological procedure and results cannot be guaranteed.

I also understand that occasionally a tooth that has had nonsurgical root canal therapy may require retreatment. Approximately 10 percent of teeth that have had nonsurgical root canal therapy may require an additional procedure, root-end surgery. Even with such a high degree of success, a small percentage of teeth may nevertheless require extraction.

Alternatives to endodontic treatment include no treatment, waiting for more definitive symptoms to develop; or extraction. Risks involved in these choices might include, but are not limited to: pain, infection, swelling, loss or shifting of teeth, and infection to other areas.

An endodontically treated tooth may be structurally weakened. A crown or other restoration providing post and core and/or cuspal protection will be necessary to restore the tooth to function.

At times, medication will be prescribed. I understand medication for discomfort and infection may cause drowsiness which can be increased by use of alcohol and other drugs. I am advised against the use of alcohol or operating any vehicle or hazardous devices while taking such medications.

I, _____, understand the benefits and risks of the proposed treatment.

_____ _____
Patient Signature Date

_____ _____
Witness Signature Date

I certify that the matters set forth above were explained to the patient, that the patient was given an opportunity to ask questions, and that all questions were answered in a satisfactory manner.

_____ _____
Doctor Signature Date

Fig 10-2 A suggested Consent Form for endodontic treatment.

Presentation "dont's"

- Do not present too much material.
- Do not use language that is too scientific.
- Do not speak too quickly.
- Do not fail to respond to questions.
- Do not exhibit a lack of empathy toward patients' apprehensions, fears, or economic situation.
- Do not intimidate the patient or guardians.
- Do not show attitude.
- Do not leave patients with the impression that they are unimportant.

Supporting case-presentation aids

The AAE (800-USA-ENDO) has published brochures and posters designed to assist patients in understanding conventional and surgical endodontic therapy. The pamphlets answer the most frequently asked questions about treatment procedures, problems, and prognosis.

The presentation form should include the following data:

- Consultation
- Diagnosis
- Exam
- Medical and dental history
- Radiographs
- Emergency service
- Conventional endodontic treatment
- Observations
- Surgical procedure (when necessary)
- Medication (when necessary)
- Occlusal adjustment
- Anesthetic
- Temporary restoration
- Biopsy (when necessary)
- Total fee
- Patient's signature
- Date
- A notice that repeated cancellations of assigned appointments or failure to keep confirmed appointments may entail additional charges
- Dentist's and/or surgeon's office address and telephone number

PART THREE

Preparation for Treatment

LESSON 11

Endodontic Instruments and Equipment

OBJECTIVE

To furnish an operating room with the instruments and equipment necessary to meet all endodontic treatment needs.

INTRODUCTION

The armamentaria you choose to perform highly effective and successful root canal therapy may range from the practical to the sophisticated. The decision will likely be influenced by the percentage of the practice devoted to endodontics, the personal desire to practice at the highest level, and the cost. This lesson focuses on the instruments and equipment that are commonly found in a modern endodontics office (Fig 11-1).

Fig 11-1 A treatment suite for an endodontic specialist is typically equipped with a dental chair and an x-ray unit. An operating microscope, often ceiling- or wall-mounted, can be brought into position when the patient is seated. (Image courtesy of Dr Nava Fathi, San Jose, CA.)

INSTRUMENTS FOR NONSURGICAL ENDODONTICS

Perforated cassettes

When there is a place for everything and everything has its place, order at the workstation becomes a habit (Fig 11-2). Knowing exactly where a particular instrument is located while in the midst of a procedure saves time and reduces the possibility that the doctor or assistant might experience an inadvertent stick.

Another way to minimize the potential for sticks is to minimize the number of times an instrument is physically touched. To do this, the assistant assigned to sterilizing instruments need only reload the cassette, place it in an ultrasonic cleaner for the manufacturer's recommended minutes, wrap it in appropriate breathable material, and put it into a sterilizer. The cassette rails hold the instruments in place and apart, exposing all surfaces of the instrument to the chemical and/or the steam. Cassettes are easily stored, maintain their sterile state, and can be personally designed to accommodate any number of instruments.

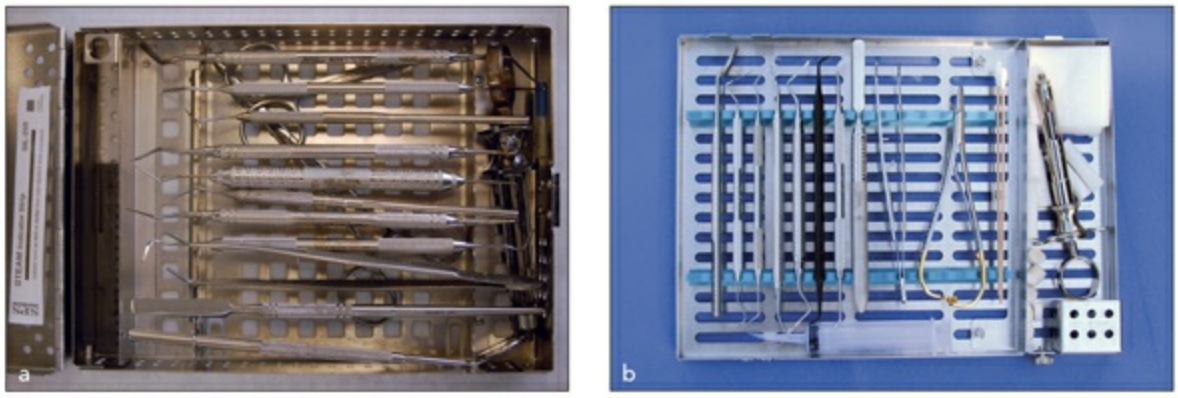


Fig 11-2 *(a and b)* Perforated cassettes offer certain advantages: they standardize instrument usage and facilitate room turnaround. Due to the specialized nature of endodontic therapy, most instruments such as pliers, excavators, and pluggers fit into the cassette, while many larger items, including handpieces and nonsterile items such as rubber dam and restorative materials, are stored elsewhere.

Twelve basic and essential hand instruments

A list of 12 hand instruments needed to meet the operative demands of root canal procedures is given in Table 11-1.

Table 11-1	Essential hand instruments*
Description	**Part code**
Front surface mouth mirror	MIR4
Endodontic mirror handle (calibrated in mm)	MH6692K
No. 23 Expro and No. 6 UNC 15 handle (combined Shepard hook and marked periodontal probe)	XP23/UNC15
No. DG16 endodontic explorer (stainless steel)	EXDG16
No. 2 Glick excavator	EXCGL2
No. 32L endodontic excavator	EXC32L
No. 2 Woodson composite instrument (plastic, double ended)	PFIWDS2
No. 24 cement spatula (stainless steel)	CS24
No. 1 endodontic pliers (locking grooved)	EPL1
No. 17 dressing pliers (for cotton)	DP17
No. 89/92 cleoid-discoid (2-mm wide)	Endoco
No. 18 Iris scissors (curved)	S18

*Manufactured by Hu-Friedy.

Supplemental hand instruments

Table 11-2 identifies hand instruments that may (by choice) be added to the cassette to help maintain consistency with the treatment protocol.

Table 11-2	Supplemental hand instruments*
Description	**Part code**
No. 2 root canal spreader	RCP8
No. 3 root canal spreader	RCP9
No. 4 root canal spreader	RCP10
Root canal pluggers (Schilder type)	RCP8, RCP9, RCP10
System B pluggers	S, M, L
Anesthetic syringe with fine needle (eg, MaxiProbe [Dentsply])	
Additional magnifying mirrors (varied power)	
Hemostat (straight 6.5 in)	HKR

*Manufactured by Hu-Friedy.

Use of rubber dam

The standard of care in endodontics requires that rubber dam be used. Table 11-3 lists a sample of rubber dam equipment that, when included in the cassette, is always sterile and saves time in opening numerous sterilizing bags.

Table 11-3	Rubber dam equipment*
Description	**Part code**
Rubber dam punch	
Rubber dam forceps	
Rubber dam frame	
Rubber dam clamps	RDCM212, RDCM9, RDCM 7, RDCM4, RDCM1
Rubber dam 6 clamp box/lid	IMS-1271

*Manufactured by Hu-Friedy.

Auxiliary examination cassettes

Storing a small selection of instruments in an auxiliary cassette can save time and improve efficiency by avoiding the need to open the large endodontic cassette when called upon to see a patient for an examination, replacement of a temporary filling, or suture removal (Table 11-4).

Table 11-4	Auxiliary cassette instruments*
Description	**Part code**
Front surface mouth mirror	MIR4
Mirror handle (calibrated in mm)	MH6692K
No. 32L endodontic excavator	EXC32L
No. 2 Woodson composite instrument (plastic, double ended)	PFIWDS2
No. 23 Expro and No. 6 UNC 15 handle (combined Shepard hook and marked periodontal probe)	XP23/UNC15
No. 18 Iris scissors (curved)	S18
No. 17 dressing pliers (for cotton)	DP17
No. 24 cement spatula (stainless steel)	CS24
Composite/amalgam carver	
Assorted soft goods: cotton pellets, cotton tips, gauze squares (2 × 2)	

*Manufactured by Hu-Friedy.

FUNDAMENTAL DIAGNOSTIC AND PROCEDURAL EQUIPMENT

Pulp tester

•Vitality Scanner 2006 (SybronEndo)

Apex locators

• Root ZX II (Morita USA)
• Endo Analyzer Model 8005 (SybronEndo)

Endodontic files

- Hand files: sterile K-files and/or Hedström files, placed in a cassette or into a sterile sponge with holder (Fig 11-3).
- Rotary nickel-titanium (NiTi) files, also placed in a sponge or other holder for potential sterilization and reuse. There are many systems on the market, such as ProTaper (Dentsply), GT Series X (Dentsply), Profile Systems (Dentsply), RaCe Sequence (Brasseler USA), Light Speed LSX (Discus Dental), and K3 (SybronEndo).

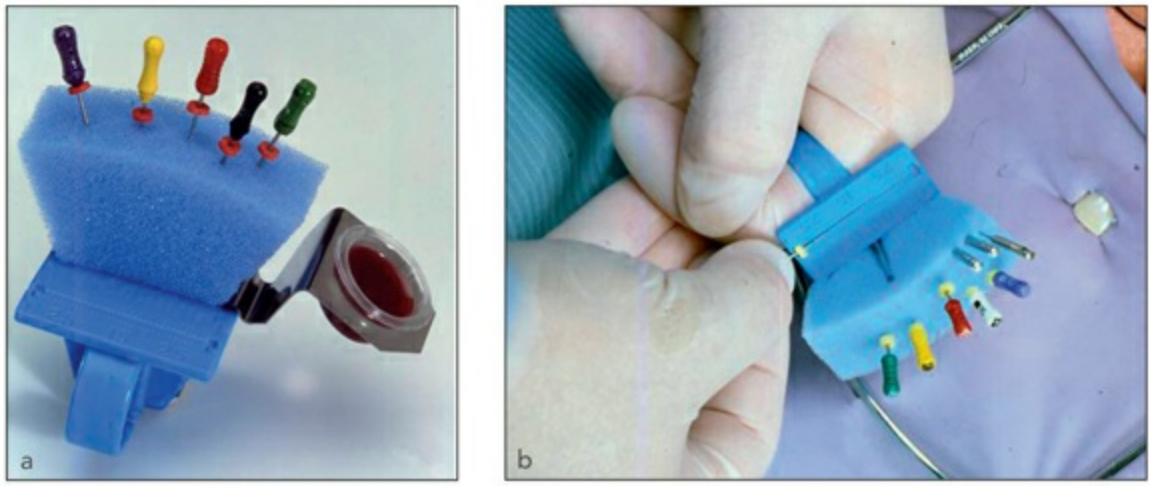


Fig 11-3 *(a and b)* Hand files can be sterilized in a sponge (Jordco) and placed into a holder, facilitating use, application of lubricant, and length measurements.

Electric motors and handpieces

- Endo Digital Torque Control (DTC) Motor (Aseptico)
- Endo Intelligent Torque Reduction (ITR) (Aseptico)

Thermal obturating systems

- System B Heat Source (SybronEndo)
- Obtura II Warm Gutta-Percha System (Obtura Spartan)
- Elements Obturation Unit (SybronEndo) combines System B technology with a motor-driven extruder handpiece

Handpieces

The handpiece must be fiber optic, true running, air pressure– controlled, balanced, and sterilizable. A conventional high-speed, contra-angle bur enters at a 90-degree angle, which may obstruct the view of both the doctor and the assistant. As an alternative, the 45-degree–angled auto-clavable Air King Fiber Optic Handpiece (Medidenta) and the Impact Air 45 (SybronEndo) facilitate unimpeded access to the most difficult-to-reach posterior regions of the mouth.

Customized cart systems

The Multi-Task Carts (MTC) (Obtura Spartan) and a variety of carts from ASI Medical (Fig 11-4) are extremely efficient and save space. In addition, they incorporate most of the fundamental diagnostic and procedural equipment already mentioned.

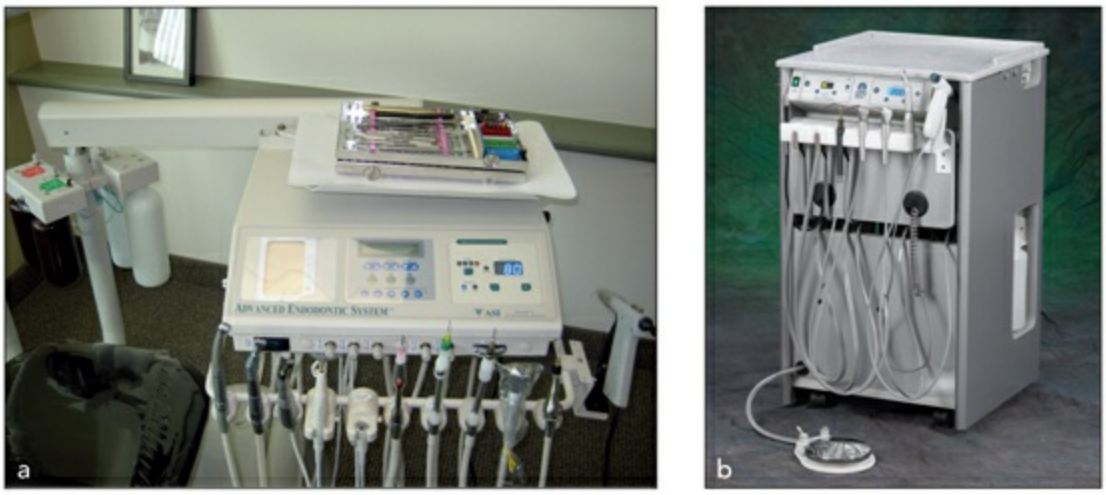


Fig 11-4 Most endodontists use a low-speed electric motor, an apex locator, and an ultrasonic unit as well as heat generators for warm gutta-percha techniques. All these instruments may be combined in an individually configured unit. *(a)* Cart from ASI Medical. (Image courtesy of Dr Nava Fathi, San Jose, CA.) *(b)* Multi-Task Cart (Spartan-Obtura).

FIXED EQUIPMENT NEEDS

Digital radiography

The majority of practicing endodontists have replaced their film and darkroom radiography techniques with digital radiography computer systems. Though a normal quality x-ray unit is needed, the radiation exposure is reduced by 70%, the target is viewable on a monitor in 30 seconds or less, the image of the target can be enlarged and rotated, and there are no chemicals to buy or change. However, as a precaution, it is wise to have a backup automatic processor available:

- Schick CDR Wireless imaging system (Schick Technologies)
- DEXIS (Dental Electronic X-ray Imaging System) (Dexis)

Illumination

The normal overhead dental light offers reflected light but must be moved frequently to focus at various vertical and semivertical angles. This is not only inconvenient and time-consuming but also threatens aseptic control. The following alternative lighting systems are available and are highly recommended. However, prior to purchasing any adjunctive lighting sources, the following issues

should be considered: power needed, weight of the unit, cost effectiveness, and comfort:

- Zeon Illuminator halogen light system, fiber-optic frame, and headlamps (Orascoptic)
- Duralite 3000, Quadrilite 6000, fiber-optic frame and headlight system (Designs for Vision)
- Fiber-optic illuminated instruments (Quality Aspirators)
- Uniglo headlight (Aseptico)

Magnification

As the level of magnification increases, your ability to inspect, evaluate, and perform endodontic procedures with precision, exactness, and quality improves. However, before purchasing any expensive fiber-optic device, you must understand that increasing the power may very well magnify and better define minute targets, but as power increases, the depth of field correspondingly decreases. Because of this relationship, endodontists are likely to be interested in a power range of 4.5×to 24×to meet the challenges of difficult canal anatomy and apical surgery, whereas a general dentist, doing limited endodontics, might be better served by selecting a scope that offers lower power settings, ranging from 3.5×to 5×, that provide wide field and depth versatility to accommodate difficult operative and prosthetic demands.

Binocular systems

The following binocular systems offer an extensive range of power and field-of-vision versatility at a reasonable cost:

- High-vision telescopes (Designs for Vision), 2.5×, 3.5×, 4.5×, and 6×
- Prism loupes (Carl Zeiss), 3.3×to 8×
- Dimension-3 telescopes (Orascoptic), 2.6×and 3.25×
- V-series microscopes (JedMed Instrument)

Surgical microscopes

True surgical microscopes offer power settings that range from 3×to 30×, and they are an outstanding source of vertically directed high-intensity illumination (see lesson 13).

Questions to ask before purchasing a microscope

- Am I willing to go through the learning curve?
- Am I willing to change my chairside position?
- Will my operating rooms need to be remodeled to accommodate a microscope?
- Am I willing to train my assistant?
- Will owning a microscope make dentistry easier and less stressful (eg, improve posture) and more fun?

• Is the cost of the unit feasible?

Additional considerations

Once you have decided to purchase a microscope, time should be spent with various manufacturers to see which unit feels most comfortable and further questions should be directed to the vendors:

• Will the magnifying lens, when focused, meet my buccal and lingual depth-of-field needs?

• Is the magnified image as clear on the peripheral edges as it is in the center?

• Is the lens coated to minimize light scatter and glare when focused on a mirror or any other reflective surface?

• Do I have flexibility, or must I have the lenses set for a particular working length?

• What are my illumination options?

• Will my operating room dimensions accommodate a microscope?

• What accessories are available (eg, splitters, cameras, video)?

• Can the accessories be added at a later time?

• What are the company's warranty and support policies?

INSTRUMENTS FOR MINOR SURGICAL ENDODONTIC EMERGENCIES

The basic and essential hand instruments listed in Table 11-5 are needed to help you meet operative and emergency needs, such as establishing drainage, inserting a drainage wick, removing a tissue-embedded foreign body or broken tooth fragment, or performing a minor gingivectomy or gingivoplasty to access the coronal border of a severely decayed or fractured tooth, as in crown lengthening. These instruments (eg, Chivian-Arens Endodontic Surgery Kit [Hu-Friedy]) should be stored in a sterile cassette when not in use.

Table 11-5	Surgical hand instruments*
Description	**Part code**
No. 1 cone socket mirror handle	MH1
No. 5 Front surface mouth mirror	MIR5
No. 23 Expro and No. 6 UNC 15 handle (combined Shepard hook and marked periodontal probe)	XP23/UNC15
No. 1 DE explorer	EXD1
No. 5 scalpel handle	10-130-05
No. 11, No. 12 scalpels	
No. 149 periosteal elevator	P149
No. 2/4 Molt DE curette	CM2/4
No. 1 Hourigan retractor-23 (serrated)	PH1
No. 85 Lucas DE surgical curette	CL85 A
No. 17/18 IU DE curette	SIU17/18
No. 13/14 Columbia DE curette	SC13/14
No. 18 Iris scissors (curved)	S18
Mathieu-Kocher Perma Sharp needle holder	NH5074
No. 03, No. 04 sutures	

*Manufactured by Hu-Friedy.

ERGONOMICS

Though it is essential to choose the appropriate instrument or device to successfully complete an endodontic procedure, it is just as important to execute that service in a manner that does not endanger the clinician's health. Studies indicate that 93% of the dentists practicing today suffer from some form of musculoskeletal disorder (MSD), and of those, 8% (according to recent insurance statistics) are permanently disabled. The complaints range from pain (tingling and burning) and numbness (loss of normal sensation) to cramping (decreased grip strength and loss of coordination). The areas most

affected are the:

- Shoulders and neck (eg, supraspinatus tendinitis, bicipital tendonitis, rotator cuff strains and tears)—71%
- Hand, wrist, and fingers (eg, carpal tunnel syndrome, stenosing tendinitis, De Quervain disease of the thumb)—65%
- Lower back (eg, stenosis, disc degeneration, spondylolisthesis, sciatica)—56%
- Forearm and elbow (eg, lateral epicondylitis [tennis elbow], radial and/or cubital tunnel syndrome)—27%

MSD risk factors

Poorly designed equipment and workstation

A workstation or equipment that is poorly designed forces the dentist to constantly change posture and chairside position(s), such as reaching, stretching, leaning, bending, twisting, and arm and elbow flexing. Room sizes and designs must not restrict efficient dual operation, which is why they should not be too small nor too narrow to ideally manage the needs of both the assistant and the doctor.

Repetition

Endodontics is basically an unchanging delivery system that requires extreme wrist flexion and extension and repeated clenched finger rotations with small and thin instruments.

Office management

Stress, fatigue, and muscle breakdown during the course of a heavily scheduled day (inadequate time per patient) or repeating the same tasks without a break takes its toll. Posture suffers, and operative movements become awkward. The body tenses, and the MSD symptoms begin: the back is slumped, the neck hurts, and the fingers tingle.

Recommendations to reduce MSDs in dentistry

Address posture

- Use an adjustable chair with lumbar support, thoracic support, and arm support for the elbows and forearms.
- Minimize forward bending and twisting motions by positioning the clinic chair close to the patient.
- Maintain an erect chairside sitting position with the feet flat on the floor and the back and lower legs perpendicular to the floor.
- Place the patient in a nearly horizontal position; sit erect, and work from behind and from above.
- Alternate work positions: sit, stand, and occasionally switch sides.

• Minimize twisting and turning movements of the wrists and fingers.
• Use magnification to improve visibility and reduce eyestrain (the microscope is best for enhancing visibility, illumination, and posture) (Fig 11-5).

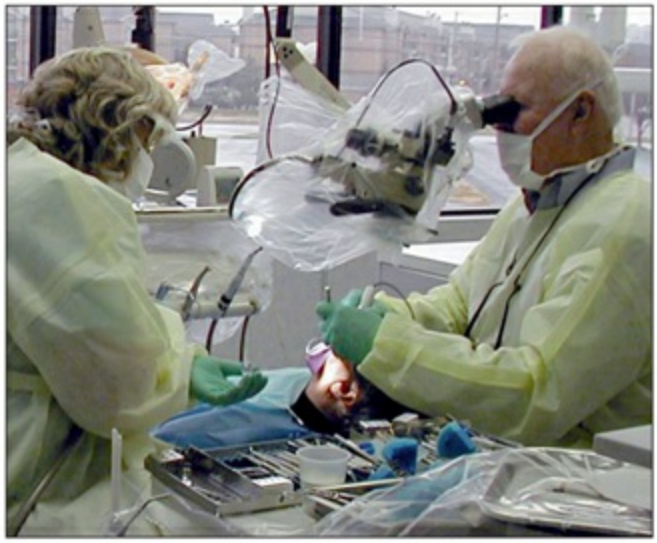


Fig 11-5 Dr Donald Arens, using proper ergonomic posture, works with his assistant and the optical microscope.

Personal health issues

• Stay in good physical condition.
• Perform staff-included exercises and stretches during the workday.
• Reduce stress level(s).
• Get enough rest and relaxation.
• Be aware of MSD symptoms, and address them immediately.

LESSON 12

Clinical Infection Control

OBJECTIVE

To create and maintain an aseptic operating facility in accordance with the Occupational Safety and Health Administration (OSHA).

PROTOCOL FOR THE DENTAL OFFICE

As the incidence of human immunodeficiency virus (HIV) and AIDS, hepatitis B, and other bloodborne diseases has increased, the risk of exposure in the dental office has become a reality. In today's environment it is imperative (legally) that the dentist and assisting staff conform to the infection control rules and regulations established by OSHA. In addition, patients are more cognizant of their susceptibility to disease transmission and have come to expect and demand the dentist take every precaution to protect their welfare. To reinforce that trust, it is quite common and appropriate to see a sign in a dental office waiting room announcing: "This dental office adheres to strict OSHA infection control mandates."

It should be the policy of every dental office to have a continuously updated, privately held manual of operations (MO) that includes employee background, hiring protocol, education and training materials and records, and infection control files.

Employee file

There should be an employee file for each current and former employee. This file should contain personal and contact information, including names, home addresses, home and cell phone numbers, and emergency contact names and phone numbers. In addition, it should include a chronicle of each employee's position and entitlement, such as job description(s), dress code, vacation time, maternity leave, sick leave, pay scales, performance evaluation forms, and for license protection, records of employee educational briefing(s) (ie, cardiopulmonary resuscitation), and personal infection control discussion(s).

Employee hiring protocol

When interviewing and hiring potential new employees, the interviewer must:

- Give applicants a formal application that requests specific information with regard to personal information (eg, name, address, work background, references).
- Disclose the employment risk(s) of working in a dental office, including contact with patients' body fluids that may harbor hepatitis, AIDS, and other bloodborne pathogens
- Inform applicants of the mandated immunization office policy, describe the office infection control policies that have been established for the employees' protection, and respond to any questions they may have regarding their safety.
- Inform applicants that within 10 days of employment they must be immunized (inoculation should be offered free of charge), show proof of immunity (via prior inoculation or exposure), or sign a waiver.
- Since a positive response to vaccines is not 100% assured, applicants must be informed they may need to be tested for seroconversion 6 to 8 weeks after immunization to verify the test results and/or be revaccinated.
- These rules pertain to those seeking operating room assistant positions and are not necessarily required for clerical positions.

Education file

It is the responsibility of the primary clinician(s) to see that an employee fully understands and complies with the OSHA infection control standards. In some states, educating the auxiliary personnel is a dental license requirement. The authors suggest you contact your individual state board of examiners for clarification.

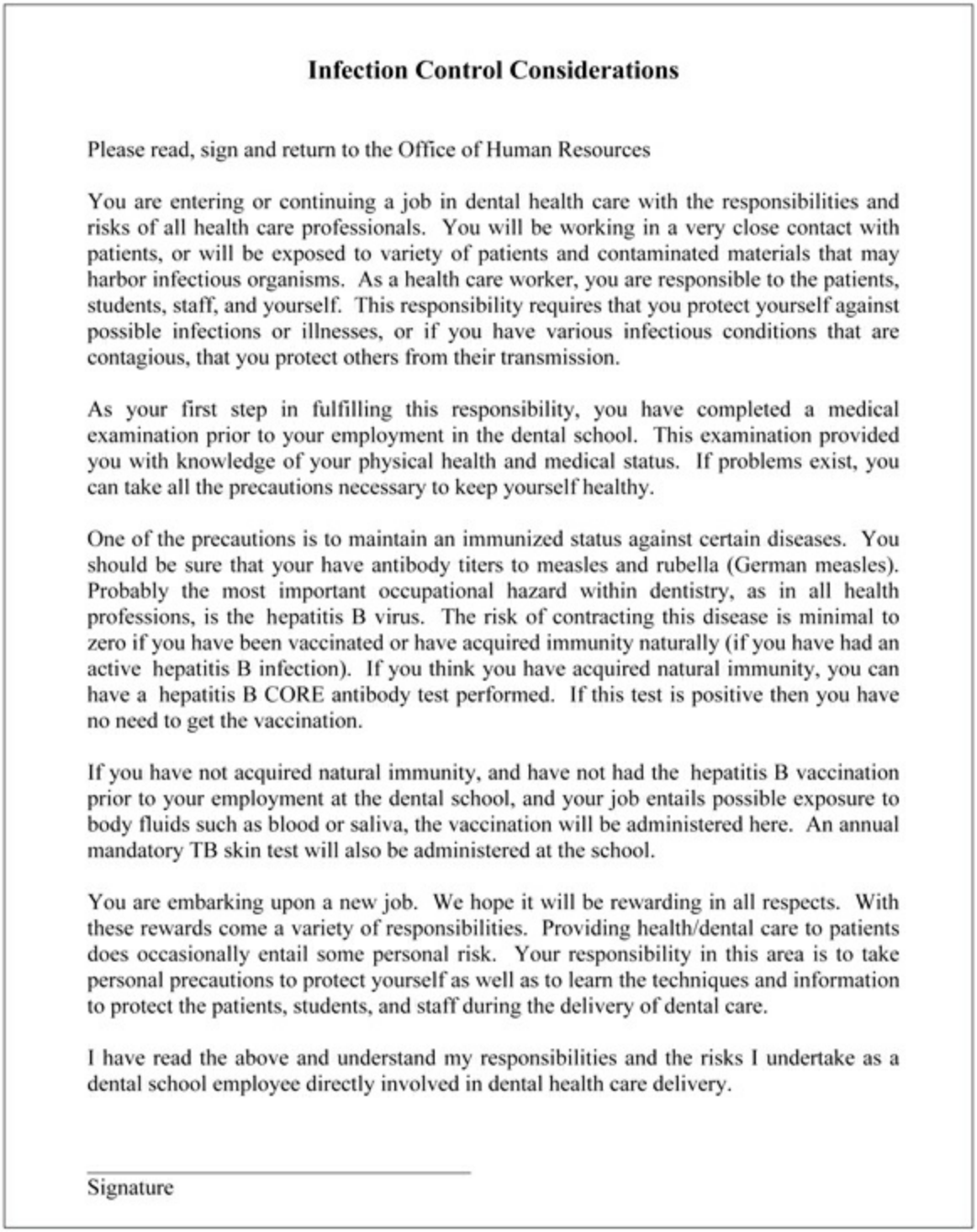
The education file should contain copies of the official and current OSHA guidelines as well as any literature from the American Association of Endodontists and the American Dental Association (ADA) that pertains to endodontic in-office recommendations on infection control, facility care, operating room cleanliness, protective materials, and techniques, and all of the above should be available to employees upon request.

Infection control file

The infection control file should include the following records and forms:

- A non-negotiable statement (rule) that all current and future employees who have or will have direct or indirect contact with a patient's blood, teeth, or saliva must be immunized with the hepatitis B vaccine, show serological evidence of immunity (HBs-antibody) from a previous vaccination or natural infection recovery, or sign a witnessed waiver (Fig 12-1).
- A vaccination record showing the date(s) of each employee's immunization, inoculation(s), or signed waiver. A copy should also be included in the staff member's employee file.
- A formal statement recommending that the entire operating room staff be vaccinated or tested for immunity of other contagious diseases, including diphtheria, tetanus, measles, varicella, and tuberculosis.
- A printed exposure incident form (Fig 12-2) describing any incident that breaches the infection control protocol (eg, an accidental stick or exposure to body fluids); the completed form should be included both in this section and in the staff member's employee file. The report should include the following information:
  - Injured person's name.
  - Patient's name.
  - Date and time of the exposure.
  - Where did the exposure occur (eg, in the operation room, laboratory, or sterilization area)?
  - What was the exposure item (eg, needle, bur, instrument puncture, fluid spray, other)?
  - What had the exposure item been used for prior to the injury?
  - Had the exposure item been in contact with blood and/or saliva before the injury?
  - What barriers were being used at the time of the incident (eg, gloves, glasses, other)?
  - What part of the body was injured?
  - Description of the incident in detail.
  - What corrective measures were taken immediately after the incident?
  - Was the injured person seen by a physician (name) or hospitalized (where) immediately after the incident?
  - All follow-up medications, physician visits, and postexposure measures of the injured person must be recorded, added to the report, and inserted in the MO.
- Evidence that all employees will be offered the appropriate postincident medical care and medication(s) (eg, prophylactic antiviral or antibiotic medications) in accordance with the published OSHA Standard of Care for Exposure.
- A formal set of responses from the patient if he or she is the subject of the breach:
  - The patient must be informed of the incident (exposure) and the possible sequelae.
  - The doctor should request and convince the patient to voluntarily submit to an evaluation for HIV, hepatitis C, hepatitis B, and tuberculosis at the office's expense.
  - The patient should understand that all appropriate postincident medical care and medication(s) judged to be necessary will be prescribed.

– The results of the patient's tests or a signed and witnessed waiver confirming the patient's refusal to be tested must become an integral part of the infection control file.



Infection Control Considerations

Please read, sign and return to the Office of Human Resources

You are entering or continuing a job in dental health care with the responsibilities and risks of all health care professionals. You will be working in a very close contact with patients, or will be exposed to variety of patients and contaminated materials that may harbor infectious organisms. As a health care worker, you are responsible to the patients, students, staff, and yourself. This responsibility requires that you protect yourself against possible infections or illnesses, or if you have various infectious conditions that are contagious, that you protect others from their transmission.

As your first step in fulfilling this responsibility, you have completed a medical examination prior to your employment in the dental school. This examination provided you with knowledge of your physical health and medical status. If problems exist, you can take all the precautions necessary to keep yourself healthy.

One of the precautions is to maintain an immunized status against certain diseases. You should be sure that your have antibody titers to measles and rubella (German measles). Probably the most important occupational hazard within dentistry, as in all health professions, is the hepatitis B virus. The risk of contracting this disease is minimal to zero if you have been vaccinated or have acquired immunity naturally (if you have had an active hepatitis B infection). If you think you have acquired natural immunity, you can have a hepatitis B CORE antibody test performed. If this test is positive then you have no need to get the vaccination.

If you have not acquired natural immunity, and have not had the hepatitis B vaccination prior to your employment at the dental school, and your job entails possible exposure to body fluids such as blood or saliva, the vaccination will be administered here. An annual mandatory TB skin test will also be administered at the school.

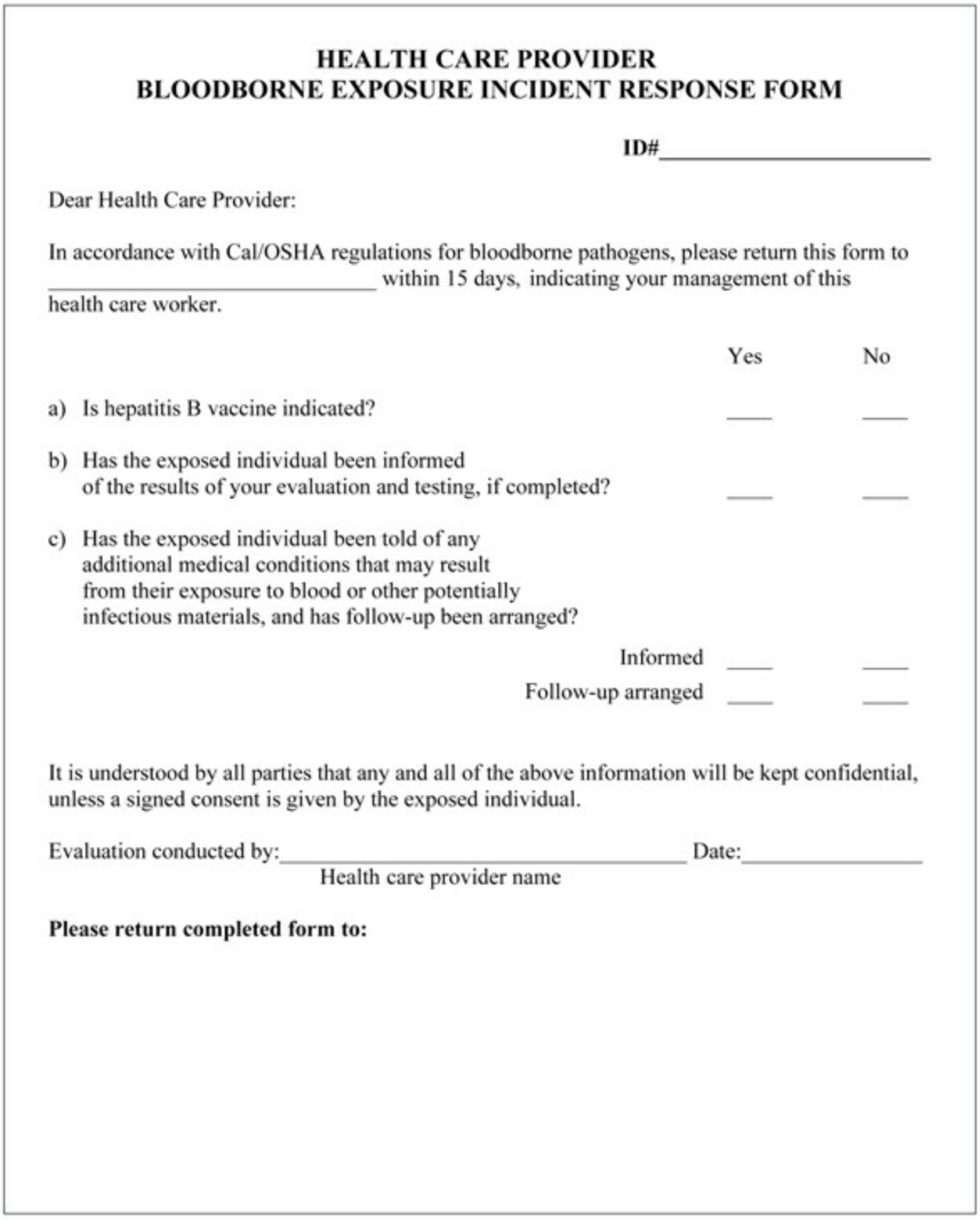
You are embarking upon a new job. We hope it will be rewarding in all respects. With these rewards come a variety of responsibilities. Providing health/dental care to patients does occasionally entail some personal risk. Your responsibility in this area is to take personal precautions to protect yourself as well as to learn the techniques and information to protect the patients, students, and staff during the delivery of dental care.

I have read the above and understand my responsibilities and the risks I undertake as a dental school employee directly involved in dental health care delivery.

_____

Signature

Fig 12-1 An example of a New Employee Hepatitis B Vaccination Form.



HEALTH CARE PROVIDER
BLOODBORNE EXPOSURE INCIDENT RESPONSE FORM

ID#_____

Dear Health Care Provider:

In accordance with Cal/OSHA regulations for bloodborne pathogens, please return this form to _____ within 15 days, indicating your management of this health care worker.

	Yes	No
a) Is hepatitis B vaccine indicated?	____	____
b) Has the exposed individual been informed of the results of your evaluation and testing, if completed?	____	____
c) Has the exposed individual been told of any additional medical conditions that may result from their exposure to blood or other potentially infectious materials, and has follow-up been arranged?		
Informed	____	____
Follow-up arranged	____	____

It is understood by all parties that any and all of the above information will be kept confidential, unless a signed consent is given by the exposed individual.

Evaluation conducted by:_____ Date:_____
Health care provider name

Please return completed form to:

Fig 12-2 An example of a Bloodborne Exposure Incident Response Form. (Courtesy of Arthur A. Dugoni School of Dentistry, University of the Pacific, San Francisco, CA.)

Clinical infection control measures

Materials, methods, equipment, and techniques needed to acquire and maintain a disinfected operating room environment (Fig 12-3) are described in the next section of this lesson. This information should be included in the MO and copies made available to all employees. You will find it particularly helpful when training a new employee.

Fig 12-3 Appropriate personal protection for clinicians in endodontic therapy: dedicated clinical gown, protective eyewear with side shields, mask, and gloves.

PROTOCOL FOR DENTAL CLINIC AND PERSONAL PROTECTION

Hand washing

Exposed hands and lower arm skin should be thoroughly washed and scrubbed with an antimicrobial liquid or alcohol-based soap. Vionex Antimicrobial Liquid Soap (Metrex) kills 99.94% of germs in 30 seconds, and its active ingredient contains a skin conditioner and emollient that prevents dry skin.

Gloving

- Wear powder-free latex or other treatment care gloves during all intraoral procedures and/or whenever there may be exposure to a patient's body fluids (eg, discarding wet gauze, cotton rolls, sharps, or extracted teeth or pouring impressions).
- If a glove is torn or punctured, discard it immediately.
- Once a glove has been in contact with a patient's body fluids, remove and discard it before leaving the operating room (eg, to use the phone, touch the chart, or retrieve an item from a central supply station or laboratory).
- Rubber gloves are more durable than are treatment gloves and offer greater protection when scrubbing instruments and cleaning large cabinet tops, dental chairs, dental units, x-ray machines, and water bowls.

Protective eyewear

- All eyeglasses or full-face semicurved shields should have protective side guards.

- Wear protective eyewear during all intraoral procedures and/or when using polishing or grinding equipment in the clinic or laboratory.
- Wear protective eyewear when brush scrubbing instruments.
- When contaminated, wash protective eyewear with an antimicrobial liquid.
- It is wise from a liability standpoint to have the patient wear protective eyewear throughout the endodontic procedure.

Masks

- The doctor and the assistant(s) must wear a mask during all examination and treatment procedures.
- According to the US Centers for Disease Control and Prevention (CDC), 75% of the protective masks are worn incorrectly. The CDC recommends "the masks be carefully fitted over the nose with a metal bridge (responsible for 71% of the compliance failures) and the head straps be correctly placed over the ears (responsible for 52% of the failures)."
- Wear a fresh mask for each patient.
- Wear a mask when using polishing or grinding equipment in the clinic or laboratory.

Protective clothing

- Washable surgery scrubs, doctors' and nurses' uniforms, and inexpensive disposable gowns that have a high neck are the most appropriate attire for use in a dental clinic.
- To protect patients' clothing from accidental blood or sodium hypochlorite spray or droplets, it is wise to have them wear an inexpensive disposable gown or long (neck to foot) drape throughout the endodontic procedure.
- Doctors' and/or assistants' clothing must be changed whenever they have had contact with blood or saliva.

Protection against oral fluid spray

- Having patients prerinse with either Peridex (Zila Pharma-ceuticals) or Listerine (Pfizer) for 1 minute can significantly reduce the microbial count of their oral fluids.
- The standard of care for endodontic therapy demands that rubber dam be applied and maintained throughout the entire endodontic treatment procedure.
- Use high-volume evacuation during access opening and irrigation procedures.

Laundry

- Linens and other laundry contaminated with blood and/or saliva are glove-handled as little as

possible and disposed of in an appropriately marked biohazard bag.

- Never take the office laundry home. It may be washed at the facility or sent to a cleaning service that processes bio-hazardous materials.
- Paper gowns, drapes, napkins, masks, and gloves may be thrown away with the normal trash.

Operating room fixtures and equipment care

Since it is virtually impossible to completely sterilize an entire dental office operating room, chemical agents and scrubbing techniques must be relied on to disinfect large cabinet surfaces, equipment, and certain materials (eg, boxes, cases). The ideal chemical agent is fast acting, broad spectrum, nontoxic, noncorrosive, easy to use, nondisintegrating, odorless, cost effective, and has no residual effect. Few products meet these criteria, however, so a critical selection process must be used to assess the merits and practicality of a product with regard to its use (ie, manufacturer's recommendation, and/or whether it is an approved Environmental Protection Agency (EPA)–registered hospital-level tuberculocidal disinfecting agent).

Gloves, masks, eyewear, and gowns must be worn when using cleaning solutions and disinfectants. Furthermore, all surfaces exposed to an intraoral procedure must be disinfected or barrier-covered at the end of each patient appointment. Available disinfecting agents are listed below. Recommended products are marked with an asterisk:

- Alcohols are protein denaturants and lipid solvents and, as such, are not regarded by the ADA as acceptable surface or instrument decontaminating agents. The use of Vionex Antimicrobial Liquid Soap for washing the hands prior to treatment is fine.
- Anionic soaps contain alkyl and/or alkyl aryl sulfates or sulfonates and are only effective when accompanied by vigorous scrubbing.
- Quaternary ammonium preparations affect microbial cell membranes and can be highly effective germicides even in low concentrations.
- Iodine is a highly effective halogen germicide, but it is caustic and stains clothing and equipment.
- Chlorine,* in its hypochlorite state, destroys tough bacteria, mold, and mildew at their source and meets the disinfection requirements of OSHA's bloodborne pathogens standard.
- Glutaraldehydes* (0.25% to 0.50%) are effective and inexpensive and enjoy EPA approval as a hospital disinfectant.
- Betadine (Purdue Pharma) when buffered to an alkaline pH range is a highly effective sporicidal, virucidal, bactericidal, fungicidal, tuberculocidal, and pseudomonacidal disinfecting agent.

Infection control products

Between patients

For cleaning and disinfecting hard nonporous surfaces between patients:

- Clorox (Clorox) destroys tough bacteria, mold, and mildew at their source. It sets a new standard

for disinfectants with shorter contact kill time. Clorox eliminates tuberculosis (TB), HIV, *Escherichia* organisms, salmonellae, hepatitis A and B, streptococci, and staphylococci in 30 seconds, and most viruses in 1 minute. It is inexpensive and meets disinfection requirements of OSHA's bloodborne pathogens standard. Its downside is the lingering medicinal odor.

- Lysol (Reckitt Benckiser) meets hospital disinfection standards and is especially effective against TB, HIV-1, poliovirus type 1, and hepatitis A. Its lingering odor is the downside.
- Citrace Hospital Germicide (Caltech Industries) is a broad-spectrum disinfectant that is environmentally safe—it emits no chlorofluorocarbons—and is effective against TB, hepatitis B virus, and HIV. Citrace Hospital Germicide is odorless and even eliminates existing odors.
- Sani Cloth HB and Sani Cloth Plus (Nice-Pak Products) are convenient, inexpensive disposable cloths that are odorless, germicidal, bactericidal, tuberculocidal, and virucidal.

At end of day

For more thorough cleaning and disinfecting of hard nonporous surfaces at the end of each day when more time is available, the following products are useful:

- ProSpray Surface Disinfectant (Certol International), Birex SE (Biotol), Banicide (Pascal), and Maxi-cide (Henry Schein) (active ingredients are 2.5% glutaraldehyde and a rust inhibitor) are excellent germicidal, fungicidal, virucidal, tuberculocidal, deodorizing solutions that meet OSHA's blood-borne pathogens standard. They are not to be used on intraoral instruments.
- Precise Hospital Foam Cleaner Disinfectant (Caltech Industries) is particularly effective against TB, hepatitis B virus, hepatitis C virus, and HIV-1 on stainless steel, chrome, plastic, and vinyl.

Plastic barriers

A fast, efficient, and safe, though more expensive, method of maintaining a scrupulously clean and disinfected operating room is to cover any item or piece of equipment that might come into contact with blood, saliva, or hands with disposable plastic sleeves, bags, and plastic wrappings (Fig 12-4). The expense of this method is offset by the fact that discarding and replacing the plastic barriers between patients can be done quickly and effortlessly, leaves no cleaning odor, and saves production time. The time-consuming scrubbing and chemical decontamination process can then be completed after working hours.

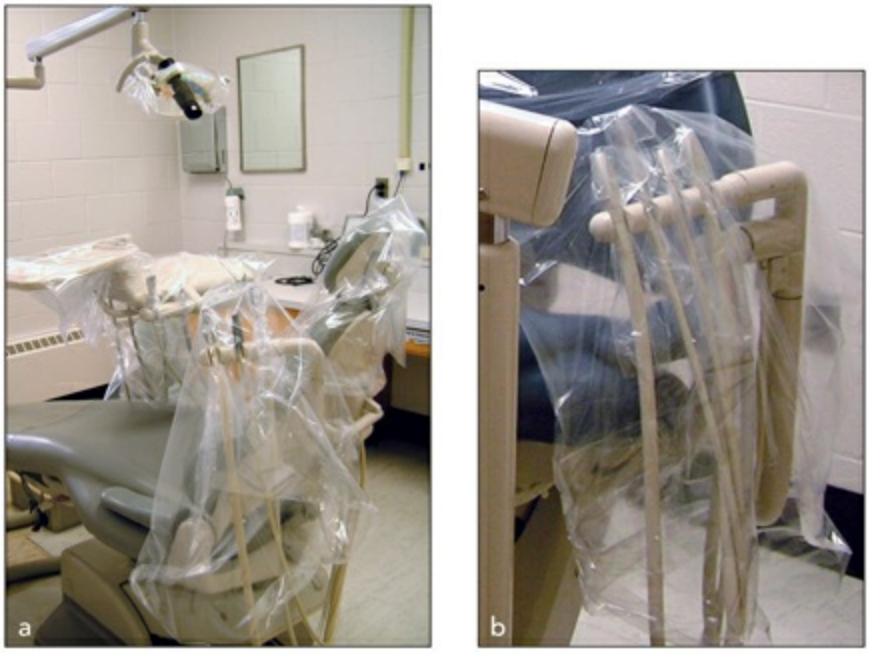


Fig 12-4 *(a and b)* Plastic barriers are an effective and efficient solution for the protection of large areas of the operating arena which can come in contact with splattered fluids.

Water lines

The ADA Council on Scientific Affairs stated, "Dental unit water lines (all tubes that connect to the handpiece, suction apparatus, ultrasonic scalers and drilling units, and the main water drain) have been shown to harbor a wide variety of microorganisms that colonize and replicate." Routine daily water line flushing with an antiseptic-based disinfectant such as Sterilex Liquid Ultra (Sterilex) and saliva vacuum ejection hose flushing with a diluted solution of Sani-Treet Plus (Enzyme Industries) help to minimize biofilm accumulation and to clear the hoses and traps of any damaging residual hypochlorite solution.

Instrument sterilization

- All instruments should be scrubbed with a brush and either soap and water or Sporox (Sultan Healthcare), a peroxide formula known to oxidize away dental debris and contaminants, and water rinsed before being placed in the ultrasonic unit (avoid overloading).
- Ultrasonic solutions:
  - Glutaraldehydes, though effective, inexpensive, and EPA-approved as a hospital surface disinfectant, are extremely deleterious to metal.
  - Tartar and Stain Remover (Sultan Healthcare) is an inexpensive and efficient ultrasonic solution.

Remove the instruments from the ultrasonic unit, rinse them with water, and place them evenly in a chemical indicator wrapping or bag. Do not overload the bag.

Sterilizing equipment

- To be truly effectively at removing all forms of microorganisms, regardless of their status, moist heat (250°F under 15 pounds of pressure for 15 to 20 minutes) and dry heat (350°F for 1 to 2 hours) are the two most practical methods.
- Technology is improving rapidly and some manufacturers offer sterilizing units (eg, STAT *IM* [SciCan] and Cox Rapid Heat Transfer [Alfa Medical]) with 6-minute "between-patient" cycles.
- Ethylene oxide is presently the surest and most effective alternative, but in the dental office, it is not cost effective.
- The sterilizing bags should be laid out evenly on the sterilizing trays with cassettes and instruments inside (Fig 12-5).
- Do not overload a sterilizing tray.
- To test the efficiency of the sterilizing unit, periodically insert a spore indicator into one of the bags.
- It is important to properly maintain and service your sterilizer. Speed-Clean (Midmark) is an effective autoclave cleaner (safe for all types of sterilizers) that breaks down the deposits that build up within the chamber.

Fig 12-5 Cassette of instruments placed inside a self-sealing sterilization pouch.

Handpieces

The weakest link in the asepsis chain is the dental handpiece. Presently, the external surfaces of high- and low-speed handpieces are sterilizable, but not so the internal components. Ethylene oxide would be the most effective alternative sterilizing method for handpieces, but it is neither practical nor cost effective. Major manufacturers are aware of these deficiencies, and some have marketed handpieces that are totally sterilizable (via autoclave or dry heat) without causing damage or decreasing their use-life. Because no sterilization assurance can be given with the currently popular hand-pieces, the available choices are to *(1)* use disposable hand-pieces (cost inhibitive), *(2)* purchase the new sterilizable hand pieces (another cost to consider), or *(3)* use a protective plastic barrier sleeve (most cost effective) to cover all but the working part of the handpiece.

Regulated waste

- Sharps are categorized as regulated waste.
- *Sharps* can be defined as anything that can puncture the skin, including scalpel blades, needles, anesthetic carpules, matrix bands, nonreusable burs, broaches, files, bent or broken instruments, and wire.
- Sharps should be disposed of in designated *sharps* containers located at each dental unit, the central service area, and all other areas of the office where they may be used or found.
- Broken pieces of glass are considered *sharps* and should be picked up with forceps or tongs and placed in a sharps container.
- Do not bend or break needles or files before placing them in the sharps container.
- Sharps containers should be filled to the three-quarter mark and delivered or mailed to an authorized sharps disposal company or service.
- An extracted tooth, although a non-sharps waste, may be placed into a sharps container.
- Never place regulated waste items in the trash!

Non-sharps regulated waste

Non-sharps waste include items that are wet, soaked, or caked with blood and/or saliva, such as gauze and cotton rolls. They must be placed in an autoclavable biohazard bag. If the primary bag is punctured or contaminated, place that bag and its contents in a second biohazard bag. Process the biohazard bags through a steam sterilizer; label the bags, and dispose of them in the same manner as sharps.

Dispose of liquid body fluids by flushing them down the drain with running water. Gloves and masks must be worn during the process, and care must be taken to avoid splashing.

Radiographic asepsis

Wet-film technique: Requirements for one assistant

1. Remove the gloves, place the lead apron on the patient, retrieve a film from central supply, and set the x-ray timer.
2. Rewash the hands, re-glove, and use the normal intraoral approach to take the radiograph(s).
3. Unglove, and press the timer.
4. Rewash the hands, re-glove, and remove the film from the patient's mouth.
5. Unglove, develop the film(s) in the dark room, place the film(s) on the viewer for the doctor to review, and if the image(s) is satisfactory, remove the apron.
6. Rewash the hands, re-glove, and continue with the normal assisting activities.

Note: For efficiency, it is far more prudent to use a second assistant for all of the ungloved procedures (ie, placing the apron, setting and activating the timer, developing and delivering the film to the primary assistant, and dropping the film packet in a biohazard bag). In addition, the use of less expensive over-gloves can save the use of new latex gloves during key steps in the procedure without the risk of contamination. Over-gloves can also simplify the tasks when only a single assistant is helping.

Digital radiovisiography: A viable alternative

1. A digital scanner that has been disinfected and stored in a small barrier wrapping is retrieved by a second assistant.
2. The second assistant places the apron on the patient and unloads the disinfected scanner onto the operating instrument surface.
3. The primary assistant, using the normal intraoral approach, places the scanner in the appropriate position and leaves the room.
4. The second assistant sets and activates the x-ray machine, and the digital image appears on an appropriately placed monitor within 3 seconds.
5. If the image is satisfactory, the primary assistant removes the scanner from the mouth and drops it on the working surface for additional scans.
6. The second assistant removes the apron.
7. At the end of the appointment, the scanner is disinfected and packaged for future use.

Accidental sticks

An *accidental stick* is defined as an exposure to body fluids:

- Prevention begins with education and training:
  - To prevent a needle stick, the needle should be recapped immediately after use even when a second injection is anticipated.
  - Needles must never be recapped with an unprotected hand holding the cap.
  - Do not pass an exposed needle to a third person for recapping, needle removal, or disposal.
  - All sharp and/or pointed instruments must be emptied from sterilizing bags with care.
- In case of a stick, attention should be immediately directed toward the injured party (assistant or patient):
  - Bleeding from a stick may be controlled by applying pressure over a gauze pad.
  - The site of the stick must be vigorously washed with an antimicrobial liquid (ie, an alcohol-based soap such as Vionex Antimicrobial Liquid Soap or a chlorhexidine liquid soap.
  - A preprinted Bloodborne Exposure Incident Response Form, available in the MO (see Fig 12-2, infection control file), should be retrieved, and the required information must be meticulously recorded.

– Once the immediate action (site care) has been satisfactorily managed, attention returns to the appropriate postinjury care responsibilities of the doctor to the injured party.

CONCLUSION

Though the requirements and expenses of creating and maintaining a disinfected operating room environment are demanding, it is the duty of the primary doctor to make sure that every precautionary measure has been taken to prevent a serious breach of the OSHA-required Infection Control Standard.

LESSON 13

Value of Magnification

OBJECTIVE

To explain the importance of magnification and optimal lighting in modern contemporary endodontic therapy.

MAGNIFICATION TOOLS

In dentistry, loupes (also referred to as *telescopes*), endoscopes, and microscopes have been used to enhance vision during patient treatment. Loupes are the most widely distributed optical armamentarium for magnified vision due to their comparatively lower costs and shorter learning curve (Fig 13-1).

With enhanced magnification and illumination made possible by using microscopes (Fig 13-2), it is possible to predictably locate additional canal orifices, remove obstacles such as pulp stones, close perforations from inside a root canal, and remove fractured instruments and posts. Endodontic macrosurgery, which historically has demonstrated acceptable healing rates, has now evolved quickly to endodontic microsurgery accompanied by outstanding improvement in the quality of technical outcomes and healing. Photographs and video sequences of treatments taken though a microscope camera allow for better education of patients, communication with colleagues, and documentation of treatment steps.

Along with enhanced vision, microsurgical instruments and materials were developed for orthograde and retrograde endodontic treatment. Recently, other specialties, such as restorative

dentistry, prosthodontics, and periodontics, have adopted the microscope as an important part of their armamentarium.

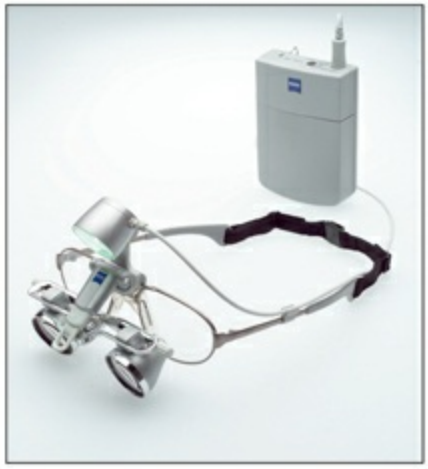


Fig 13-1 Eyeglasses with loupes and an attached light source. (Image courtesy of Carl Zeiss.)

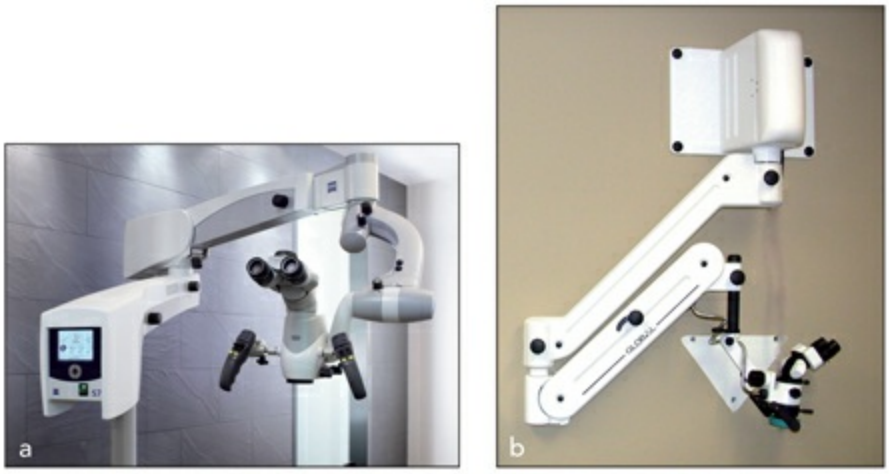


Fig 13-2 Examples of microscopes used in dentistry. *(a)* OPMI pico dental microscope, floor model. (Image courtesy of Carl Zeiss.) *(b)* G6 dental microscope, wall mounted. (Image courtesy of Global Surgical.)

Loupes or microscope

Many clinicians have purchased loupes in magnifications varying from 2×to 8×(Fig 13-3). While loupes offer great advantages over normal vision, certain procedures are best performed at magnifications of 12×or higher. Technically, loupes are still satisfactory, notwithstanding that they are very heavy to wear. However, the slightest head movements of the clinician or the patient can bring an area out of focus. Loupes require convergent optics that may cause eyestrain.

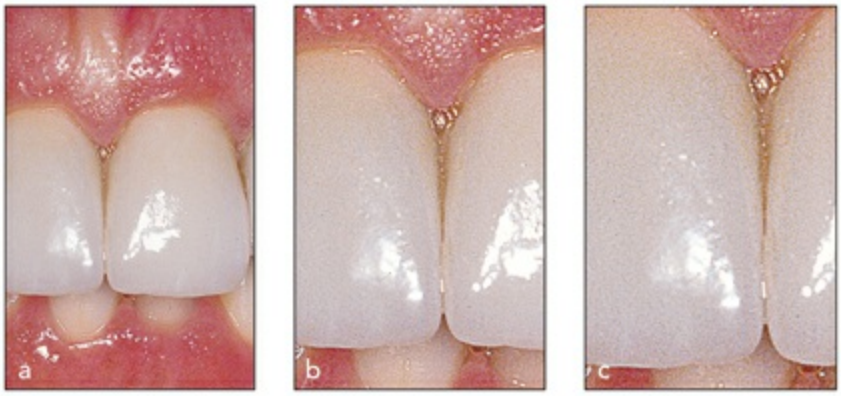


Fig 13-3 Examples of different magnifications of maxillary incisors. *(a)* Incisors at 5× magnification. *(b)* Incisors at 10× magnification. *(c)* Incisors at 15× magnification. (Images courtesy of Carl Zeiss.)

Positioning of the microscope

A microscope can be a rolling floor model, a wall-mounted model, or a ceiling-mounted model. The mounted microscopes are more convenient than the floor models, which require space on both sides of the dental chair. Magnification ranges from 4×to 40×, if desired. Some offices choose to have mounts in the operatories with only one or two optics that can be attached to the mounts. Loupes can be a less expensive way to begin working under higher magnification, eventually leading to the purchase of a microscope as the clinician recognizes its significant clinical value.

Positioning of the dental surgeon and assistant

When the clinician uses the microscope, she or he should be seated in an upright, neutral, and balanced posture with lower arms and hands supported (see Fig 11-5). Vertically adjustable chairs with armrests are available from many companies and help to reduce fatigue and tremor. Arm support may be adapted to the individual user and can be moved in front of the clinician for optimal assistance. In the learning phase, if a microsurgeon's chair is not available, cloth or towel rolls may be placed on the patient's shoulder for arm support.

The assistant may also require a chair with armrests to allow for viewing of the procedure through beam splitting and assistant binoculars. If this is the case, a second assistant can pass instruments or materials that are needed for the procedure.

Positioning of the patient

- Position the patient's chair so that it is horizontal.
- In most situations the tooth in question is viewed through a mouth mirror with indirect vision. In some instances, by inclining the binoculars, direct vision is possible.
- Pillows on headrests help immobilize the patient's head while adding comfort.
- Rubber bite blocks allow stable jaw positioning, which is necessary in larger magnifications with

decreased field of view.

- The optics and tube may be adjusted to eye distance and for visual depth.
- Most manufacturers offer courses on their websites as well as office visits to instruct new users and their assistants.

MAGNIFICATION FOR PATIENT TREATMENT

Benefits during orthograde root canal therapy

- Less eye fatigue when using a microscope.
- Better ergonomic posture of the clinician.
- Avoidance of work-related physical injuries.
- Inspection of the tooth crown for microfractures, craze lines, and caries lesions (Fig 13-4).
- Visualization of the entire pulp chamber, including developmental lines on the pulp chamber floor that can lead to mineralized orifices.
- Location of additional canal orifices (eg, mesiobuccal [MB2] canals and distobuccal [DB2] canals in maxillary molars, distolingual [DL] canals in mandibular molars, and extra canals in premolars).
- Removal of obstacles inside the pulp chamber or canal space during treatment or retreatment, such as root canal filling materials, silver cones, fractured instrument tips, and posts (Fig 13-5).
- Sealing of perforations on the pulp chamber floor or inside the root canal.
- Fewer radiographs may need to be taken.
- Enhanced patient trust in the doctor's ability to perform high-quality treatments.
- Photo- and video-documentation is possible.
- The high quality of treatment due to more accurate diagnoses, exact removal of diseased tissues, and better-fitting restorations is gratifying for both the clinician and the patient.

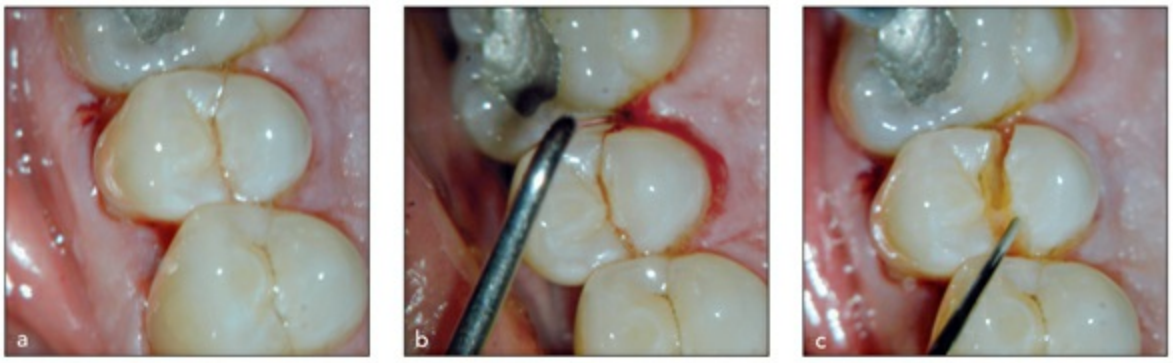


Fig 13-4 Inspection of a tooth crown for microfractures. *(a)* Crack in clinical crown suspected and viewed under high power with a microscope. *(b)* Associated probing creates the suspicion that the crack is not self-limiting. *(c)* After anesthesia, the crack is evidently separated, making the prognosis questionable.

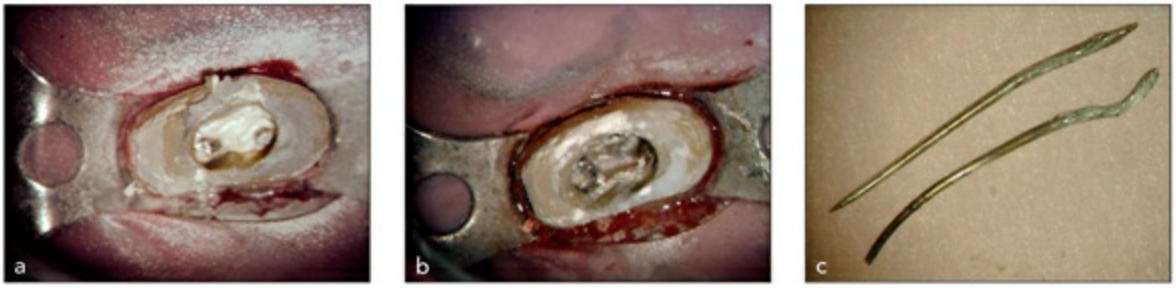


Fig 13-5 Removal of obstacles during retreatment. *(a)* Use of higher magnification offers considerable advantages when disassembling restorative materials prior to endodontic retreatment. *(b)* Silver cones have been uncovered from their cementation within a premolar access. *(c)* The removed silver cones demonstrate the corrosion and leakage that led to the retreatment.

Benefits during endodontic surgery

- Precise incision, reflection, and retraction without tearing or traumatizing the reflected tissue.
- Location of nerve exits or fenestration of cortical bone.
- Smaller osteotomy sizes of 5 mm or less.
- Resection of the root tip with no bevel or less than 10 degrees of bevel.
- Removal of an exact length of root from the tip (eg, the apical 3 mm that contains most canal ramifications).
- Inspection of the resected surface for vertical root fractures, cracks, additional canals, and isthmus areas.
- Enhanced confirmation of circumferential visibility of the periodontal ligament to ensure complete resection.
- Conservative retrograde preparation of class I cavities at the root apices.
- Enhanced alignment of the cutting instrument with the long axis of the roots.
- Application of root-end filling, compaction, and finishing of the restoration.
- Debridement of the granulation tissue.
- Exact reapproximation of the flap and placement of sutures less than or equal to 5-0.

LESSON 14

Local Anesthesia

OBJECTIVE

To skillfully produce a profound working level of anesthesia that will last the duration of an endodontic procedure.

INTRODUCTION

The management of pain in endodontics obliges the practitioner to understand patient anxiety and the methods to allay it. The anxiety associated with root canal therapy and/or the anxiety felt during an acute pain emergency, though closely aligned from the patient's perspective, is a separate entity from the pain involved.

NEEDLE FEAR

The anxiety over an injection and the possibility of "anesthetic failure" are the real concerns patients bring to the dental operatory. The inability to obtain adequate pulpal anesthesia, particularly in the mandible, is a well-known phenomenon. This problem is compounded when the involved pulp is acutely inflamed. Fortunately, there are a number of adjunctive measures which, when combined with standard injection techniques, provide profound anesthesia.

Problem

The pain process involves pain reception (nociception). The brain recognizes pain as it reaches and surpasses a perception threshold. The patient's response to that experience, in terms of suffering and anxiety, can lower the pain threshold and heighten the patient's reaction. Toothache and orofacial pain can evoke unreasonable anxiety in a fearful patient. One of the most anxiety-producing procedures for patients is the administration of local anesthetic. Because local anesthesia is first and foremost the foundation for pain control in endodontics, you must not only recognize but also address this psychosocial factor (see lesson 6).

LOCAL INJECTIONS

A painless injection can exemplify care and build a trusting patient-doctor relationship. A patient may not appreciate the sophisticated skills involved in rendering quality endodontics, but all patients are experts in understanding what constitutes a painless injection. By providing a comforting verbal promise to control pain and prevent discomfort in a calm and soothing professional manner, a doctor reduces anxiety and conveys professional competence. The doctor should use language and behaviors that reduce anxiety, understand the biologic basis of the disease course, and display an empathetic attitude to help moderate patient reactions to treatment.

Inferior alveolar nerve block

Of all the nerve blocks in the practice of dentistry, the inferior alveolar nerve block (IANB) is the one that has the greatest potential to produce an unpredictable result and/or failure. The anesthesia literature depicts this block as the most frustrating of all nerve block techniques in providing profound pulpal anesthesia. Worse yet, its success rate diminishes in the presence of pulpal or periapical inflammation.

The IANB is strongly recommended for premolars or mandibular anterior teeth. Although the mental nerve block can anesthetize premolars and anterior teeth, the IANB anesthetizes the lingual tissues in the entire arch and provides a more predictable and profound means to anesthetize these teeth. Hence, the IANB, in combination with a long buccal infiltration to anesthetize the buccal roots and tissues adjacent to the molars, should be sufficient in most cases to provide complete anesthesia for any mandibular tooth. To avoid injection directly into the associated vasculature, all anesthetic procedures, especially block injections, require the use of an aspiration (repeated) technique.

Demands of the IANB

- The tip of the needle must be in close proximity to the inferior nerve. A 25- or 27-gauge long needle is recommended for the traditional IANB. Short needles do not allow the clinician to align and focus the area he or she wishes to inject, and being thin and flexible, they are easily deflected away from the mandibular nerve.

- A sufficient amount of anesthetic solution must be delivered to bathe the greatest number of inferior nerve fibers.
- The pH value of the tissue must not be influenced by infection because it will cause the anesthetic solution to fail to produce the chemical exchange of potassium (K), leaving the nerve unaffected.

Delivery recommendations

To avoid the sudden distention of tissue and the resultant pain, the IANB can be given without discomfort when it is administered slowly. A patient's appreciation for a well-received and easily tolerated IANB builds trust and cooperation for the ensuing procedures. It is important to confirm the efficacy of anesthesia before starting endodontic therapy. Though all the profound signs of anesthesia of the jaw and soft tissue may be apparent, the fibers of the pulp tissue may still be sensitive to stimuli. Generally, the totality of the block should be questioned if lip tingling occurs without the corresponding tongue numbness (lingual anesthesia). Pulp sensitivity tests can be used to quantify a pulpal response (ice probe or the electric pulp tester). When it is determined that a patient retains sensitivity, it is extremely important to recognize the danger of assuming the mandibular block was successful.

When the IANB appears to have been successful but still fails to provide the desired anesthesia level, supplemental and adjunctive techniques must be implemented. Adjunctive techniques will be more successful with the underlying support of a well-dispensed block.

Alternative to the IANB: Gow-Gates division III block

The Gow-Gates injection technique is an acceptable alternative to the IANB, and while it is well tolerated by patients, its administration requires a more technique-sensitive application. This technique, however, should not be regularly substituted for the conventional IANB, which is appropriate in the vast majority of patients.

According to studies, the Gow-Gates division III block technique offers a 96% to 98% success rate and not only anesthetizes the major branch of the third division of the trigeminal nerve but also simultaneously anesthetizes all of the ancillary nerves associated with the mandible. The following steps describe the technique to administer the Gow-Gates block:

1. Position the patient's head so that the intertragic notch assumes an upward inclination.
2. Have the patient open his or her mouth as wide as possible.
3. Palpate the anterior border of the ramus with the forefinger.
4. Paint an antiseptic solution and a topical anesthetic on the lateral margin of the pterygomandibular depression (just medial to the medial tendon of the temporal muscle).
5. Align the needle with an imaginary plane that is parallel with the angulation of the ear to the face (through the corners of the mouth).
6. Aim the needle (a 27-gauge long) at the posterior border of the tragus and advance. The depth of penetration should be approximately 25 mm.

7. Aspirate and slowly inject the anesthetic solution.

Maxillary blocks and infiltration

To anesthetize the pulps of the maxillary anterior teeth and premolars, buccal infiltration should suffice. Slow administration of anesthetic is very important to minimize pain. All anesthetic solutions must be deposited in relation to their apex to be effective.

Injection recommendations

- Short thin-gauge needles are appropriate in this area and aid the tactile acuity of the dentist in providing a slow painless injection.
- Often, the anterior teeth, especially the canines, are excessively long. It is highly advisable to administer the infiltration high in the vestibule directly over the apex in these long teeth to achieve the required level of anesthesia.
- Many practitioners gently massage the anesthetic against the buccal alveolar bone to assure penetration and diffusion. Most often, an entire carpule of anesthetic is required for profound pulpal effects.
- On occasion, a lingual infiltration is required in teeth such as lateral incisors with apices that diverge in the palatal direction or when rubber dam impinges on palatal tissues. Though not common, it is desirable—when the anatomy of the tooth requires—to seat the rubber dam clamp at or below the palatal gingiva.
- In the majority of clinical situations, premolars require only buccal infiltration, and lingual infiltration is necessary only for inflamed maxillary two-rooted premolars.
- Maxillary first and second molar anesthesia requires an injection of the posterior superior alveolar nerve (PSA) block. This necessitates that the anesthetic solution be administered behind the zygomatic arch into the pterygomaxillary space (Fig 14-1). All maxillary molars require a palatal infiltration directly over the palatal roots. For best results, the recommended nerve block for the maxillary first molar requires that the clinician infiltrate solution over the mesiobuccal root to anesthetize that portion of the tooth innervated by the middle superior alveolar nerve (Fig 14-2).

Note: Palatal infiltrations for anesthesia are not easy injections to accomplish with a painless technique. There are a number of recommended strategies for administering this injection in an empathetic and less painful way. Some suggest the use of topical anesthetics applied just over the site of injection. Others combine topical anesthetic with applied pressure (a mirror handle or gloved finger) over the injection site for several seconds to blanch the blood from the site and render the tissue less sensitive. Just prior to the actual injection, the mirror handle or finger is moved a few millimeters away, still applying continuous pressure as a distraction, while the needle is employed. Many practitioners also use the smallest available clinical needle, most often the 30 gauge, for palatal administration.

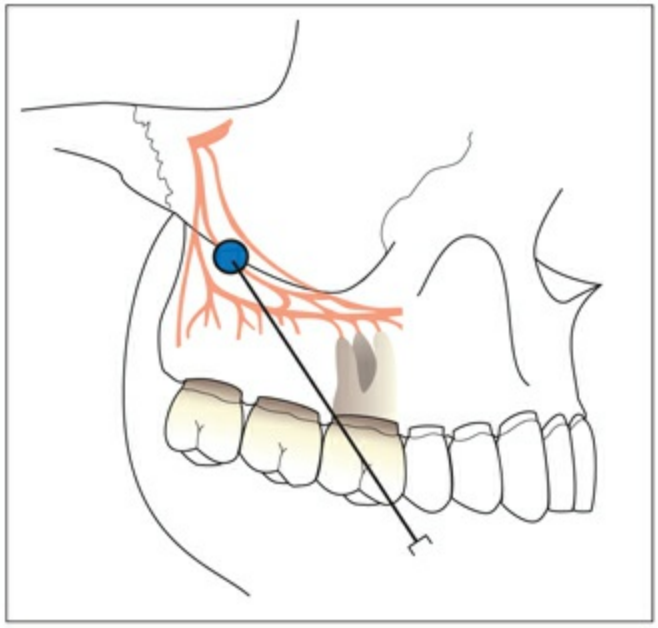


Fig 14-1 A PSA block is necessary to anesthetize the maxillary first and second molars. The PSA nerve branches just behind the zygomatic arch.

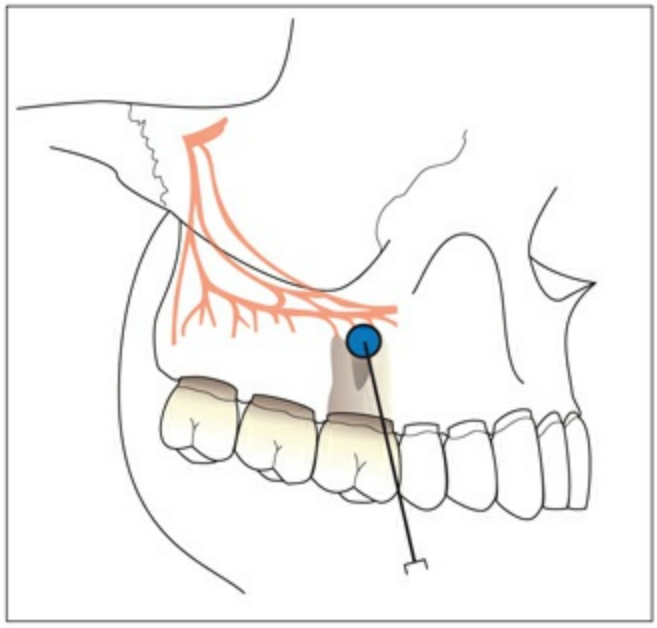


Fig 14-2 A depiction of the needle placement required for infiltration of the mesial root of a maxillary first molar, completing the anesthesia process for that tooth.

Maxillary division II block

Buccal approach

The maxillary division II block anesthetizes all of the nerves involved in innervating the entire maxillary arch:

1. Advance a $1^{5}/_{8}$–inch needle (in an aspirating syringe) medially and superiorly along the posterior surface of the tuberosity (behind the zygoma). The acute angle of insertion is easily facilitated if the anesthetic needle has a bend of 45 degrees.

2. Aspirate as you advance toward the pterygoid venous plexus to reduce the potential of an intravascular injection and a consequential hematoma.
3. If the syringe is clear of blood, deposit the anesthetic solution at a depth of about ¼ to ½ inch.

Lingual approach

A second option to performing the maxillary division II block is to use a lingual approach:

1. The foramen is typically located between the palatal roots of the second and third molars and ascends through the palate in a superior and lateral direction.
2. The canal is typically oriented at a 45-degree angle to the palatal plane. Therefore, direct the syringe approach from the opposite side of the mouth.
3. Though the length of the canal varies among individuals, a 5- to 8-mm needle depth is usually sufficient.
4. Inject the solution rapidly.
5. If the injection site bleeds, hold finger pressure over the foramen for 2 to 5 minutes.

Periodontal ligament injection

The periodontal ligament (PDL) injection is a supplemental injection that can aid in the attainment of profound pulpal anesthesia when swelling is not present and the tooth is resistant to conventional anesthetic techniques. It cannot be used as the sole means of anesthesia for a tooth:

1. Deposit several drops of anesthetic, under pressure, into the soft tissue adjacent to the bone, both mesial and distal to the tooth, usually with a 30-gauge needle (Fig 14-3).
2. Blanching of the tissues and considerable back-pressure during the injection ensure the proper administration.
3. Complete administration may require injection at all four proximal positions surrounding the tooth.

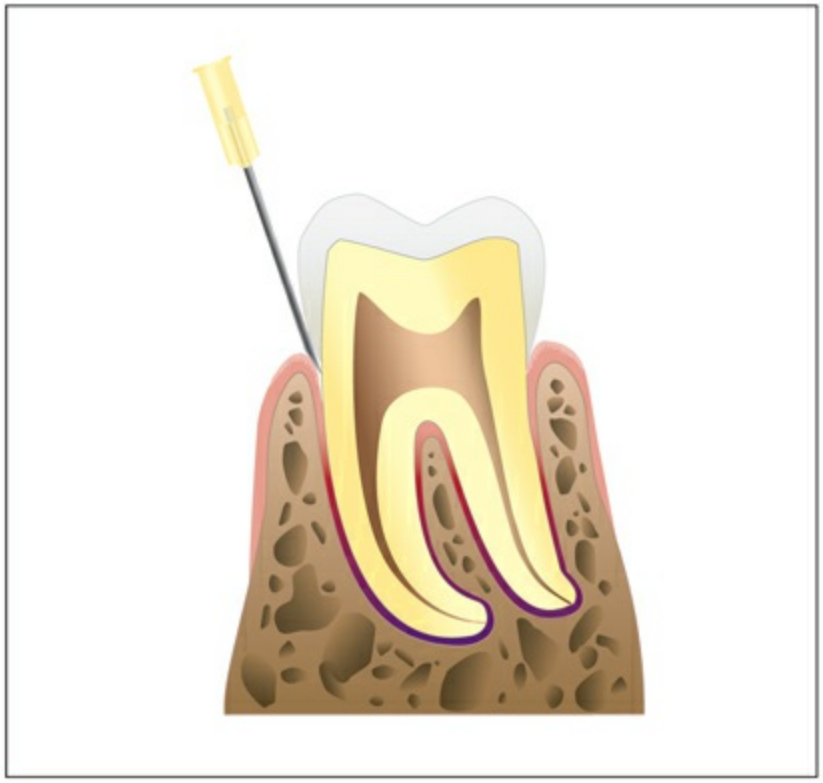


Fig 14-3 Anesthetic is delivered under pressure to the junction of the base of the attachment and the tooth.

Intraosseous injection

The intraosseous (IO) injection delivers local anesthetic directly into the cancellous bone adjacent to the involved tooth. The onset of anesthesia is quick but has a short duration. If used in conjunction with the IANB for mandibular molars, pulpal anesthesia of a "hot" tooth is more predictable for the purpose of painless access. The two most common devices available to practitioners to deliver this injection are the Stabident System (Fairfax Dental) and the X-tip intraosseous anesthesia delivery system (Dentsply). The site of the perforation is usually in the attached gingiva, distal to the tooth involved. In cases where the cortical bone may be quite thick, as in mandibular second molars, the injection may be moved to the mesial with similar results (Fig 14-4). The armamentarium for the X-tip intraosseous anesthesia delivery system is:

- A 9-mm (27-gauge) stainless steel perforator that fits onto a slow-speed contra-angle handpiece
- A plastic guide sleeve to identify and keep the drill hole open
- A 27-gauge needle to deliver the anesthetic solution

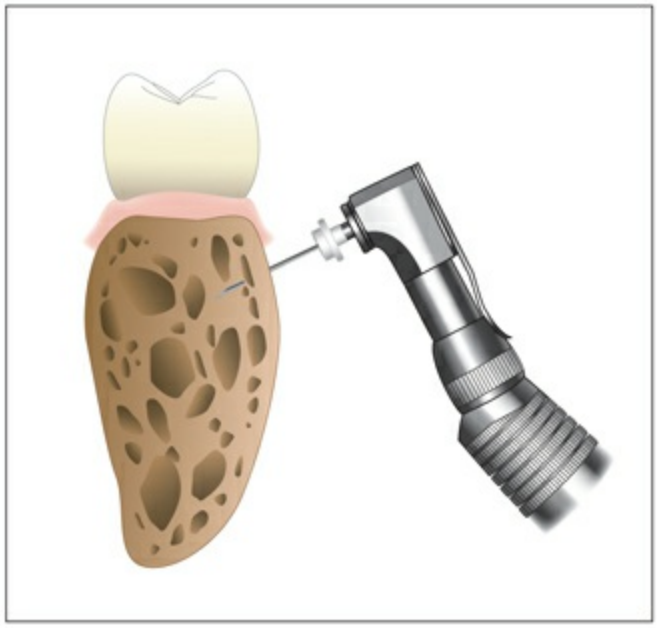


Fig 14-4a Perforator drill advancing into the cancellous bone.

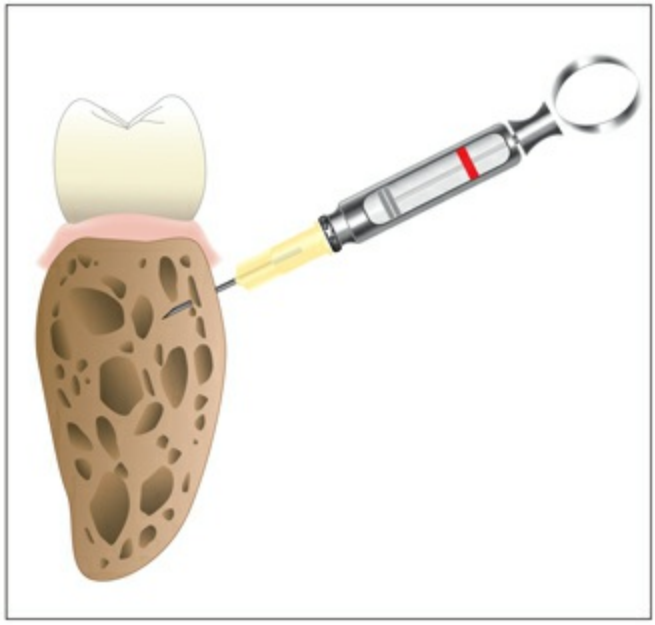


Fig 14-4b The drill is followed immediately by the placement of local anesthetic directly through the cortical perforation.

Technique

1. The IO penetration and injection site should be approximately 2 to 3 mm apical to an imaginary horizontal line along the gingival crest margins between the roots.
2. Apply a topical anesthetic to the site, and superficially inject a few drops of local anesthetic (with a vasoconstrictor) into the mucobuccal fold.
3. Place and secure the perforator (drill), and temporarily attach a guide sleeve into a slow-speed contra-angle handpiece.
4. With the perforator held at a 90-degree angle to the bone, activate the handpiece at a maximum speed of 20,000 rpm. Use a gentle “pecking” motion to penetrate the buccal plate.

5. Continue drilling through the lamellar bone until the drill penetrates the cancellous bone. (Since this spongy bone offers no resistance to the drill, penetration into the cancellous bone is easily identifiable.)
6. Hold the guide sleeve in place with cotton pliers, and remove the perforator.
7. Insert the needle into the opening of the guide sleeve at a 90-degree angle (for difficult-to-access areas of the mouth, it may be helpful to bend the anesthetic needle).
8. Slowly inject ¼ to ½ of a carpule of anesthetic solution (with or without vasoconstrictor) into the cancellous bone.
9. Cancellous bone is highly vascular, and a rapid systemic uptake and absorption may cause the patient to experience a rapid heartbeat (tachycardia).
10. Remove the needle, and leave the guide sleeve in place until the endodontic procedure has been completed, which allows the clinician to reinject at any time during the procedure.
11. Remove the guide sleeve at the end of the appointment.

Recommendations and cautions

- The IO system is not recommended for use on young children with mixed dentition.
- The IO system can only be used where there is cancellous bone. That excludes areas between the maxillary and mandibular incisors.
- If greater than normal resistance is met while drilling, you may be drilling into the root. In this case, stop drilling, and start the procedure on the opposite side of the tooth within the target area.
- No IO injection (anesthetic solution) should be delivered into an actively acute (abscess) site.
- Administer only the minimum dose needed to assure profound anesthesia.
- Always be mindful of the toxic effects of a local anesthetic. Even with low levels of vasoconstrictors (1 to 200,000 or 0.005 mg/mL), patients may experience a temporary tachycardia. If this occurs, the patient should be assured that it is a normal temporary condition and is not a cause for alarm.
- Always remember to remove the guide sleeve before releasing the patient.
- The perforators, guide sleeves, and needles must be disposed of in appropriate sharps containers.

Intrapulpal injection

The intrapulpal injection provides immediate pulpal anesthesia through local action of the drug on the pulp and the application of pressure during administration. This method of anesthetizing an inflamed pulp that is resistant to block anesthesia is quick and effective but requires accurate skills in needle placement and quick administration of the anesthetic.

The growing popularity of the IO route for local anesthetic has made the intrapulpal injection become the injection of last resort. There is great potential for pain in the deposition of the solution if the operator is not straightforward in negotiating the pulp chamber or canal proper and in creating back-pressure with the needle as the solution is being expressed. Therefore, this injection process

requires the doctor to explain that the injection will be painful but immediately effective and that anesthesia and pain relief will occur the instant the pain is perceived. The requirement here is that the doctor lives up to that description to maintain patient trust and confidence.

Caution

- The intrapulpal injection should be reserved for those teeth deemed hot by the clinician after all supplemental injections have been utilized.
- Despite the intrapulpal injection being a proven and effective method, it may not have the efficacy required unless the regional block has been administered correctly and the patient demonstrates the associated clinical signs.
- Occasionally, the use of a small round bur to quickly penetrate the pulp chamber is necessary to introduce the needle.
- A 30-gauge needle is most effective for penetration, and strong back-pressure on the syringe must accompany the needle's advance deep into the chamber or canal to accomplish the desired outcome (Fig 14-5).

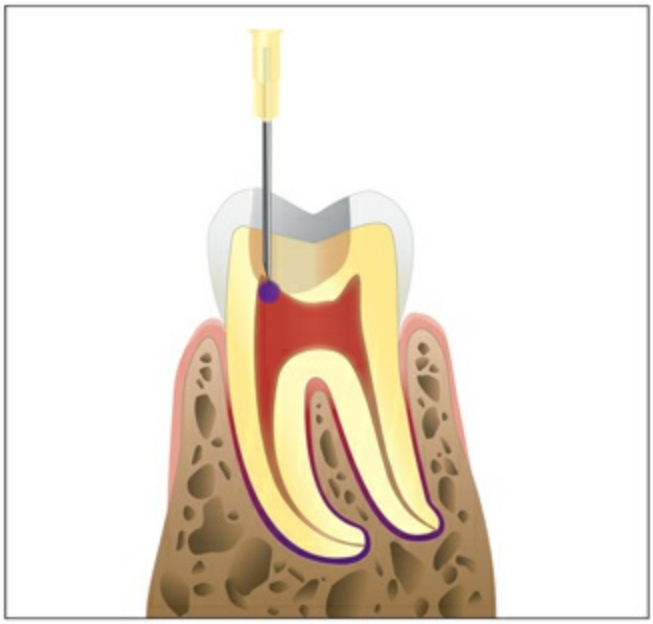


Fig 14-5 An intrapulpal injection requires that a small needle be expertly placed and be directed down into the chamber as the clinician quickly advances the solution into the pulpal tissues.

Injection for hot teeth

The clinician's reputation will rise or fall in the patient's judgment with the successful administration of a local anesthetic for a hot tooth. No other area of emergency dentistry carries so much risk of falling short of the mark. The best way to achieve profound anesthesia for the hot tooth is to:

- Use multiple injection techniques.
- Administer each technique competently and effectively.

• Administer intraligamentary (PDL) injections after infiltration or block anesthesia.
• Administer a follow-up IO injection if profound anesthesia is still elusive.
• The final administration of an intrapulpal injection always provides profound anesthesia.

NERVE INJURY ASSOCIATED WITH ANESTHETIC ADMINISTRATION

There are an increasing number of clinical reports in the literature that describe the sequelae to injury from the administration of a local anesthetic. The permanent alteration of sensation after a nerve block can be very distressing for both patient and doctor and often results in litigation. Permanent nerve damage after receiving a nerve block, though very rare, is nevertheless a clinical reality. The majority of these reports involve the inferior alveolar nerve or its lingual branch or both. The lingual nerve is involved almost four times more than is the inferior alveolar nerve as an outcome of injury in a mandibular block. Often these complications get confused with an endodontic or surgical procedure, but evidence shows all dental procedures can result in this outcome, hence these reports focus on the injection itself. Knowledge of the risks and complications of local anesthetic administration is crucial for a clinician to understand as there is no known prevention or treatment for these injuries. A number of hypotheses linked to the etiology of permanent nerve damage caused by injection are presented below.

Direct trauma to the nerve by the needle

It is commonly observed that patients can experience an "electric shock" when local anesthetic is administered in an IANB. However, while this is universally understood to mean the needle has engaged the nerve directly, there is no correlation between this event and damage to the nerve. Researchers have reported an approximately 3% occurrence of this electric shock phenomenon, yet the reported injuries of altered sensation are far less, and 80% of those injuries are fully resolved within 2 weeks. It is thus felt that it is highly unlikely that direct injury by the needle is responsible for permanent injury.

Intraneural hematoma

A more likely explanation for injury after injection centers on the possibility that the needle can create bleeding in one of the small blood vessels within the neural sheath. The subsequent hemorrhage causes compression degeneration to the fascicles within the nerve or a fibrosis that subsequently disrupts transmission. This type of event occurs very quickly, even before the patient's anesthesia has worn off and certainly before she or he might report any altered sensation to the doctor.

Toxicity of the local anesthetic

While some local anesthetics present more risks than others, most local anesthetics are considered neurotoxic. However, the potential damage of a local anesthetic is not a clinical expectation because of the way these drugs are used in conventional dental treatment. Neurotoxicity would require high concentrations of anesthetic within the nerve fascicles, and this does not occur clinically. The answer may lie with an individual's metabolism of the drug producing destructive byproducts of breakdown, or the likelihood that some anesthetics have a greater potential for neurotoxicity.

Epidemiology

Studies have suggested that the more concentrated, 4% solutions of prilocaine (Citanest [AstraZeneca]) and articaine (Septocaine [Septodont]) used in dentistry have a greater association with the occurrence of nerve injury. It is proposed that the higher concentrations—not the drugs themselves—actually produce this risk. Permanent lingual paresthesia involving the tongue is especially incapacitating for patients and occurs in the highest percentages. Therefore, based on the available epidemiologic evidence, it is difficult to support the decision to use prilocaine or articaine in the administration of an IANB.

Procedural problems

Dentists must always take into account the risks and benefits of all therapeutic treatments they render. In administering local anesthetics, care should be given to the rate of administration. In addition, aspiration must accompany administration. The risks versus benefits of using any drug for a dental procedure must be well understood, and the response to any allergic or anaphylactic episode must be clear to everyone in attendance at all times.

LESSON 15

Guidelines for Rubber Dam Use

OBJECTIVE

To isolate a tooth (or teeth) from oral contaminants and prevent patients from inhaling or swallowing an endodontic instrument, material, or debris.

INTRODUCTION

The Law

Choosing not to use rubber dam in endodontics is a departure from the accepted standard of care. If a patient takes legal action with regard to a root canal treatment and rubber dam was not used during the procedure(s), the doctor has little to no defense in a court of law. In the eyes of a jury, it suggests "a pattern of negligence."

Benefits

Well-applied rubber dam provides:

- Unobstructed access.
- Improved visibility: Prevents mirror fogging and resists (retracts) intra- and extraoral soft tissue forces (eg, tongue, cheeks, lips, mucosa, and gingiva).

- Improved operating efficiency: Provides a clean dry operating field.
- Infection control: Inhibits intraoral contamination.
- Patient protection: Prevents inhaling, aspirating, or swallowing an instrument, irrigation solution, medicament, or filling material; protects the eyes and nostrils from flying debris during access.
- Time management: Minimizes patient conversation and frequent mouth rinsing.

Purpose of this lesson

- *Training*. A high percentage of endodontists have shifted the application and removal of rubber dam to their dental assistants. The first section has been designed to provide a step-by-step teaching tool for those doctors who would like to transfer the routine application of rubber dam to their assistants.
- *Dealing with atypical situations*. Unfortunately, patients often present with deteriorated clinical conditions that present atypical rubber dam challenges that demand the doctor's attention. To apply rubber dam to a tooth that has lost extensive tooth structure as a result of caries, trauma, and/or aggressive operative procedures calls for skill and ingenuity. The second section responds to those situations on a case-by-case-basis by offering rubber dam application options and solutions.

TRAINING FOR THE DENTAL ASSISTANT

Rubber dam equipment

Rubber dam material

- Choose powderfree light-colored material that reflects light and illuminates the field.
- Ask the patient about a latex allergy.
- For safety, select a 5-in medium (for general use) or 6-in heavy (for lip/cheek retraction) rubber or nonallergenic latex dam material.

Rubber dam punch

- ARDP (HuFriedy)
- To prevent leaks and tears, the hole punch must be sharp enough to cut a clean tag-free edge.
- The hole punch and hole edge can be sharpened with small finishing stones.

Rubber dam forceps

- ARDF (Hu Friedy)

Plastic rubber dam frames

- Nygaard-Osby and Young frames are user friendly, curved to fit the face, comfortable, and radiolucent, which helps prevent metallic overlap.
- Flexible (Handidam [Aseptico], Quickdam [Ivoclar Vivadent]) and collapsible frames are also available.

Rubber dam anchorage

For clamp selection:

- Target tooth size and the amount of remaining coronal tooth structure dictate clamp choice.
- Bow and winged clamps provide greater retraction of the tongue, cheeks, and lips.
- Limited tooth structure may require apically directed jaws and large wings. Examples of clamps (Fig 15-1) are listed below; the most commonly used clamps are marked by an asterisk:
  - For anterior teeth: Nos. 9*, 0, 00, 2, 2A, 211*, 212*
  - For premolars: Nos. 2*, 2A*, 8A, 212*, 209*
  - For maxillary molars: Nos. 14*, 14A* 3, 4, 13A
  - For mandibular molars: Nos. 7*, 14*, 56*, S-G*, 12, 13, 14A

Supplemental aids and techniques

1. Use dental floss (preferably waxed) to guide the rubber through the contact points. Once through a contact point, remove the floss to the labial.
2. To prevent suspected cuff leakage, pass the floss through the contact point on one side of the tooth, and return it under the contact point on the opposite side. Join the two ends at the labial surface, pull tight, and tie around the neck of the tooth.
3. You can also use floss in a similar fashion to provide anchorage when a clamp might chip a ceramic crown or veneer margin or cause an irreversible gingival recession:
   - OraSeal (Ultradent Products) is a paste material that helps seal leaking dam margins.
   - Wedges (V-wedge and Wave Wedge [TrioDent]) lock rubber dam in place when forced below the contact points of approximating teeth.
   - Endodontic nonabsorbable facial tissue prevents skin irritation and has centered nasal cutouts.

Rubber dam preparation

1. Select premarked rubber dam (appropriate size and thickness) with a simple-to-use and accurately spaced dental dam template (see Fig 15-1). Though premarked ink stamps may be purchased, a marking pen may be used to sketch a normal dental arch curve (spaced within normal tooth limits on the arch) and to highlight the target tooth (or teeth) to be isolated.
2. Center the incisor marks in the dam at least 2 in from the bottom and lateral border, and progressively mark the remaining incisors, canines, and posterior tooth by following along the arch

curvature.

3. Base the size of the hole punch on the width and arch location of the tooth (or teeth) to be isolated.
   - For single-tooth isolation, one hole is punched in the appropriate target tooth location on the template (or the penned mark).
   - For multiple-tooth isolation, the size of each hole must account for the width and position (location on the scribed arch) of each tooth to be isolated.
   - Appropriate space must be accounted for when an edentulous area is to be included in the isolation field.
4. Bow and wing clamp(s) should not only accommodate the size of the tooth to be clamped but also have flanges that are sharp enough to tightly grip the existing tooth structure at the cementoenamel junction (CEJ).
5. For comfort, the patient's face should be covered with the special soft endodontic facial tissue.

Fig 15-1 A premarked rubber dam template (Roeko) displaying the position and spacing of the teeth in both arches serves as a guide for punching the correct holes in the dam. A selection of appropriate rubber dam clamps accompanies the template.

Rubber dam placement

Rubber dam placement depends on the condition and size of the target tooth to be treated and the number of teeth to be isolated. There are a number of ways to apply rubber dam, and each method has its advantages and disadvantages. At times, ingenuity may be required to accommodate abnormal situations (eg, malpositioned irregularities within the arch, edentulous areas, and patient management problems such as apprehension, anxiety, fear, claustrophobia, asthma, bronchitis, and other respiratory inadequacies). The most popular and efficient application methods are presented next.

Method A: Uncompromised single-tooth isolation

Technique

1. Select an appropriately sized clamp. Though some clamps are designed for single isolation, any clamp that fits well (trial test if unsure) may be used (Fig 15-2a).
2. Stretch the dam material over the rubber dam frame and attach it at the sides and corners (Fig 15-2b).
3. Slide the appropriately sized rubber dam and punch hole for the tooth to be clamped over the bow (bow to the distal) and flanges of the clamp.
4. Grasp the clamp (bow to the distal) with the forceps, and force apart the clamp wings.
5. While grasping the widened clamp with the forceps, carry the entire assembly to the mouth, and slide the expanded clamp over (bow to the distal) and onto (below the height of contour) the target tooth (Fig 15-2c).
6. Once the clamp has been seated at the height of contour at the CEJ, release the spreading force, remove the forceps, and finger test the clamp for anchorage.
7. Adjust the dam material on the frame.
8. Gently slide the dam material off and under the clamp wings with a finger or a flat-bladed composite plastic instrument (Fig 15-3a).
9. Use dental floss to guide dam material through the lateral interproximal contact points (Fig 15-3b). If leakage is suspected, tie the dental floss around the neck of the tooth (see Supplemental aids and techniques).
10. Tighten the entire assembly in place (Fig 15-3c), and swab dam material approximating the tooth to be treated with a cotton tip saturated with a surface disinfectant (eg, chlorhexidine gluconate or a sodium hypochlorite solution).
11. Place the saliva ejector in the mouth under the dam (never through a hole in the dam).

Fig 15-2 Preparation of the rubber dam using Method A. *(a)* Choose an appropriate size and thickness of rubber dam, a clamp, and a nonabsorbable facial napkin. *(b)* Spread and attach the dam material to a plastic frame, and punch an appropriate-sized hole in the position of the target tooth. *(c)* Attach the clamp to the dam material (bow to the distal and rubber over the wings). Grasp the clamp with the forceps, and carry the entire assembly to the target tooth. The clamp is seated to the cervical margin.

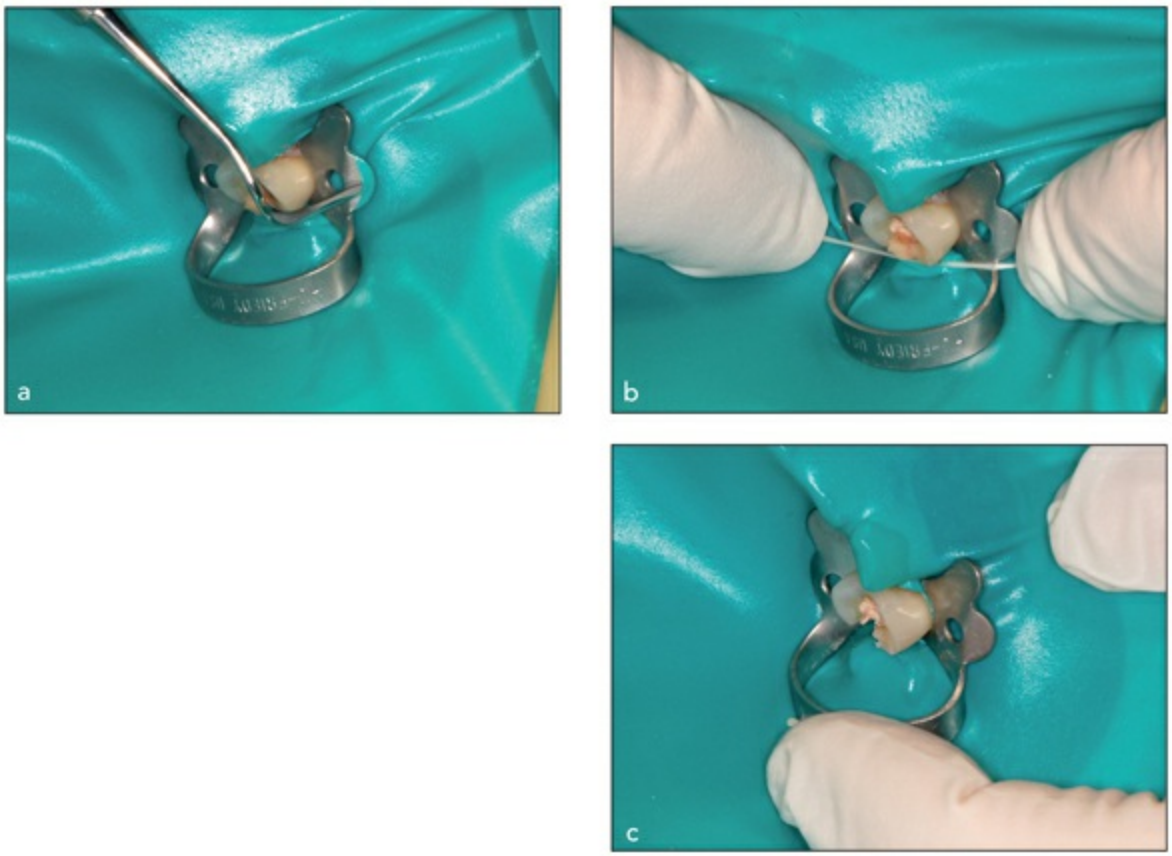


Fig 15-3 Application of the dam-frame assembly. *(a)* Once the clamp has been seated on the target tooth, free the wings of rubber dam material with a tarno instrument. *(b)* Force the dam material through the contact points with waxed dental floss. *(c)* Finger test the dam for stability.

Advantage

The entire assembly is carried to the tooth and clamped in one movement, making the process fast (Fig 15-4).

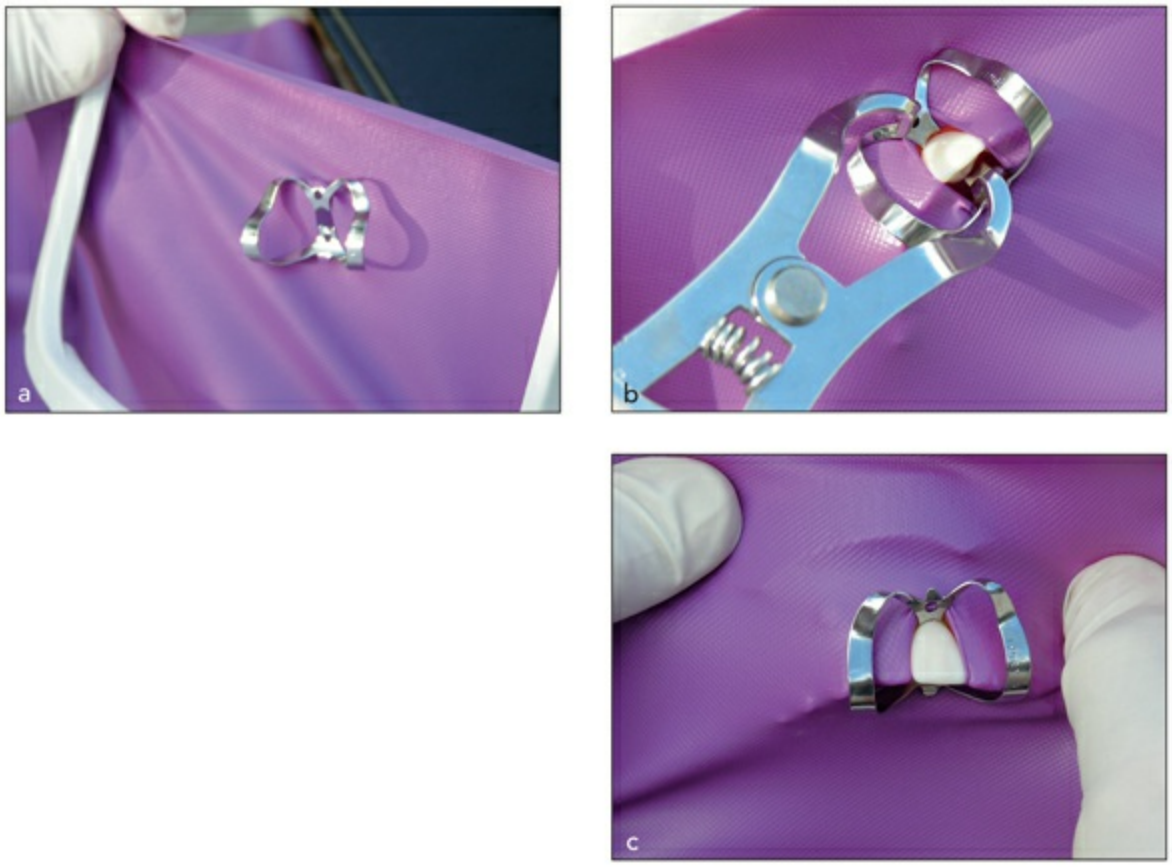


Fig 15-4 Single-tooth isolation using a No. 9 butterfly clamp on an anterior tooth. *(a)* Place clamp wings through the punched hole, and attach the frame to the dam material. *(b)* Engage the clamp with rubber dam forceps, and place the entire assemblage over the tooth and seated to cervical margin. *(c)* Stretch rubber dam material under the wings to create a tight seal.

Disadvantage

Dam assembly obstructs the dentist's or assistant's view while placing the clamp, making it easier to clamp the wrong tooth. To avoid such an incident, it is wise to premark the target tooth with an indelible pencil prior to seating the clamp.

Method B: Alternative for uncompromised single-tooth isolation

Technique

1. Select an appropriately sized clamp; any clamp that fits well (trial test if unsure) may be used.
2. Grasp the clamp (bow to the distal) with the forceps, and force apart the clamp wings.
3. Carry the clamp to the mouth in the forceps, and slip it over and onto the target tooth (bow to the distal).
4. Once the clamp is seated below the height of contour at the CEJ, release the spreading force of the forceps, and remove the forceps. Test for anchorage.
5. Punch an appropriately sized hole in the template (pen mark) for the tooth to be isolated.
6. Stretch the punched dam material over the rubber dam frame and attach it to the four corners of the frame.

7. Carry the assembly (dam and frame) to the mouth, and finger stretch the hole in the dam over the bow and flanges (Fig 15-5). Test for anchorage.
8. Use dental floss to guide the dam material through the interproximal contact points.
9. Tighten the entire assembly in place and check for leakage. If leakage is suspected, see Supplemental aids and techniques.
10. Swab dam material approximating the tooth to be treated with a cotton tip saturated with a surface disinfectant (eg, chlorhexidine or a sodium hypochlorite solution).
11. Place the saliva ejector in the mouth under the dam (never through a hole in the dam).

Fig 15-5 After seating the dam clamp on the tooth, affix rubber dam to the frame holder and stretch the punched hole over the bow of the clamp to be placed under the wings.

Advantage

Visibility is unobstructed during clamp placement, thereby assuring the correct target tooth is clamped.

Disadvantage

Stretching the dam hole over the bow and wings of a clamp can be awkward, and the force required to do so lends itself to tearing the dam material and/or pulling the clamp off the tooth.

Method C: Uncompromised multiple-tooth isolation

Technique

1. Punch an appropriately sized hole for the target tooth and at least one tooth anterior and posterior to the target tooth (more if necessary) in the dam template.
2. Select a clamp for a tooth that is posterior to the target tooth.
3. Grasp the clamp (bow to the distal) with the forceps, and force apart the clamp wings.
4. Carry the clamp to the mouth in the forceps, and slip it over and onto the target tooth (bow to the distal).
5. Once the clamp is seated below the height of contour at the CEJ, release the spreading force of the forceps, and remove the forceps.

6. Test for anchorage.
7. Stretch the punched dam material over the rubber dam frame, and attach it to the four corners of the frame.
8. Carry the assembly (dam material and frame) to the mouth, and finger stretch the hole for the most posterior tooth over the bow, tucking it under the wings of the clamp with a flat-bladed composite plastic instrument.
9. Individually stretch the remaining anterior holes over and onto the other teeth to be isolated (posterior to anterior), and use dental floss to guide the dam material through the interproximal contact points (Figs 15-6 and 15-7).
10. Tighten the entire assembly in place, and check for leakage. If leakage is suspected, use wax dental floss, OraSeal, or wedges (see Supplemental aids and techniques).
11. Swab the dam material with a cotton tip saturated with a surface disinfectant (eg, chlorhexidine gluconate or a sodium hypochlorite solution).
12. Place the saliva ejector in the mouth under the dam.

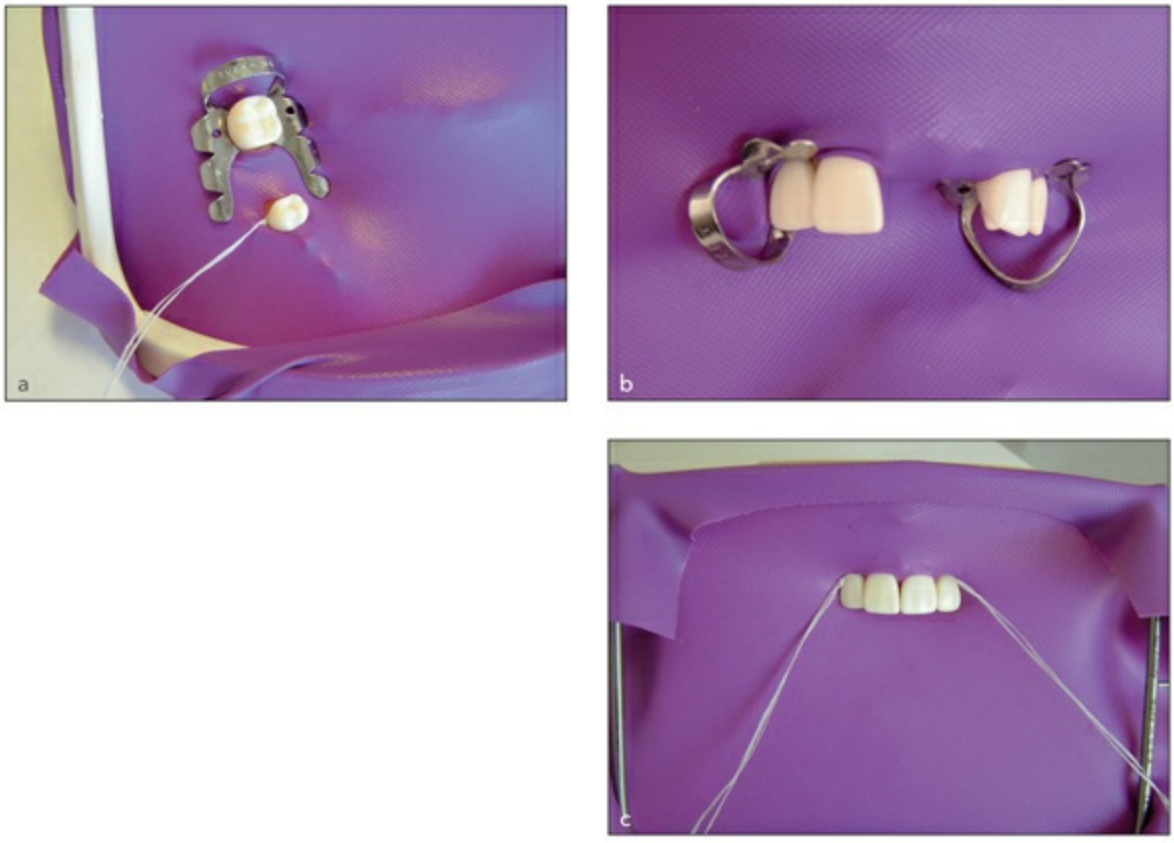


Fig 15-6 *(a and b)* Variations on multiple-tooth isolation around edentulous gaps. These variations use adjacent teeth and dental floss for anchorage of the dam material. *(c)* Dental floss anchorage used alone to protect the margins of ceramic crowns from clasp damage. Additional leakage protection may be necessary.

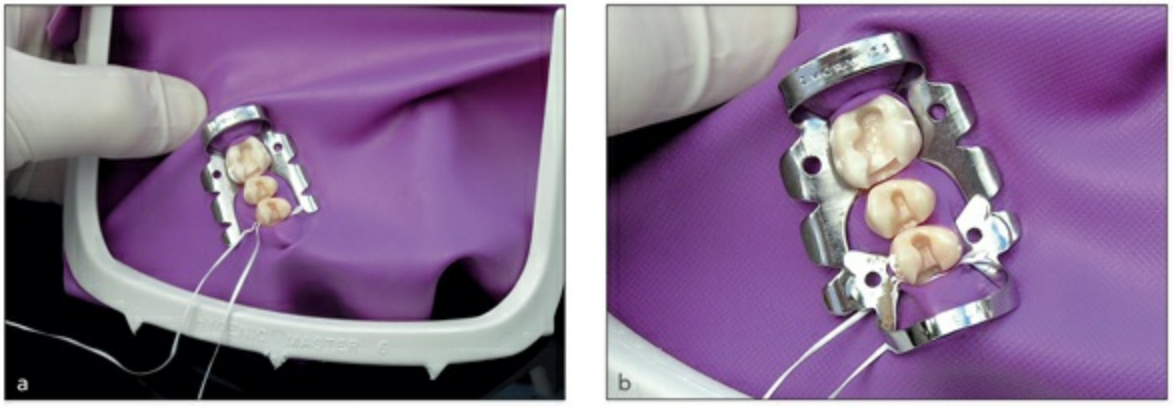


Fig 15-7 Options for multiple-tooth isolation. *(a)* Three-tooth isolation with the anterior tooth tied off with floss. *(b)* Same scenario using a rubber dam clamp placed backwards to hold the dam in place and to provide access to all three teeth.

Advantage

Though similar to Method B in isolating multiple teeth, Method C is also simple and direct.

Disadvantage

Slipping the dam hole over the clamp can be awkward, and the force required to spread the dam material over the clamp lends itself to tearing the dam material and/or pulling the clamp off the tooth.

Rubber dam removal

More care should be given to the removal of rubber dam than was given to its application. It is during removal that the patient, doctor, and assistant are most vulnerable to being sprayed with contaminants such as saliva, irrigation solution, and debris from the pulp chamber and canal. The following technique is advised:

1. Disinfect the dam and remove the saliva ejector.
2. Cut the interproximal dam material with scissors.
3. Free the cut tags from between the teeth.
4. Detach the dam from the frame.
5. Fully cover the collapsed rubber dam with facial tissues.
6. Gently wrap rubber dam and the underlying protective endodontic facial tissue into a tight ball.
7. Remove the ball from the face while simultaneously covering the patient's mouth with clean facial tissue.
8. Either personally clean the patient's face with the fresh tissue(s), or give the tissue(s) to the patient to do so.
9. Place the rubber dam material, a non-sharps waste, in a biohazard bag.

ATYPICAL RUBBER DAM CHALLENGES AND SOLUTIONS

Alternatives for compromised situations that must be managed on a case-by-case basis.

Case 1: Posterior tooth with insufficient coronal tooth structure

The target tooth is the last posterior tooth in the maxillary or mandibular arch and has insufficient coronal tooth structure to routinely grasp.

Option a

1. Select and test grasp the tooth with a clamp that has apically directed wings such as a No. 14A.
2. Test to assure anchorage by attempting to remove the clamp with finger pressure:
   - If successfully anchored, move to steps 2 to 11 in Method B for dam placement completion.
   - If unsuccessful, move to Option b or c.

Option b

1. Select a No. 14 or No. 14A clamp, and seat it directly into the anesthetized gingival tissues at least 2 to 4 mm apical to the crestal gingival margin.
2. Test to assure anchorage by attempting to remove the clamp with finger pressure:
   - If successfully anchored, move to steps 2 to 11 in Method B for dam placement completion.
   - If unsuccessful, move to Option c.

Option c

1. Electrosurgically (or with a laser) remove the crestal gingival tissue, and expose at least 2 to 4 mm of solid root surface.
2. Place a No. 14 or No. 14A clamp, and test to assure anchorage by attempting to remove the clamp with finger pressure:
   - If successfully anchored, move to steps 2 to 11 in Method B for dam placement completion.
   - If unsuccessful, move to Option d.

Option d

1. Semi-isolate the maxillary target tooth by placing cotton rolls in the buccal fold, or use a cotton roll–laden mouth retractor for a tooth in the mandible.
2. Remove all caries, and access and clear the pulp chamber of tissue. Place a cotton ball moistened with sodium hypochlorite into the pulp chamber and over the canal orifices.
3. Build and secure (cure) a temporary resin core and crown (with a band or prefab crown), and test try a No. 14 or No. 14A clamp on the restoration.
4. If successfully anchored, move to steps 2 to 11 in Method B for dam placement completion and reaccess.

Case 2: Anterior tooth with insufficient coronal tooth structure and healthy adjacent teeth

The target tooth is an anterior tooth in the maxillary or mandibular arch that has insufficient coronal tooth structure to grasp but has approximating natural teeth that are in good clinical condition.

Option a

1. Select a No. 9 butterfly clamp.
2. Test the anchorage with finger pressure:
   - If successful, leave the clamp on, and move to the remaining steps 2 to 11 in Method B for dam placement completion (see Fig 15-4).
   - If unsuccessful, move to Option b.

Option b

1. Use a crown-lengthening procedure (electrosurgery, laser, and/or scalpel) to expose root structure.
2. Select and test grasp a No. 9 butterfly clamp to secure anchorage:
   - If successfully anchored, move to the remaining steps 2 to 11 in Method B for dam placement completion.
   - If unsuccessful, move to Option c.

Option c

1. Punch an appropriately sized hole positioned for the target tooth and a hole for the most adjacent teeth (mesial and distal) to the target tooth. (You may use one or two on each side of the target tooth).
2. Select and test a No. 209 clamp for anchorage on the tooth adjacent and posterior to the target tooth.
3. Remove the clamp once tested, and attach rubber dam and the clamp (bow to the distal) to the frame as described in Method A.
4. Carry the assembly to the mouth, and seat the clamp (bow to the distal) on the selected tooth to be clamped.
5. Slip the dam material off the wings of the clamp, stretch the dam material across the target tooth, and slip the most anterior hole(s) over the tooth (teeth) anterior to the target tooth.
6. Use floss to pass the dam material through the distal contact points of the adjacent teeth.
7. If contact between the unclamped tooth and its adjacent tooth is not tight, force wedges between the two teeth to help lock the dam in place.
8. Cut the intervening tags of the dam between the two anchored adjacent teeth, leaving only a slit or split between the two anchored teeth. (This technique is often referred to as the *split dam* or *slit*

technique.)

9. Treatment access, instrumentation, and obturation are done through the slit.

   Note: If no adjacent tooth directly anterior to the target tooth is available (edentulous space), select the closest anterior tooth that is sound and increase the size of the hole for the target tooth.

10. Stretch the dam across the span to the nearest tooth anterior to the target tooth, and choose and place another clamp (with its bow distal) on that anterior tooth.
11. Follow the slit technique as previously explained (see Fig 15-5).

Case 3: Posterior tooth with insufficient coronal tooth structure and healthy adjacent teeth

The target tooth is a posterior tooth in the maxillary or mandibular arch that has insufficient coronal tooth structure to grasp but has approximating natural teeth that are in good clinical condition.

Option a

1. For mandibular molars, select and test an S-G clamp on the tooth adjacent and posterior to the target tooth (bow to the distal).
2. Punch a double-sized hole for the tooth to be clamped and one normal-sized hole for the tooth adjacent (anterior) to the damaged target tooth.
3. Slide the punch hole (double size) for the tooth to be clamped over the bow (bow to the distal) and flanges of the elongated S-G clamp.
4. Stretch the punched dam material and clamp over the dam frame where it is attached at the four corners.
5. Carry the entire assembly (dam material, clamp, and frame) to the mouth, and seat the clamp on the tooth that is posterior to the damaged target tooth.
6. Once seated, finger stretch the hole for the most posterior tooth off the bow, tucking it under the extended clamp wings with a flat-bladed composite plastic instrument.
7. Stretch the remaining hole over and onto the adjacent tooth anterior to the target tooth.
8. Use dental floss to guide the dam material through the interproximal contact points, and tie it at the neck.
9. If contact between the unclamped anterior tooth and its adjacent anterior tooth is not tight, force wedges between the teeth to lock the dam in place.
10. Tighten the entire assembly in place, and check for leakage. If leakage is suspected, use dental floss, OraSeal, or wedges.
11. For security purposes, clamp the adjacent anterior tooth (bow away from the target area).

    Note: For maxillary teeth, use the slit technique as described in Case 2.

Advantage

This modified slit technique easily isolates the target tooth.

Disadvantage

As with all slit techniques, the opened span does increase the potential of inhaling, aspirating, or swallowing an instrument, irrigation solution, or medicament.

Case 4: Target tooth with a dislodged crown

In this case, the target tooth was prepared for a crown, and the crown has been dislodged. Without a mid-crown height of contour, securely seating a clamp ranges from difficult to impossible.

Option a

1. Select and test grasp a clamp that has apically directed wings, and seat the wings into the gingival tissue, 2 to 4 mm apical to the crest (see Method B, Case 1, Option b):
   - If successfully anchored, leave it in place, and move to the remaining steps in Method B for dam placement completion.
   - If unsuccessful, move to Option b.

Option b

1. Cut a small trough in the cervical level of both the buccal and lingual surfaces of the crown core.
2. Select, seat, and test grasp an appropriately sized clamp that fits in the trough. To assure anchorage, try to remove the clamp with finger pressure:
   - If successfully anchored, leave it in place and move to the remaining steps in Method B for dam placement completion.
   - If the trough depth might threaten the pulp space, move to Option c.

Option c

1. Clean and dry the core surface, and bond and cure a small bar of composite on the buccal and lingual surfaces.
2. Select, seat, and test grasp an appropriately sized clamp under the bonded bar of composite.
3. To assure anchorage, try to remove the clamp with finger pressure:
   - If successfully anchored, leave it in place, and move to the remaining steps in Method B for dam placement completion.
   - If unsuccessful, move to Option d.

Option d

For maxillary or mandibular target teeth that cannot be grasped via Options a, b, or c but have approximating natural teeth that are in good clinical condition, the slit technique described in Case 2

is always a good option (see Fig 15-6).

Advantage

There is no doubt about one clamping the correct tooth, the target tooth and gingival tissues have been kept out of danger, visibility is unaffected, and the standard of care criteria have been met.

Disadvantage

The opening in the material does increase the potential of inhaling, aspirating or swallowing an instrument, irrigation solution, or medicament, and the material sometimes tears when stretching the dam hole over the clamps.

PART FOUR

Canal Instrumentation: Shaping, Disinfection, and Case Management

LESSON 16

Access Preparation and Orifice Identification

OBJECTIVE

To facilitate safe and efficient access of root canal systems prior to root canal preparation and to avoid serious mishaps that are sometimes associated with access cavity preparation.

Note: Remember tooth development.

INTRODUCTION

The morphologic foundation for endodontic access cavities is that, during tooth development, the mineralized structures of dentin and enamel are laid down around soft tissues that later become the dental pulp. This means that the pulp space normally resembles a smaller version of the shape of the tooth as it is seen in the mouth—including the pulp horns located beneath the cusps, for example. This relationship is very helpful for the clinician attempting to gain access to the pulp. Fig 16-1 shows this relationship with cross sections showing virtual mirror images between outer enamel and dentin compared to the pulp space. Therefore, all roots must incorporate at least one root canal, however small the canals may be. The following factors must be taken into consideration before undertaking access preparation:

- Orientation of the long axis of the tooth
- Size of the pulp chamber; length of the roots
- Number and location of expected root canals

- Degree of mineralization, which is related to the age of the patient and to the size of caries and/or restorations
- Esthetics
- Fracture resistance
- Visibility
- Distance to furcation
- Root invaginations below the cervical line

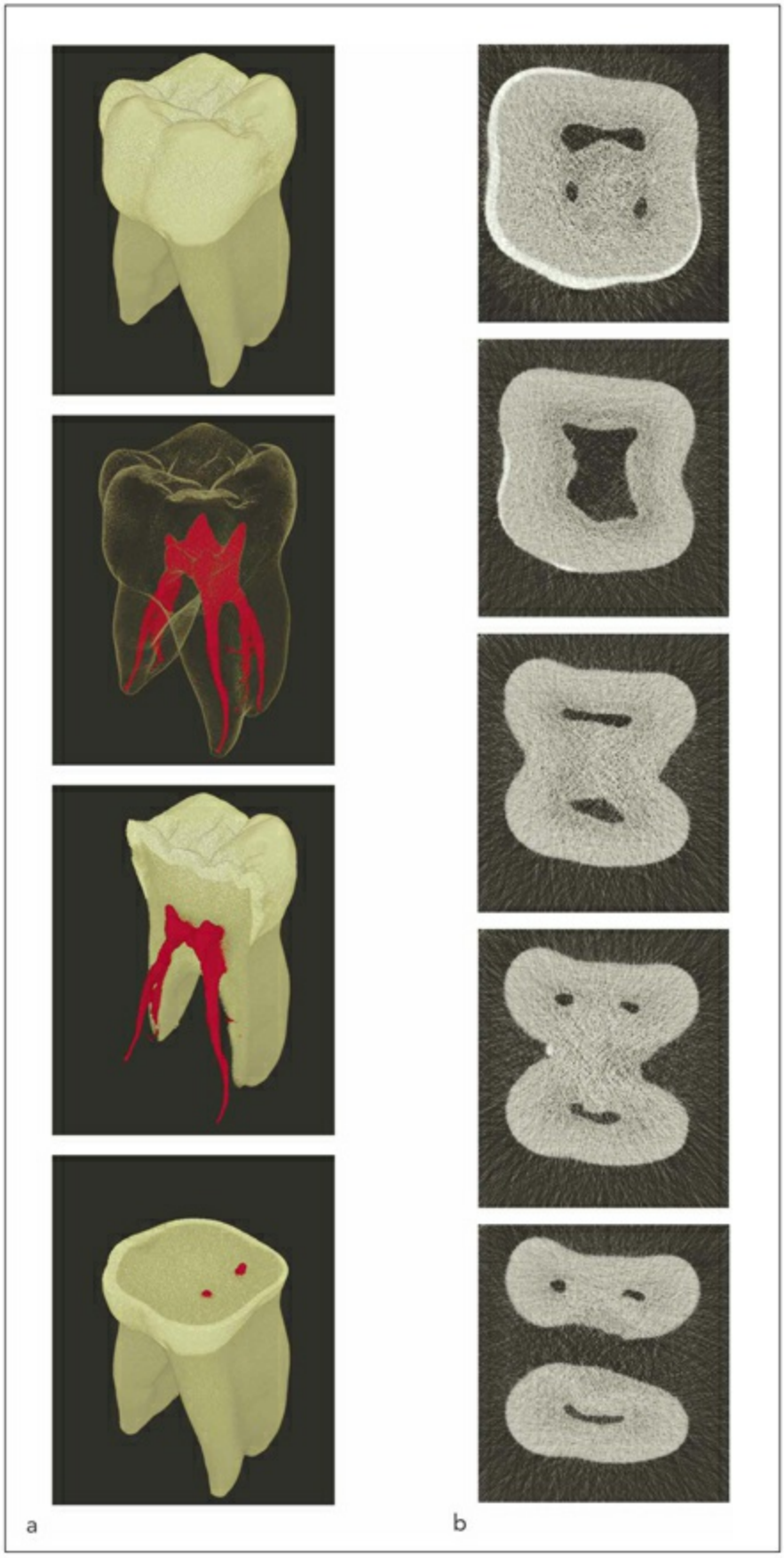


Fig 16-1 Relationship between outer root contours and the pulp space demonstrated using microcomputed tomography. *(a)* Three-dimensional reconstructions of a mandibular molar. *(b)* Cross sections of the same tooth at various root canal levels.

ACCESS CAVITY PREPARATION

Considerations

Conceptually, one has to decide how large the access to the pulp space is going to be. During access, underpreparation does not allow root canal instruments to negotiate into the root canals directly and in a straight line. This makes subsequent preparation more difficult and in fact promotes preparation errors such as stripping and perforation, particularly in curved canals (see lesson 21).

In contrast, overpreparation, while exposing all canals, easily weakens the tooth structure and possibly results in fracture. It is structural weakening more than changes in dentin composition that renders a root canal–treated tooth more prone to fracture.

The next step, finding the pulp space while drilling, poses another dilemma: Where will the pulp chamber be? The pulp is often small, particularly for a tooth with a crown or large restoration. If the direction of entry is off axis, a perforation into the furcation can readily occur. In maxillary anterior teeth, a perforation into the sulcus or below the crestal bone can also arise if the bur direction has an incorrect angulation (Fig 16-2).

Another principal complication is that restorative material may need to be removed to gain access. Standard carbide and diamond burs readily cut enamel and dentin, but non-precious alloys used in crowns are much harder to remove.

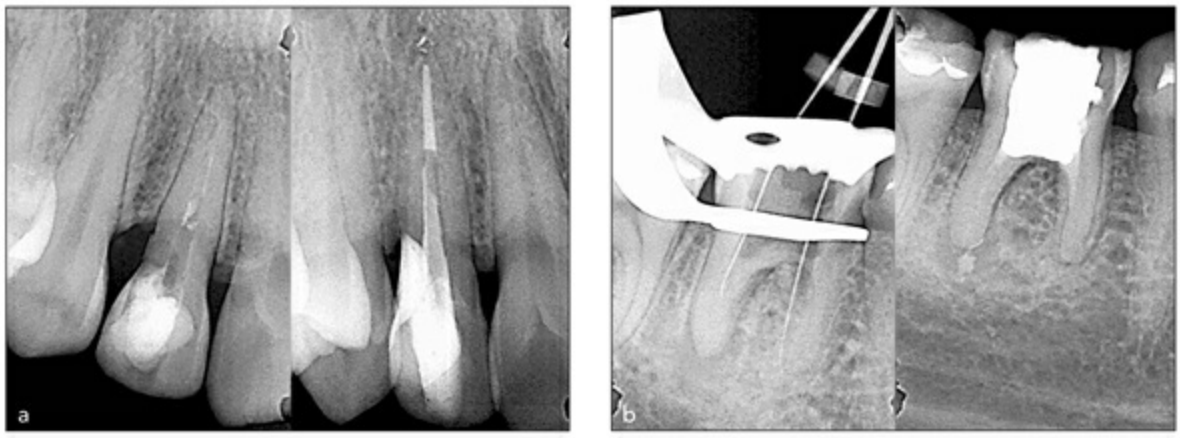


Fig 16-2 Examples of perforations during access. (a) Perforation of a maxillary incisor directed to the buccal periodontal ligament. Repair was done using Geristore (Den-Mat), and root canal treatment was completed. (b) Perforation into the furcation of amandibular molar. This tooth was temporized with glass ionomer cement and scheduled for extraction. (Images courtesy of Dr Tony Vera, San Leandro, CA.)

Guidelines and tips

Access cavity preparation consists of:

1. Analyzing pulp chamber anatomy
2. Penetrating overlying hard structures
3. Enlarging the opening-the unroofing
4. Refining and flaring the cavity outline

5. Demonstrating all root canal openings

Analyzing pulp chamber anatomy

The first step in access preparation is to use all diagnostic means necessary to understand pulp chamber anatomy for a specific case. Diagnostic radiographs are very helpful to get a picture of pulp size and location. Oftentimes a bitewing radiograph is used in addition to periapical films, since it is metrically a more accurate representation of the pulpal position within the tooth (Fig 16-3). The amount and thickness of overlying enamel and dentin can be measured directly from a bitewing radiograph by holding a periodontal probe to the film.

Next, the clinical presentation is examined to evaluate the position of the tooth in question: Is it tilted or rotated, or has the gingival margin receded? This assessment is best done before rubber dam placement; in fact, some clinicians even recommend that the entire access preparation be done before rubber dam placement to make sure that there is no gross alignment error.

Is the tooth in question restored with a crown or another restoration? Are the margins clinically acceptable? Accessing through a crown poses special problems since one cannot know for sure what lies underneath. This is true for restorative materials as well as for the original position of the tooth before crown preparation. In any case, it is recommended that you go around the gingival margin of a tooth or its crown with a periodontal probe to get a feel for the circumferential outline of the root, including potential undercuts or rapidly tapering root trunks.

If there are defective margins or caries, it is preferable to remove the crown and place a temporary restoration. Similarly, a defective existing amalgam or composite filling should be removed, all caries excavated, and the tooth restored to allow rubber dam placement.

A main element for diagnostics before root canal access is to understand the number and position of roots and root canals that are expected for any tooth. As stated before, hard tissue is deposited around the developing pulp. Table 16-1 shows typical canal numbers and root lengths.

For esthetic reasons, anterior teeth and canines are usually accessed from the lingual aspect and premolars and molars from the occlusal aspect. Individual teeth vary anatomically, but the following principles of access apply for all.

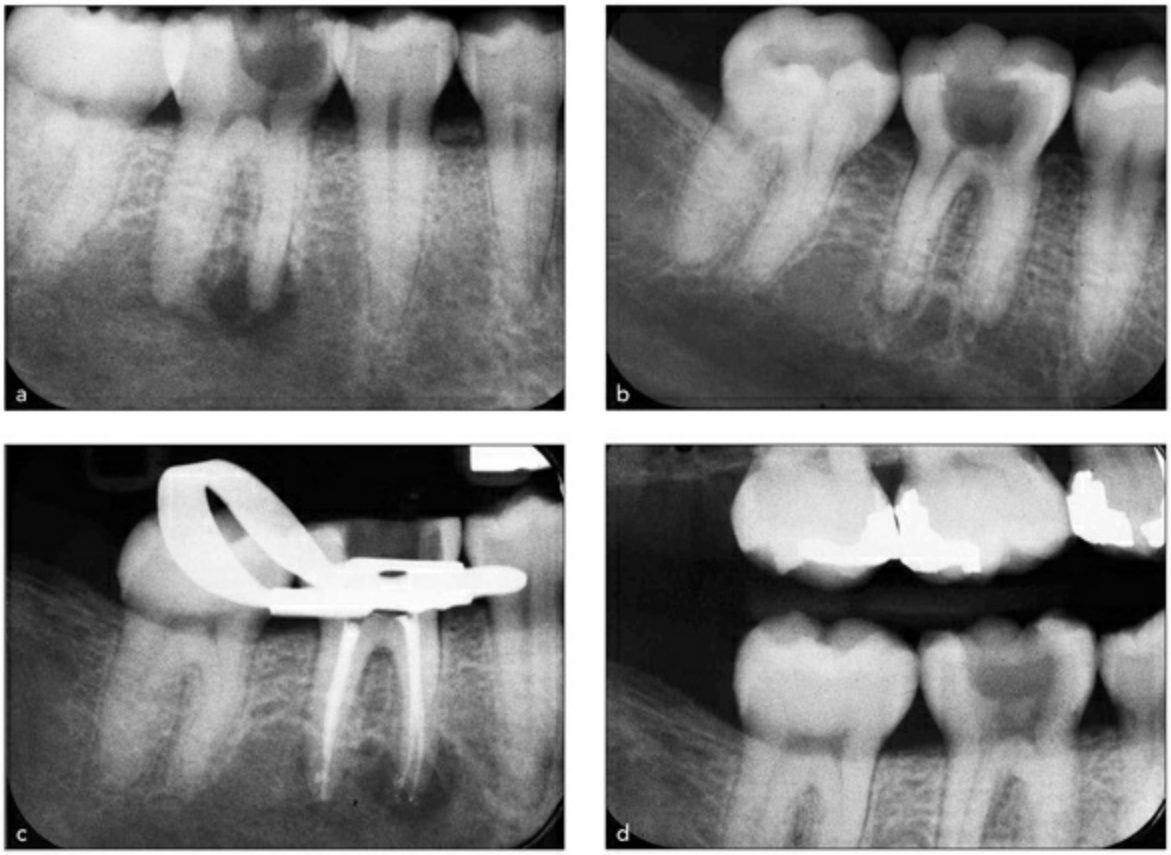


Fig 16-3 Typical radiographs taken before accessing a mandibular molar: three periapical films *(a to c)* and one bitewing radiograph *(d)*. Holding a periodontal probe against the bitewing radiograph allows for a direct estimation of the depth of entry.

Table 16-1 **Overview of canal configurations and average canal lengths**

	Number of canals			Lengths in mm
Teeth	Usual	Variations (1% to 40%)	Unusual	Average (min/max)
Maxillary				
Central incisors	1	–	2, 3; abnormal crown shapes possible	22.0 (18.0/29.0)
Lateral incisors	1	–	2, 3; abnormal crown shapes possible	23.0 (18.5/29.5)
Canines	1	–	2	26.5 (20.0/33.5)
First premolars	2	1	3	21.5 (17.0/25.5)
Second				

premolars	1	2	–	21.5 (17.0/26.0)
First molars	4	–	5, 6	21.5 (18.0/25.5)
Second molars	3	4	5, 6	22.0 (17.5/27.0)
Third molars	3	Multiple	–	–
Mandibular				
Central incisors	1	2	–	22.0 (17.0/28.0)
Lateral incisors	1	2	–	22.0 (17.0/28.0)
Canines	1	2	–	23.0 (20.0/25.0)
First premolars	1	2	3	22.0 (17.0/26.5)
Second premolars	1	2	–	22.5 (17.5/27.5)
First molars	4	3	5, 6	22.0 (19.0/27.0)
Second molars	3	4	1; C-shaped canal possible	22.5 (19.0/26.0)
Third molars	3	Multiple	–	–

Penetrating overlying hard structures

Since accessing the pulp space is obviously not reversible, it is useful to follow a checklist to prevent serious errors from occurring, in particular when rubber dam has been placed:

- Is it the right tooth?
- Does the restoration need to be replaced?
- What do we expect to find: Pulp space? With or without blood in it?
- What is the expected distance to the pulp space?

Figure 16-4 identifies typical access cavity shapes and the most common localizations of canal orifices. For maxillary and mandibular incisors as well as for canines, access is typically done from the lingual, aiming right into the middle of the occlusal surface. Remember that maxillary anterior teeth stand somewhat protruded (Fig 16-5) in the arch, similar to the slight lingual tilt of the mandibular molar crowns.

For posterior teeth, access is typically started in the middle of the occlusal surface, with the bur directed toward the expected greatest pulp volume. For example, in maxillary molars, the mesiobuccal pulp horn is usually the tallest, but the palatal one is the largest. Therefore, the bur is

positioned in the main occlusal pit and directed slightly toward the palatal. Figure 16-6 demonstrates the access entry angle to a mandibular molar in which the distal canal has the largest volume.

It is best to begin with a smaller version of the final access cavity and progress into the enamel and dentin. As soon as an opening into the pulp is felt or seen, switch to a bur that is not end-cutting.

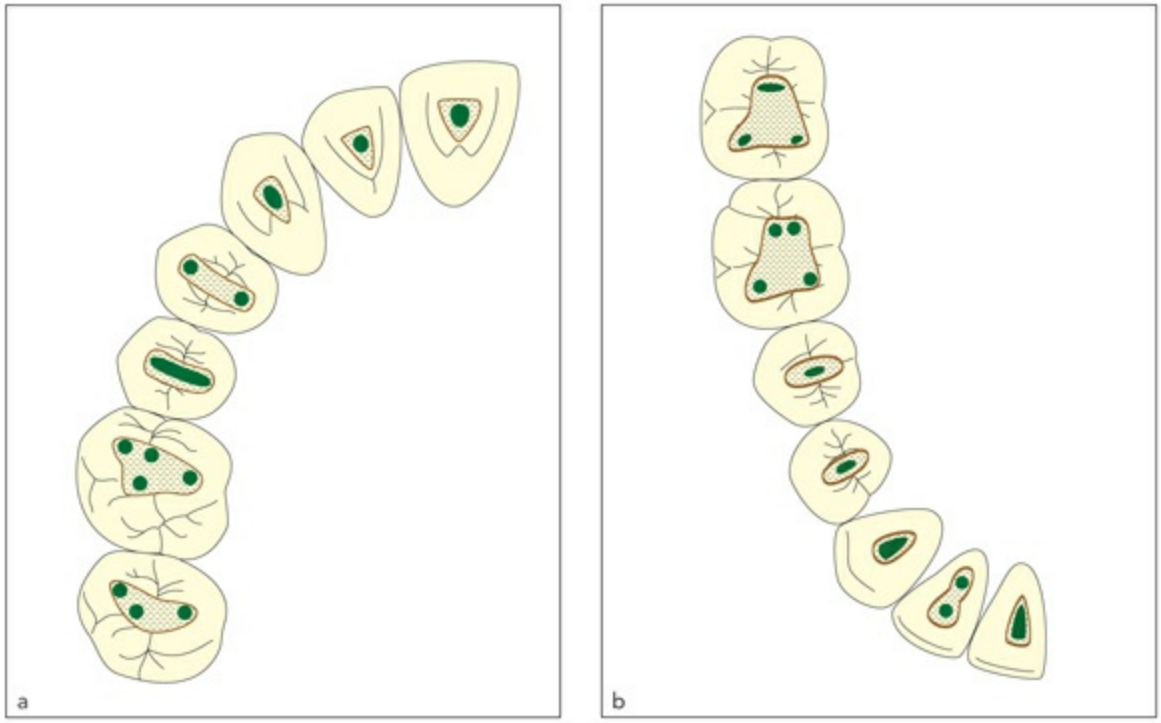


Fig 16-4 Schematics demonstrating the number and arrangement of root canal positions in relation to the occlusal table. *(a)* Maxillary arch. *(b)* Mandibular arch.

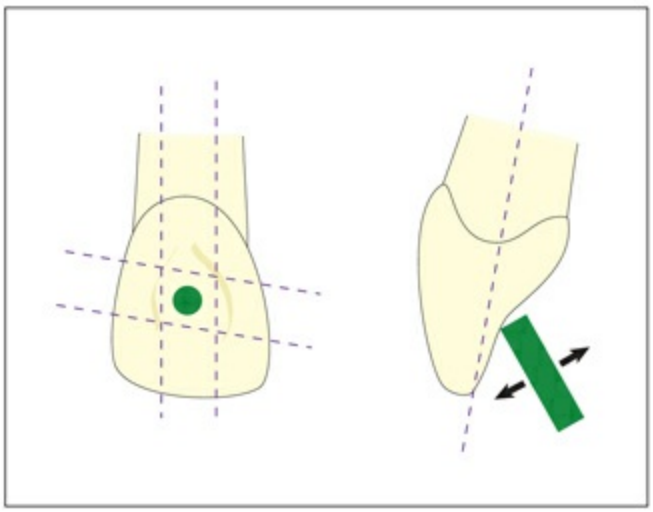


Fig 16-5 Schematic demonstrating the penetration into the pulp chamber of a maxillary incisor. Note the angulation of the bur to the lingual surface. This angulation needs to be carefully assessed to avoid perforation toward the facial aspect.

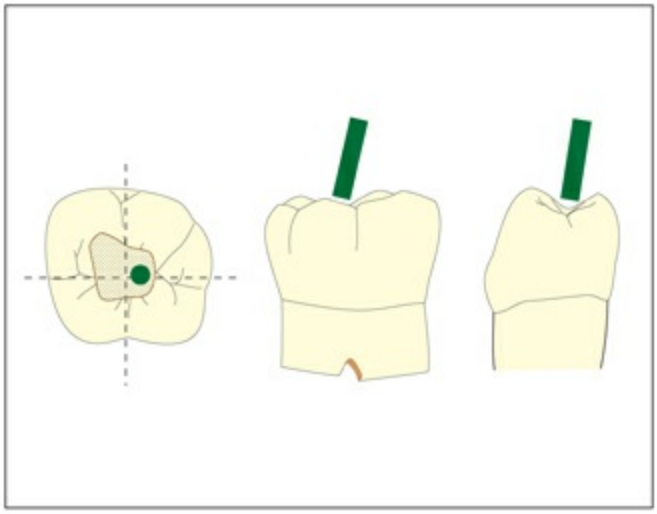


Fig 16-6 Schematic demonstrating penetration into the pulp chamber of a mandibular molar. Note the angulation of the bur which should match the lingual tilt of the clinical crown and also the entry angle to the distal root canal.

Enlarging the opening—The unroofing

With a bur with a noncutting tip, enlarge the opening to expose all root canal orifices, using lateral movements. It is useful to wash away debris frequently to make observation easier; verify that unroofing of the pulp chamber is complete with a probe. If undercuts and pulp horns are noticed, use a small round bur in pulling motions to remove those areas where needed.

Refining and flaring the cavity outline

Next, refine the overall outline so that there is a slightly divergent cavity. At this point, you should be able to see all canal orifices with one direct line of sight and to position a probe into the orifices without excessive wall contact. In mandibular molars, start the access in the central pit, and angle the bur slightly to the distal. The cavity is mapped out and unroofed as explained earlier (Fig 16-7).

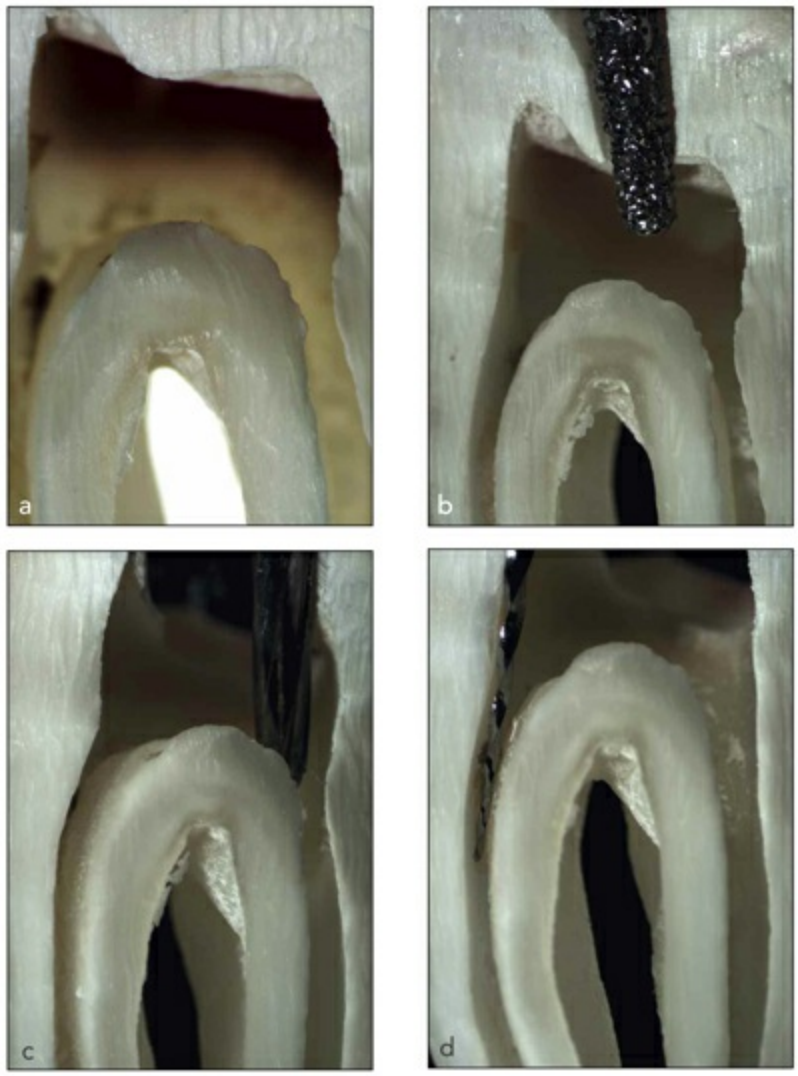


Fig 16-7 Important steps during access cavity preparation in a mandibular molar demonstrated on an extracted tooth using a microscope. *(a)* Lateral section through the pulp chamber. *(b)* Penetration into dentin with end-cutting diamond bur. *(c)* Refining access with non–end-cutting EndoZ bur (Dentsply). *(d)* Removal of dentin triangles, here with a lateral-cutting nickel-titanium rotary instrument used with brushing movements.

Materials

- Friction grip (FG)–high-speed and slow-speed handpieces
- Set of sterile burs
- K-file Nos. 8, 10, 15 nickel-titanium rotaries (eg, Orifice Openers, Nos. OS0319, OS0419 [Dentsply])
- Endodontic probe (eg, DG16 [Hu-Friedy] or 43-504-00 [Martin])
- Periodontal probe

It is recommend to select a set of three to five burs dedicated for root canal access and preparation and that these burs be clinically readied in a sterilized package (Fig 16-8). A small round bur, used in combination with a high-speed handpiece and water spray, may be selected for penetration of enamel and dentin, but a slightly tapered or parallel long diamond is preferred (eg, No. 859-012 [Brasseler

USA]). This type of bur works equally well on a natural tooth or on porcelain surfaces. A transmetal bur (EATMB [Dentsply]) is an excellent option for cast gold or nonprecious alloys. The EndoZ bur (EAEZ [Dentsply]), with its noncutting rounded tip (see Fig 16-8a), is a safe and very effective bur for unroofing and refining the access cavity. This bur has a slight taper and produces an optimized access cavity very quickly. Perforations of the pulp chamber floor are unlikely due to the non-cutting tip. As an adjunct during unroofing, round burs may be used in a pulling motion to remove undercuts.

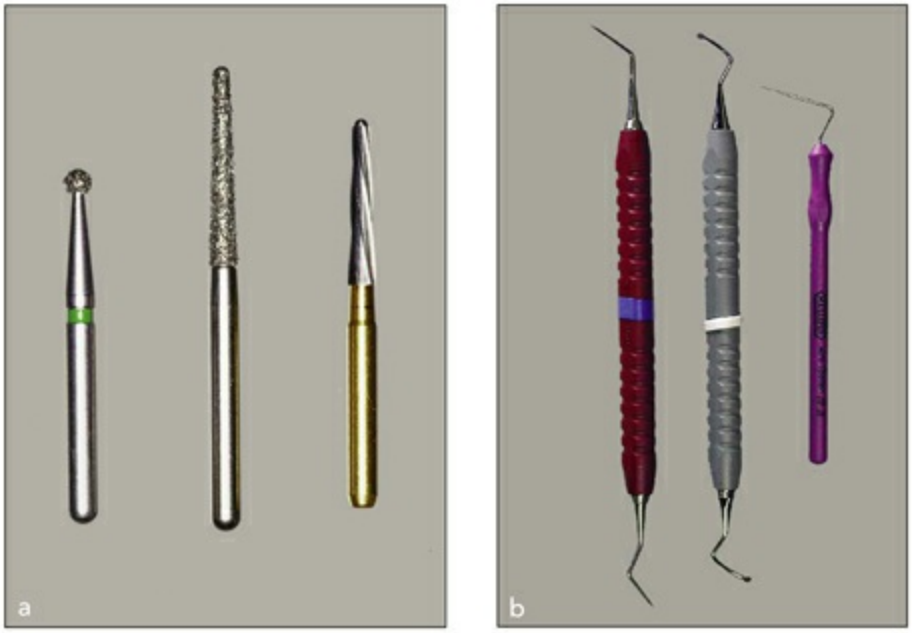


Fig 16-8 Materials typically used for access cavity preparation: a set of burs and several hand instruments. *(a)* End-cutting diamonds and an EndoZ bur. *(b)* A DG16 explorer (Martin), a small excavator (Martin), and a Micro-Orifice Opener (Dentsply).

FINDING THE ROAD MAP

During access, it is important to have a picture of what the pulpal floor is going to be like even before it becomes visible (Fig 16-9). Typically, canal orifices are centered in each root cross section (see Fig 16-1). That means, if only one orifice is found, for example, far toward the mesiolingual aspect of a mandibular molar, there is most likely another orifice equidistant from the midline to the buccal. The degree of restoration, caries, crown preparation, and other stimuli will alter the internal anatomy. In fact, canal orifices may be covered with reparative dentin and appear mineralized. In such situations, it is crucial to understand the typical road map of pulpal floors (Fig 16-10). This road map is best viewed with magnification, loupes, or microscopes (see lesson 13). The basic color of dentin on the pulpal floor is darker than that of intracoronal dentin. A transition from dark to light yellow indicates that overextension has taken place, and no orifice is going to appear in the direction of the extension.

Fine lines quite often connect the root canal orifices (see Fig 16-10) and can be used to search for a canal that is not easily detectable. Again, the use of loupes and good lighting facilitates this search, since the structures sought are fairly small. The DG16 explorer is a relatively stiff instrument that allows some force to be applied to remove adhering mineralization, for example. It is imperative for the use of this road map that the pulpal floor is not destroyed by the indiscriminate use of end-cutting

burs.

As soon as all orifices are found, proceed to the canal preparation, a task that can be split into several steps. Oftentimes, the orifice itself needs to be enlarged to allow straight-line access. This is particularly important when using nickel-titanium rotary instruments. The steps to reach the canal apex are detailed in lesson 19.

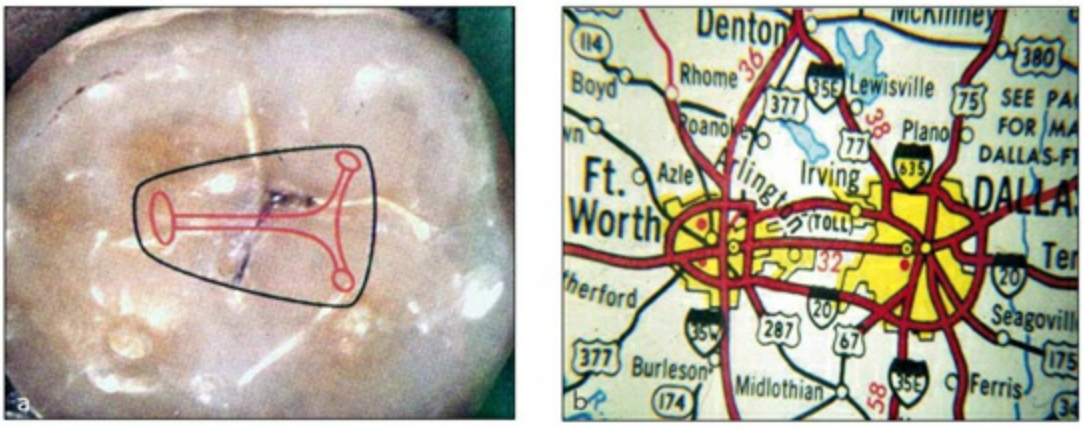


Fig 16-9 Pulpal anatomy is literally a developmental roadmap to the orifices. The internal anatomy must be visualized prior to access *(a)* much like a traveler understanding the route on a map *(b)*.

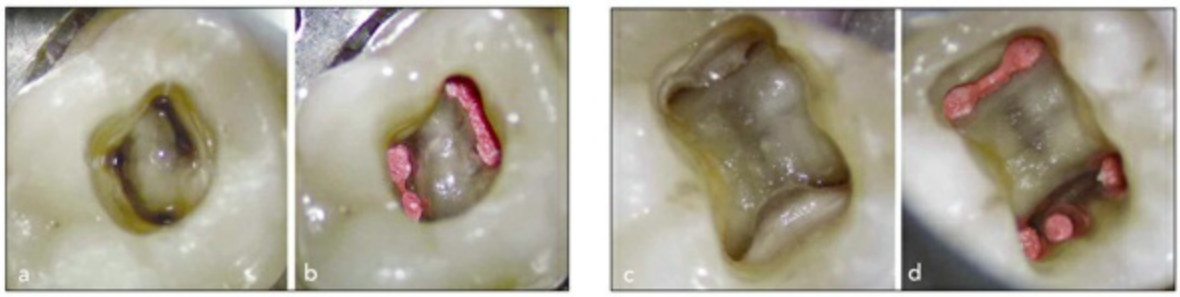


Fig 16-10 Pulpal floor anatomy seen clinically in the operating microscope. *(a and b)* Maxillary first molar, unprepared canals *(a)* and finished treatment *(b)*. Note connecting isthmus between the two mesiobuccal canals. *(c and d)* Mandibular first molar, unprepared canals *(c)* and finished treatment *(d)*. Note filled middle mesial canal. (Images courtesy of Dr Helmut Walsch, Munich, Germany.)

LESSON 17

Instrument and Material Choices

OBJECTIVES

To understand the basic principles of file design, behavior, and usage.

INTRODUCTION

Efficacy of canal shaping procedures is in great part dictated by the choice of instrument for the specific task at hand. Root canal preparation serves two purposes: to eliminate intracanal tissue and pathogens both mechanically and with irrigation solutions, and to create a canal shape that facilitates root canal obturation. For both objectives, enlargement of the original canal is necessary, and root dentin has to be cut. For two centuries, metal wires have been used to extirpate pulp and enlarge root canals.

MATERIAL CHOICES

Carbon steel

Due to its hardness and cutting efficiency, carbon steel is still used for burs. However, it corrodes in oral fluid and is therefore no longer the material of choice for endodontic instruments. Some endodontic access burs are diamonds; others are tungsten carbide. Both materials have their benefits:

diamond burs cut smoothly through dental ceramics, whereas tungsten carbide burs are efficient at cutting through base metal crowns.

Stainless steel

Stainless steel is widely used for both hand files and endodontic burs.

Nickel-titanium

Endodontic therapy from 1990 to the present has utilized super elastic nickel-titanium (NiTi) instrumentation. This material has enhanced the armamentarium, and NiTi is now the material of choice for engine-driven endodontic instruments. Plastic files have recently appeared on the market, but they have limited cutting ability and are intended to facilitate irrigation and disinfection rather than actually cut dentin.

STAINLESS STEEL VS NiTi

There are many differences between stainless steel and NiTi alloys, with regard to corrosion resistance, hardness, and fatigue. For the purposes of canal preparation, stainless steel and NiTi differ primarily in their stress-strain curves (Fig 17-1). The steep initial curve for steel indicates a much higher stiffness, and its ultimate tensile strength is not much different from that of NiTi. On the other hand, NiTi is very flexible and can be extended by approximately 7% before plastic deformation occurs.

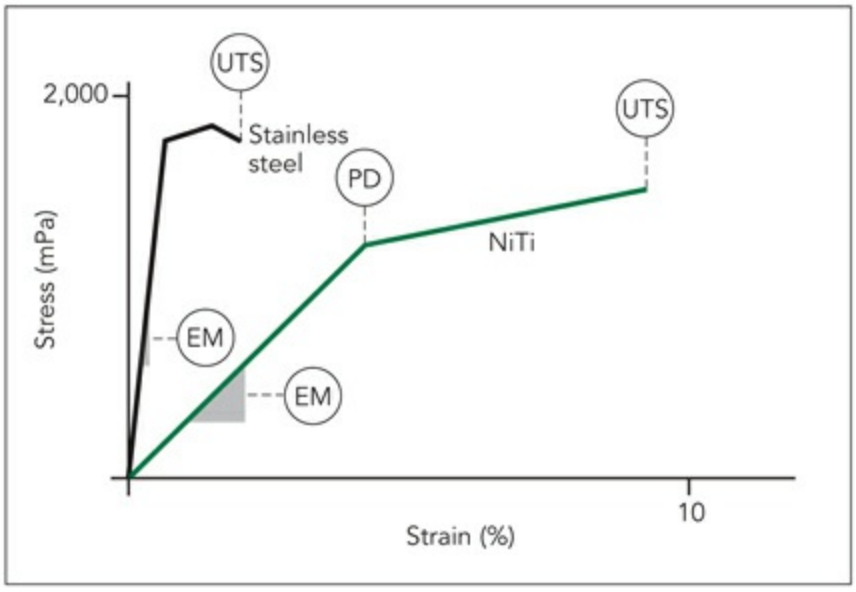


Fig 17-1 Stress-strain diagrams of stainless steel and NiTi alloys. The ultimate tensile strength (UTS) and the elastic modulus (EM, *gray triangles*) are shown. PD = plastic deformation.

Why there are differences in properties

The fundamental differences between stainless steel and NiTi (Table 17-1) are based on the arrangement of the atoms within the two metal alloys. The plastic deformation of stainless steel occurs at a low amount of strain (see Fig 17-1), whereas much more strain (not more force) is required to cause the plastic deformation of NiTi. These properties each have practical consequences:

- Stainless steel files, being less flexible, can be more readily precurved than can those made from NiTi.
- The superior flexibility of NiTi allows root canals to be prepared with less force between canal walls and enables the abrading instrument to lessen cyclic fatigue accumulation during rotary preparation.

Table 17-1 **Comparison of properties of NiTi and stainless steel alloys**

Property	NiTi	Stainless steel
Flexibility	⇑⇑	⇔
Corrosion resistance	⇑	⇑
Cutting efficiency	⇔	⇑
Torsional resistance	⇑	⇑
Fatigue resistance	⇑ ⇑	⇔
Machinability	⇔	⇑
Cost	⇑ ⇑	⇑

⇔ = neutral; ⇑ = increased; ⇑ ⇑ = significantly increased.

Why endodontic files fracture

Both hand and rotary files can fracture inside root canals, leaving file fragments behind. There are two basic mechanisms leading to file breakage (Fig 17-2):

- Torsional overloading occurs when the fine tip of a file binds and the shank (handle) continues to rotate.
- Cyclic fatigue occurs when a file is rotated for some time in a curved canal, resulting in repetitive bending, work hardening, and the creation of a brittle structure.

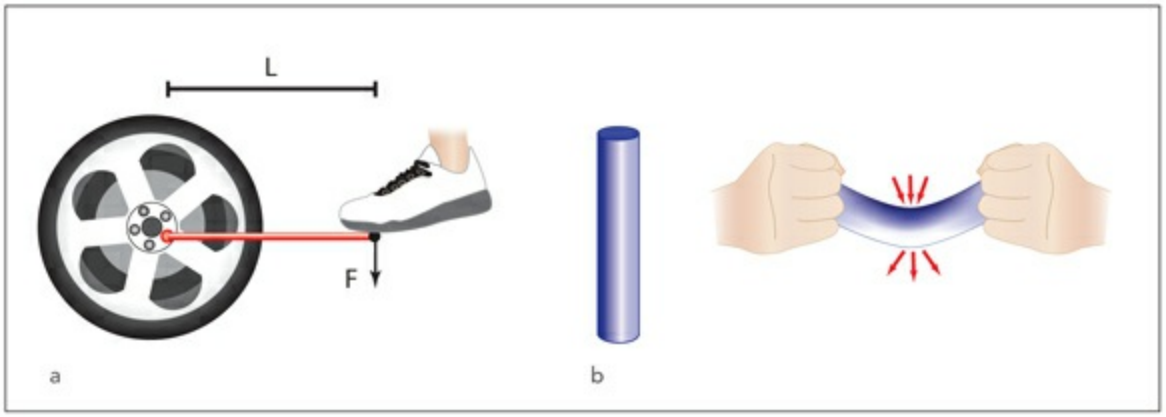


Fig 17-2 Two causes of NiTi breakage are torsional load and cyclic fatigue. *(a)* Torsional overload, and ultimately fracture, occurs when the tip of the file is locked in a narrow canal. *Torque*, defined as lever length (L) times force (F), then rises above the fracture limit. *(b)* Even without torsional overload, a file is bent back and forth with every rotation, creating zones of compression and elongation, that result in localized work hardening and ultimately fracture.

When to use stainless steel and when to use NiTi

The ability of stainless steel hand files to be precurved makes them excellent instruments for canal negotiation. Prior to the use of NiTi rotary files, canal paths must be explored and a smooth canal path verified. Sometimes, ledges need to be bypassed, which requires precise precurving to a desired shape (see lessons 19, 21, and 23).

Cutting ability

- Stainless steel files are manufactured with rather sharp transitions from the very tip to the lateral aspect (ie, the cutting flutes) (Fig 17-3). These sharp points can give rise to preparation errors such as ledging. On the other hand, the potential for hand K-files to cut dentin can be utilized to our benefit in situations where there is a need for material removal (eg, a retreatment) (see lesson 23).
- NiTi is preferred for the preparation of curved canals and is prerequisite for the use of continuous rotation in shaping curved canals. In fact, in experimental canals, rotary instruments manufactured from NiTi lasted an average of 500 to 1,000 rotations in extremely curved conditions. In contrast, stainless steel Gates Glidden drills used into and beyond a curvature broke from fatigue in a couple of seconds.

Curvatures

- Small stainless steel files, Nos. 8 to 15, should precede the use of NiTi rotary files. They can be systematically used to prepare curved canals to full length.
- Large stainless steel files should only be used to working length in straight canals (rare).
- Rotary files have their own limits, particularly in canals with very abrupt changes in direction (eg, double-curves, acute coronal curves, and very tight apical turns).

Reuse

- Since NiTi is much costlier than stainless steel, many clinicians reuse NiTi files. There are two problems with this reusage: current sterilization procedures do not completely remove adhering material from a used file, and it is sometimes very difficult to detect minute plastic deformation and weakening for subsequent use.
- For safe use, it is recommended to carefully inspect both stainless steel and NiTi files for plastic deformation during the filing process and replace all small-sized files after every patient. Any deformation sets up a file for fracture, and this holds true even for files that were intentionally precurved for a specific anatomic deviation.

HAND INSTRUMENTATION VS ENGINE-DRIVEN PREPARATION

For many years hand instrumentation was considered the best way to prepare the intricacies of root canal systems. Hand instruments require artful and diligent hand movements to create the desired canal shapes. In contrast, engine-driven preparation was felt to be inferior and prone to procedural errors. That view has changed dramatically with the advent of NiTi rotary files, which are by now a mainstay of the endodontic armamentarium. Rotary instrumentation results in the predictable creation of a shape corresponding to the instruments used. This occurs, in particular, when one of the more passive rotary files is used.

Current thinking suggests that both hand and engine-driven files should be used together in a functioning sequence to provide the best possible results. An example would be to use stainless steel "pathfinder" files to patency length prior to the use of any rotary files. Though there is a place for stainless steel engine-driven Gates Glidden burs to provide the path, the approach is dictated by two main factors: *(1)* the degree of complexity (curvature) within a canal system and *(2)* the degree of skill possessed by the clinician.

Designs of both rotary and manual endodontic files dictate the actual methods of use. That is, engine-driven NiTi instruments use continuous rotation and shape root canals safely and effectively; however, ultrasonic and sonic vibrating instruments and oscillating instruments (to date) cannot adequately prepare acceptable shapes within curved canals. There are various special endodontic handpieces and dedicated electric motors on the market that allow defined presets for speed and torque.

As stated before, torque (rotational force) is one factor related to file breakage, and it is believed that so-called torque-controlled motors are beneficial in particular for clinicians who are in the beginning of the inevitable learning curve associated with rotary usage of NiTi instruments.

INSTRUMENTATION TECHNIQUES AND SYSTEMS

The shaping goals and the desired apical shape of the canal system dictate to some extent the details of the instrument sequence. This is particularly true for hand instruments. Rotary instruments, specifically those with a K-file–type cross section may also be used in a variety of ways to create

special shapes.

Endodontic hand instruments are available in several mechanical designs, with K-files and Hedström files being the most commonly used instruments (see Fig 17-3). They may be used in a variety of techniques and sequences depending on canal anatomy and desired postoperative shape.

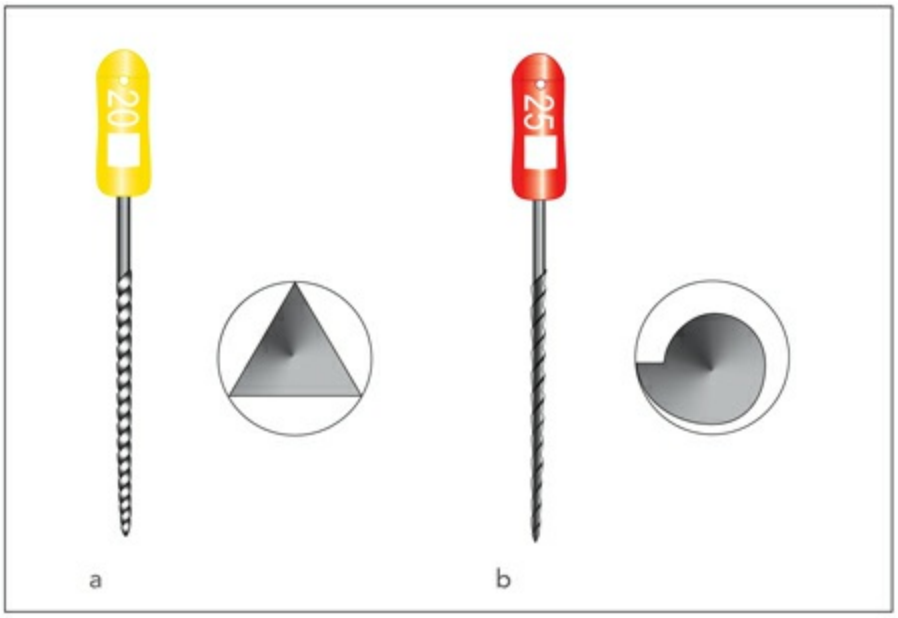


Fig 17-3 Basic design elements of two endodontic hand instruments, a K-file *(a)* and a Hedström file *(b)*. Shown are labeling and cross-sectional outlines.

Manipulation of endodontic instruments

Watch winding

With small files, watch winding is typically employed for the initial penetration into root canals. The intention is not to remove hard tissue but rather to feed a fine and well-lubricated file into the canal to a desired depth. To that end, gently and repeatedly rotate the file's handle clockwise and counterclockwise for 60 to 90 degrees each way, with light continuous apical pressure. After a couple of cycles, remove and clean the file, and irrigate the canal (Fig 17-4a).

Reaming

Rotate the instrument in a clockwise direction so as to engage the canal wall, and then remove the cut dentin by pulling the instrument outward (coronal). This technique is effective but capable of straightening the canal path if large and inadequately precurved instruments are used. It is important to maintain a moist canal; irrigate frequently with a sodium hypochlorite (NaOCl) solution (bleach) (Fig 17-4b).

Filing

Filing motions are best suited for Hedström files and K-files. Press the instrument against the wall (that needs filing), and pull up and out of the canal in 2- to 4-mm strokes. Filing is a very effective

means to remove dentin, which makes it particularly efficient for coronal flaring and removing irregularities along the canal walls. However, when larger Hedström or K-files are used in curves, there is a real danger of creating strip perforations.

Balanced force

Balanced-force hand instrumentation (Fig 17-4c) begins with the typical triad of movements: place, cut, and remove instruments only with a rotary motion. Insertion is done with a quarter-turn clockwise rotation while slight or no apical pressure is applied. Cutting is accomplished by embedding the flutes into the canal wall with a counterclockwise rotation. To do so, sufficient apical pressure must be applied to the instrument to prevent it from backing out of the canal as it cuts.

Adjust the amount of apical pressure to match the file size (ie, very light for fine instruments to fairly heavy for large instruments). Using pressure, you should be able to maintain the instrument at or near its clockwise insertion depth; then, apply counterclockwise rotation and apical pressure together to enlarge and shape the canal to the diameter of the instrument. Counterclockwise motion should be 120 degrees or greater.

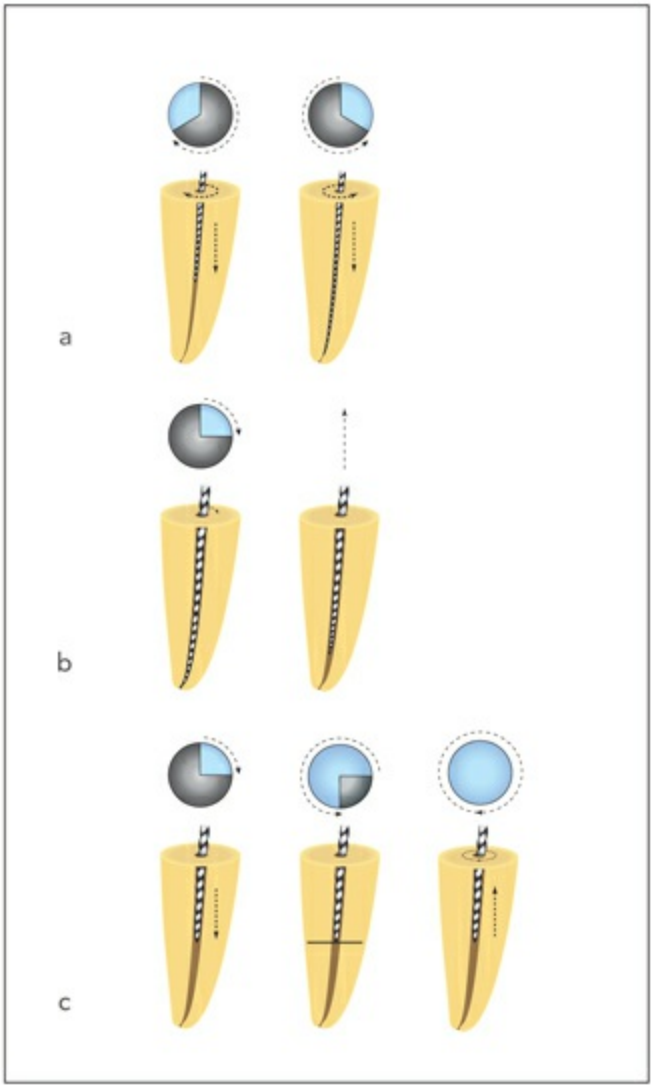


Fig 17-4 Hand movements for use in root canal preparation with hand instruments. *(a)* Watch winding, a sequence of clockwise and counterclockwise rotations, is often employed during canal exploration. *(b)* To prepare a root canal with a K-file, often a reaming motion is used that consists of a sequence of clockwise rotation and a pulling motion. *(c)* The balanced-force technique can be used in curved canals and will maintain the curvature. It encompasses three distinct movements. After file inser tion to slight resistance, a clockwise rotation engages dentin and then a counterclockwise rotation cuts dentin and creates a shaving. As the final step, the instrument is withdrawn with a gentle clockwise rotation.

Rotation

For many decades, careful manipulation of hand files was considered the gold standard in root canal preparation. It still forms a major component of endodontic therapy. However, the advent of various designs of NiTi rotary files (Fig 17-5) has shifted this paradigm, and NiTi (wire) is currently the standard instrumentation material in endodontics. Rotary instruments allow consistent shapes with very little danger of procedural errors. The most often cited disadvantages are the higher price and frequency of instrument fracture. The following represent examples of the currently marketed NiTi rotary instruments:

• LightSpeed LSX (Discus Dental)

• ProTaper (Dentsply)
• Profile Systems (Dentsply)
• GT Series X (Dentsply)
• Sequence (Brasseler USA)
• K3 (SybronEndo)

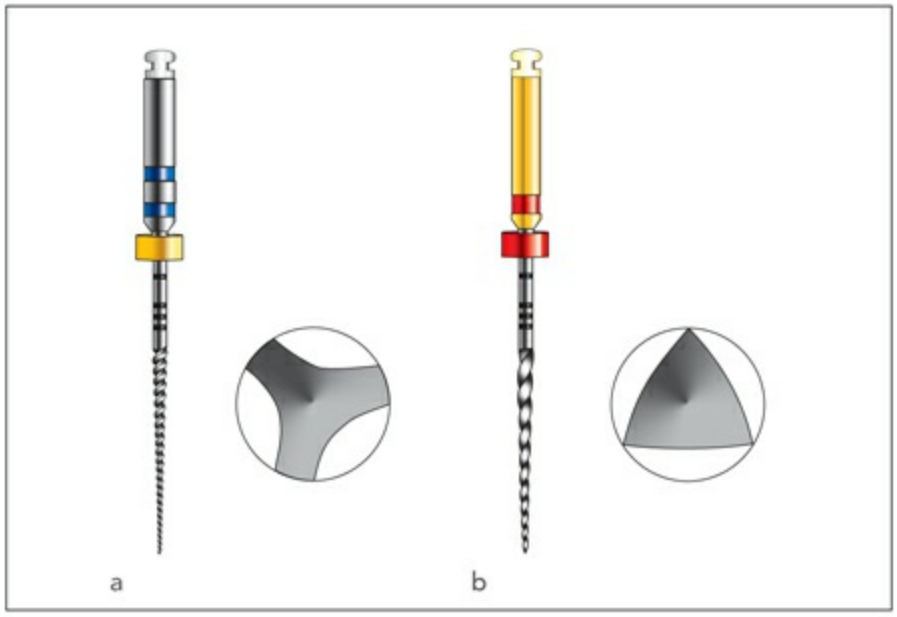


Fig 17-5 Basic design elements of two Dentsply rotary instruments, ProFile *(a)* and ProTaper *(b)*. ProFiles have so-called radial lands; ProTapers are nonlanded files, as seen in the cross section. Both files have noncutting tips, which is typical for current file designs.

Quality control

While most manufacturers provide specific guidelines for their rotary systems, some general guidelines apply for all systems and are summarized here:

• Poor access preparation promotes procedural errors.
• Sufficient access is crucial for the use of NiTi rotary instruments. Always attempt to create straight-line access into the coronal or middle third of the root canal prior to taking a rotary to working length.
• Never force NiTi rotary instruments. They require a passive technique. If resistance is encountered, stop immediately, and before continuing, increase the coronal taper and recapitulate with small stainless steel hand files.
• Canals exhibiting difficult anatomy should be detected, analyzed, and carefully instrumented.
• Do not overuse files. "Once only" is the safest number. However, the actual stress level on an instrument depends upon the case difficulty (anatomic complexity). Therefore, files may be used for more than one canal, but if the shaping of a particular canal is difficult, you may have to discard it before entering a second canal.
• Rotary breakage occurs most often for clinicians during the initial stages of the learning curve. The clinician changing from stainless steel to NiTi should take continuing education courses with

experienced clinicians and educators, followed by extensive practice on plastic blocks and extracted teeth.

- Do not use NiTi rotary files to bypass ledges. Use K-files to confirm or create a pathway prior to the use of any NiTi rotary instrument.
- Avoid cutting with the entire length of the file blade. This total or frictional fit of the file in the canal promotes taper lock and potential fracture.
- Insert and withdraw rotary files from a canal while rotating.
- Avoid making sudden changes in the direction of a rotary file, such as stopping and starting while inside the canal. A smooth gentle reaming motion is most efficient.
- The staff and doctor must carefully inspect rotary files, particularly used ones. It should be remembered that NiTi has an excellent memory. The file should be straight; if any bend is present, the rotary instrument is stressed and should be replaced.
- Establish and control the working length, as well as the actual length of the file. If a file fractures without the clinician taking notice, upon the next insertion, the file—now altered with a very sharp tip—will create procedural errors.

Preferred instrumentation technique

Two of the most important steps in using NiTi rotary instruments are improving the access cavity and verification of an open canal pathway. Access into the root canal system needs to provide a direct pathway to the orifices and into the coronal canal third, without weakening the remaining tooth structure. Current rotary instruments have noncutting tips; they may be advanced only into an explored and open canal depth.

- Instrument with stainless steel K-files (Nos. 10, 15, and possibly 20) to the depth that a subsequent rotary file should go (glide path).
- As soon as this glide path is secured, use the NiTi rotary instruments in a crown-down, rather than in a step-back, procedure. That is, use rotary files or tapers from large to small sizes. Advance any one file until a certain resistance is met. Then withdraw it, and use the next smaller rotary file, advancing it further, and in this way, sequentially prepare the canal from the crown to the apices.

CONCLUSION

This approach can be described in more detail as follows: after preparing an access cavity with high-speed burs and localizing the canal orifices, carefully explore the coronal portion of the canal with small K-files without attempting to immediately reach the expected working length, previously determined from preoperative radiographs. This way, coronal flaring facilitates direct access into the middle and sometimes even into the apical third of the canal. It promotes access of irrigants and allows NiTi rotary instruments to prepare the apical third of the canal with less wall contact and friction. Again explore the apical portion of the canal with small K-files up to the electrometrically determined working length. Prepare the canal to the previously determined working length with

straight hand files (up to a size No. 20) with a watch-winding or a balanced-force motion. This procedure is important as it secures an open glide path, allowing a subsequent NiTi rotary file to predictably reach working length.

At times, you may need to modify the guidelines mentioned above to accommodate particular canal types. Canals that abruptly curve or merge cannot easily be prepared with NiTi rotary instruments, and to avoid transportation of the canal, you may have to precurve stainless steel hand files to maintain the path. The extent and position of any curvature determines the strain and fatigue to which a rotary file is subjected; a more coronally located and/or a more acute curvature precludes a file of larger taper and/or larger tip diameter from safely operating at working length. Also, merging points and ribbon-shaped canal areas can lead to deflection of a file tip into an unexplored canal area and subsequent file fracture. An astute clinician needs to consider those situations carefully before entering a canal with a rotary file.

LESSON 18

Root Canal Irrigation

OBJECTIVE

To use the antimicrobial effectiveness of a chemical irrigation solution to maximize the disinfection of a root canal space.

INTRODUCTION

The use of irrigating solutions is a critical part of the cleaning process of a root canal space and is the synergistic counterpart to shaping. The literature commonly refers to these two processes as a single entity, "the chemomechanical preparation of a canal." Irrigation physically enhances bacterial removal from the system and facilitates the dissolution of organic and inorganic tissue. When this bioburden within the root canal is turned into a fluid mass and eliminated, the progress of cleaning the space and maintaining uninterrupted instrument working length is greatly improved.

The elimination of infection from within the root canal system is quite different than elsewhere in the body. The body's normal response would be to access and attack the source of the infection. Unfortunately, the infected tissue trapped within the root canal space is inaccessible to a host. Therefore, the clinician must assume that role. Because mechanical shaping alone is unable to eliminate all of the residual pulp tissue, microorganisms, and debris from the irregularities and complexities of the anatomic root system, clinicians have come to depend on a combination of aggressive antimicrobial irrigation with mechanical cleaning in an effort to generate a therapeutic outcome and promote the healing of apical periodontitis.

Note: Resistant organism populations that are protected in a biofilm and canal space complexities that harbor infected necrotic tissues even after thorough mechanical instrumentation are the two most common reasons for the persistence of infection and may explain those puzzling cases that fail to heal after quality root canal therapy. This speaks to the fact clinicians rarely reach the most complex irregularities within the root canal space and why thorough and copious irrigation with effective antimicrobials is such an important component of root canal therapy.

IRRIGATING SOLUTIONS

Sodium hypochlorite

Sodium hypochlorite is the most universally used irrigating solution in rendering contemporary endodontic care and is effective because it:

- Dissolves organic tissue (Fig 18-1)
- Kills microorganisms
- Acts as a lubricating agent for instruments
- Does not harm vital tissue when used properly
- Is inexpensive

Fig 18-1a Extirpated pulp from a central incisor.

Fig 18-1b Pulp placed in a beaker of 2.5% sodium hypochlorite.

Fig 18-1c Twenty minutes later, the pulp is almost completely dissolved.

Use and action

Sodium hypochlorite may be effectively used in concentrations that vary from 0.50% to 5.25%. The chlorine component of sodium hypochlorite is consumed rapidly during the process of tissue dissolution. Hence, to be most effective, the canal must be repeatedly flushed with fresh solution (every 1 to 5 minutes) throughout the instrumentation procedure. Sodium hypochlorite has been criticized for the following reasons:

- *Unpleasant taste and smell:* Both issues can be managed with the proper placement of rubber dam and the use of a dilute scented formulation.
- *Toxic effects of irrigation past the apex:* This can be managed with meticulous attention to the selection and use of the delivery system.
- *Incomplete removal of smear layer and biofilm:* Often related to the retreatment of nonhealed cases.

Chlorhexidine gluconate

Chlorhexidine gluconate (CHX) is widely used as both a disinfecting irrigant and as an intracanal dressing. It is far less toxic to host tissues and is a more effective biocide than sodium hypochlorite in killing gram positive facultative anaerobes *(Enterococci faecalis)* commonly found in the root canals of teeth that require retreatment due to nonhealing periradicular tissues. The adaptation of these organisms normally found in the human digestive tract and now found in the root canal space appears to indicate that the canal has a unique ecosystem wherein these organisms can thrive. CHX also works effectively to kill *E faecalis*, when combined with hydrogen peroxide. It is postulated that the two irrigants work synergistically, with CHX breaking down the cell wall of *E faecalis* and hyrdogen peroxide disrupting the organism's intracellular DNA.

Though CHX lacks the beneficial tissue-dissolving ability of sodium hypochlorite, there is no doubt that in concentrations from 0.2% to 2%, CHX can be an effective adjunctive antimicrobial irrigant in root canal therapy. This is particularly relevant with the emergence of the new resin sealers and obturating materials (Epiphany [Pentron Clinical Technologies] with Resilon [Resilon Research]). It has been proven that the bonding of a resin to dentin is negatively affected when the walls of a root canal or chamber have been treated with sodium hypochlorite. As such, it is currently recommended that sodium hypochlorite be used during instrumentation but that CHX be the irrigating

solution (gel) of choice from 2 to 5 minutes prior to filling a canal with the resin material.

Hydrogen peroxide

Hydrogen peroxide is a commonly used biocide for disinfection. It is used in dentistry in a variety of concentrations, ranging from 1% to 30%. In its highest concentrations, it has been used as a bleaching agent in both vital and nonvital teeth. Hydrogen peroxide is active against most organisms, yeasts, and viruses found in a root canal.

There has been renewed interest in this irrigant when it is used in synergistic combinations with other irrigants, such as CHX. Although hydrogen peroxide has long been used as a canal disinfectant in endodontics, it has not been embraced as a more effective antimicrobial than sodium hypochlorite.

Ethylenediaminetetraacetic acid

Though it has little antimicrobial activity, ethylenediamine-tetraacetic acid (EDTA) is an effective chelating agent, and when used in combination with antibacterial irrigants, it is most efficient.

EDTA removes the *smear layer*, the adherent by-product of instrumentation that leaves organic and inorganic matter and bacteria remaining on the dentin walls of the root canal. It acts by chelating the inorganic component of the dentin, thus improving the action of the local disinfectant since the deepest dentin layers are no longer covered by a smear. EDTA is most effective as the final step (1 to 2 minutes of contact between the liquid and the canal wall) in the cleaning and disinfecting process. By removing the last remnants of the smear layer, it facilitates the impregnation of the sealer into complex irregularities and tubules of the dentin walls.

Biopure MTAD cleanser

Biopure MTAD (Dentsply) is a mixture of a tetracycline isomer (doxycycline), citric acid, and a polysorbate 80 detergent. The solubilizing effects of MTAD on pulp and dentin are somewhat similar to those of EDTA. The major difference between the actions of these solutions is the high binding affinity of doxycycline for dentin.

MTAD possesses antibacterial activity against *E faecalis* and can be recommended as a final rinse to remove the smear layer and disinfect the dentin at the end of the chemo-mechanical preparation of the root canal.

IRRIGATION DELIVERY SYSTEM

- The gauge of an irrigating needle is an important consideration in cleaning the root canal. A wider, larger gauge needle may be easier to load and express solution, but its depth of penetration is restricted, which limits the amount of solution that reaches the apical third of the canal.

- Use large volumes of irrigation solution to thoroughly clean a root canal. Research has shown that the volume of solution used throughout the instrumentation is key to successful cleaning. Canal cleanliness is directly related to the maintenance of a constant volume of solution in the canals as the shaping takes place and the debris accumulates.
- The needle must never bind in the root canal space, hence smaller-diameter needles are more efficient. Side-vented, closed-end needles of No. 27 or 30 gauge are most valuable for this function (Fig 18-2).
- A fine-gauge suction system is a valuable adjunct in removing debris and in drying the canal.

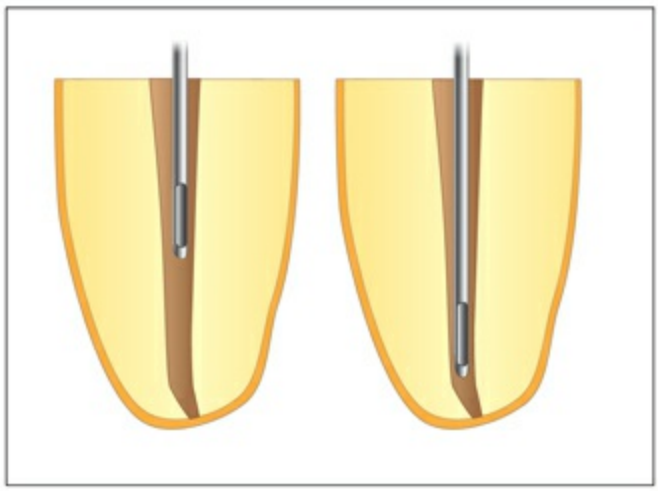


Fig 18-2 A side-vented needle advancing into the apical third of the canal.

Safe and proper irrigation

The following measures are recommended for safe and proper irrigation:

- Use side-vented needles (such as the Max-i-Probe [Dentsply]) to add a measure of safety to prevent binding and decrease intracanal pressures.
- Apply a rubber stop to all irrigating needles to monitor the insertion depth.
- Bend the irrigating needle as needed to facilitate direct access to all canals (regardless of angulation).
- Never place a needle to the point that it binds against the walls.
- Oscillate the needle in and out of the canal to ensure that the tip is free to express irrigant without meeting resistance.
- Express the irrigant slowly.
- Stop irrigating if the needle jams or if there is any detectable resistance when pressing against the plunger of the syringe.
- Check the hub of the needle for a tight fit to prevent inadvertent separation and accidental exposure of the irrigant to the patient's eyes.

Adjunctive irrigating devices

Current research has shown significant advancement in the use of ultrasonic and sonic technology (EndoActivator System [Advanced Endodontics]) (Fig 18-3), and in the use of negative pressure to irrigate and simultaneously evacuate with microcannulas (EndoVac [Discus Dental]) (Fig 18-4). When combined with a biocide, the vibratory action of these devices or the negative pressures used during irrigation produce powerful acoustic microstreaming and cavitational energy that removes more organic tissue, bacteria, and dentin debris than does traditional syringe irrigation. It is apparent from many studies that ultrasonically or sonically energizing an irrigant contributes to better cleaning of the root systems over conventional irrigation alone.

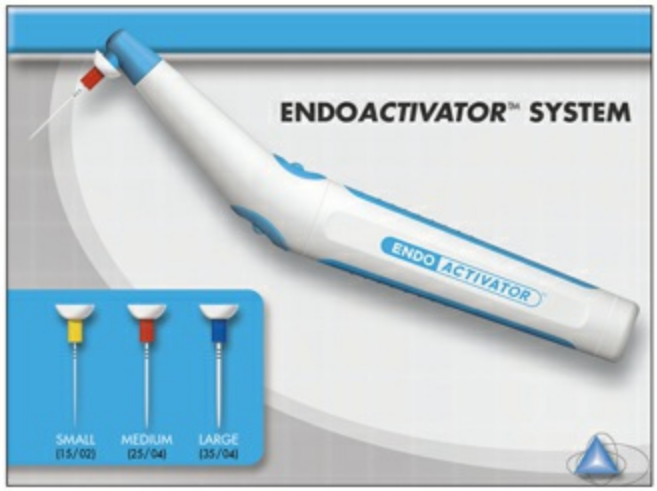


Fig 18-3a The EndoActivator System is designed to vigorously energize intracanal irrigants. The system improves debridement by disruption of the smear layer and biofilm through use of sonic energy and flexible polymer tips. (Image courtesy of Advanced Endodontics.)

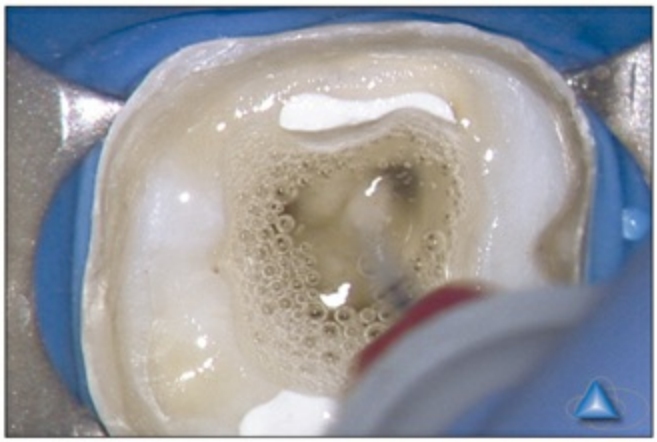


Fig 18-3b The vibrating EndoActivator System tip is used with a pumping motion to produce acoustic streaming and cavitation. The bubbling of debris is demonstrated. (Image courtesy of Advanced Endodontics.)

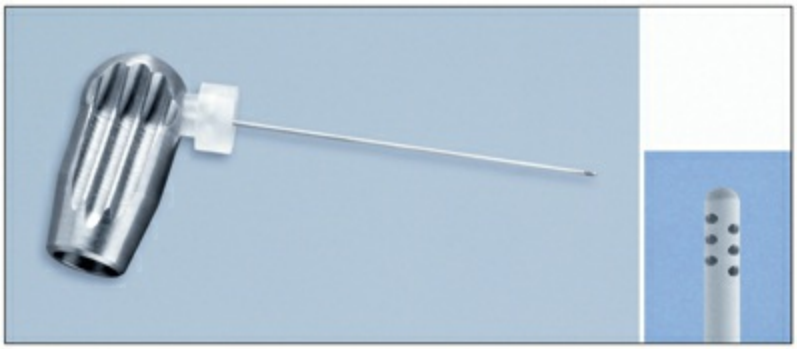


Fig 18-4 The EndoVac is a negative pressure irrigation system that pulls irrigant to working length as it evacuates through a microcannula.

Technique

- Depending on the technology used, introduce a small file or shaper, needle, polymer, or cannula in the apical terminus.
- Fill the root canal with an irrigation solution, and activate the ultrasonic, sonic, or negative pressure device.
- The prior shaping of the canal should provide sufficient space to allow the instrument to oscillate freely within the canal if it is ultrasonically energized.
- The ultrasonic or sonic energy drives the irrigation solution into the complexities, fins, and tubules of the canal walls.
- Because ultrasonic or sonic energy moves in all directions, use a pecking motion with the device to cause the debris to flow upward and out of the canal.
- A negative pressure device simultaneously delivers and evacuates irrigants.

Stropko irrigator

The Stropko Irrigator (J Bar B) is used for finite control of solutions and air when irrigating or using suction (Fig 18-5). It is highly adaptable to dental situations requiring advanced magnification.

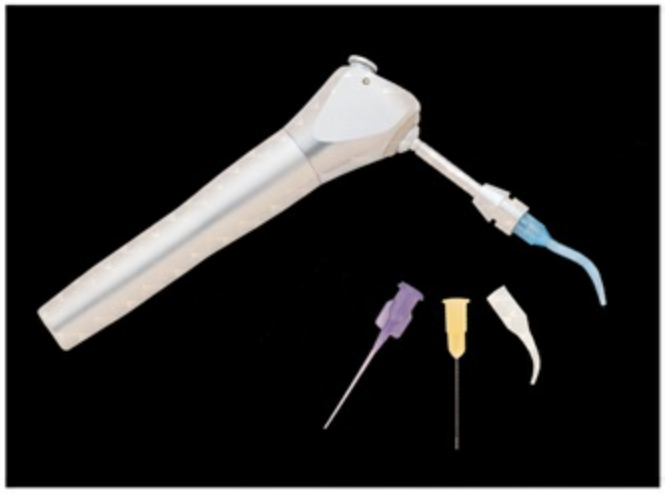


Fig 18-5 The Stropko Irrigator can accept small, Luer Lock tips of different types. These tips do not impede visibility during irrigation or drying and are excellent for use under the microscope. The irrigator fits most air/water syringes. (Image courtesy of Advanced Endodontics.)

IRRIGATION MISHAPS

Successful root canal therapy is primarily based on the removal of microbial infection from the complexities of the canal system. An effective use of the best possible irrigant during shaping procedures is of great clinical importance, and sodium hypochlorite remains the solution of choice for most clinicians. Sodium hypochlorite, used at various clinical concentrations, is a toxic solution that can be highly irritating to periradicular tissues.

Sodium hypochlorite accident

This incident refers to any event in which sodium hypochlorite is expressed beyond the apex of a tooth, and it is an experience that neither the patient nor the practitioner soon forgets.

The reasons for a sodium hypochlorite accident might include:

- Irrigating solution escaping into the periradicular space because the apical foramen has been over instrumented, it is immature or unusually large, or a perforation or resorption has created an artificial exit.
- Forcing an irrigating solution beyond the apex.
- Wedging the irrigating needle into the root canal, thereby preventing an upward escape of the solution along the walls of the needle.

Patient reaction

Considering the excellent tissue-dissolving properties and high alkalinity of sodium hypochlorite, a large volume of the irrigant under pressure leads to immediate strong reactions. The sign that the

irrigant has exited the canal may be any of the following:

- Severe pain, even in areas that were previously anesthetized for dental treatment.
- Swelling (Fig 18-6).
- Profuse bleeding, both interstitially and through the tooth.
- Some patients have several days of increasing edema and bruising (ecchymosis), accompanied by tissue necrosis, paresthesia, and secondary infection.
- Although most patients recover within 1 to 2 weeks, long-term paresthesia and scarring are possible, and hospitalization and surgical intervention may be needed.

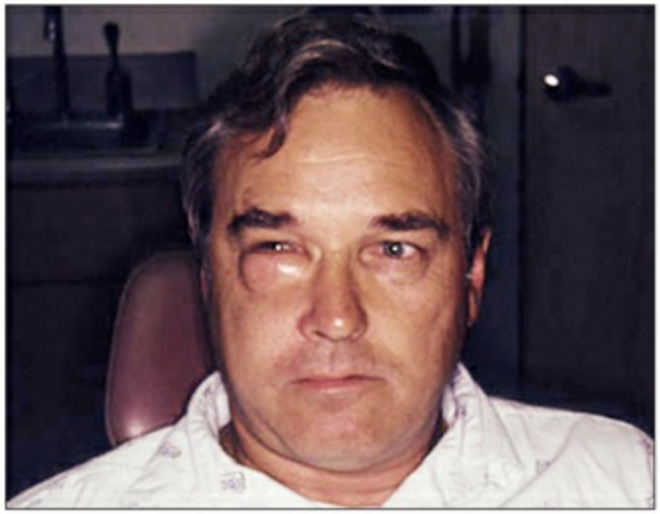


Fig 18-6a Patient presentation almost immediately after sodium hypochlorite was irrigated past the apex on a maxillary canine.

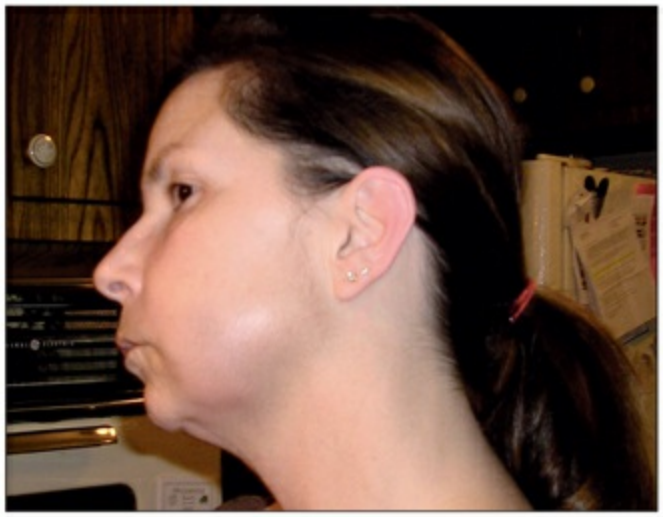


Fig 18-6b The situation several hours after 2.5% sodium hypochlorite solution was expressed through the roots of a maxillary premolar. This patient experienced immediate severe pain and swelling subsequent to the accident.

Management

Although a sodium hypochlorite accident requires immediate attention, the definite assessment and

accurate identification of this dental emergency must follow a prioritized process of recognition and response:

- Recognize that a sodium hypochlorite extrusion has occurred. Sodium hypochlorite has immediate toxic effects on vital structures and results in hemolysis, ulceration, and necrosis.
- Attend to the immediate problem of pain and swelling. Administer a regional block with a long-acting anesthetic solution. With the irrigant spreading rapidly over a wide region, pain management is difficult because symptoms from distant anatomic structures will continue to cause discomfort. This also explains the extreme pain felt during the accident despite establishment of adequate local anesthesia before treatment was begun.
- Reassure and calm the patient. The reaction, although alarmingly fast, is a localized phenomenon and will resolve with time. If available, nitrous oxide sedation can help the patient cope throughout the remainder of this emergency.
- Monitor the tooth over the next half hour. A bloody exudate may discharge into the canal. This bleeding is the body's reaction to the irrigant. Remove the fluid with high-volume evacuation to encourage further drainage from the periapical tissues. If drainage is persistent, consider leaving the tooth open over the next 24 hours.
- Consider antibiotic coverage. If the treated tooth is pulpless and cleaning and shaping procedures have not been completed, consider prescribing amoxicillin, 500 mg, 4 times a day, over the next 5 days.
- Consider administering an oral analgesic. Because of possible bleeding complications with aspirin and other nonsteroidal anti-inflammatory drugs (NSAIDs), an acetaminophennarcotic analgesic combination may be more appropriate. If swelling is extensive, it is best to caution the patient to expect severe bruising and to give assurance that it is temporary.
- Consider prescribing a corticosteroid such as dexamethasone. Steroids may help intercept and minimize the ensuing inflammatory process.
- Give the patient home care instructions. For the first 6 hours the patient should use cold compresses to minimize pain and swelling. Subsequently, warm compresses should be used to encourage a healthy healing response.
- Consider referring the patient. If the patient continues to be apprehensive or needs additional reassurance, or develops complications, referral to an endodontist or oral surgeon is appropriate. Informing the specialist about the patient and the nature of the problem will ensure a smooth transition between offices for the patient.

Prevention

An NaOCl accident is completely avoidable. As an endodontic irrigant, sodium hypochlorite solution is meant to flush debris from the root canal system. Part of the efficacy is delivering the sodium hypochlorite to the deepest segment of the canal without the solution being forced beyond that point. Because root canals are coronally flared during the cleansing and shaping process, it becomes easier to penetrate the irrigating needle deeper into the canal without its binding against the walls. For that

reason, the operator must be acutely aware of the needle depth and must always deliver the solution in a passive manner. Although most patients recover from a sodium hypochlorite accident within 1 to 2 weeks, it can result in long-term paresthesia and scarring, hospitalization, and surgical intervention according to reports in the literature.

LESSON 19

Strategies to Reach the Root Apex

OBJECTIVE

To predictably explore the full length of a root canal from its orifice to its apical foramen without causing a procedural error.

INTRODUCTION

It is crucial to determine and retain working distance from a coronal reference point to an end point within the canal where canal preparation and obturation should end. Recognizing and reaching the apical canal constriction—at the cementodentinal junction (CDJ)—predictably and without complication is essential.

For many clinicians, the first step after gaining access to the pulp space is to negotiate a small hand file into the canal as far as it will go. This technique may work in straight and large-root canals, but in more complicated canals, procedural errors such as ledges and blocks are the more likely result. The consequences may lend themselves to short preparations, short fills, perforations, and broken instruments.

To accomplish the treatment goals in complicated canals, clinicians have been forced to make a philosophic and procedural paradigm shift. Rather than thinking "apex first" as was taught for years, clinicians must now think "apex last" whenever canal resistance is met. This "crown-down" approach conceptually divides a canal into coronal, middle, and apical thirds and treats each segment serially and individually (Fig 19-1).

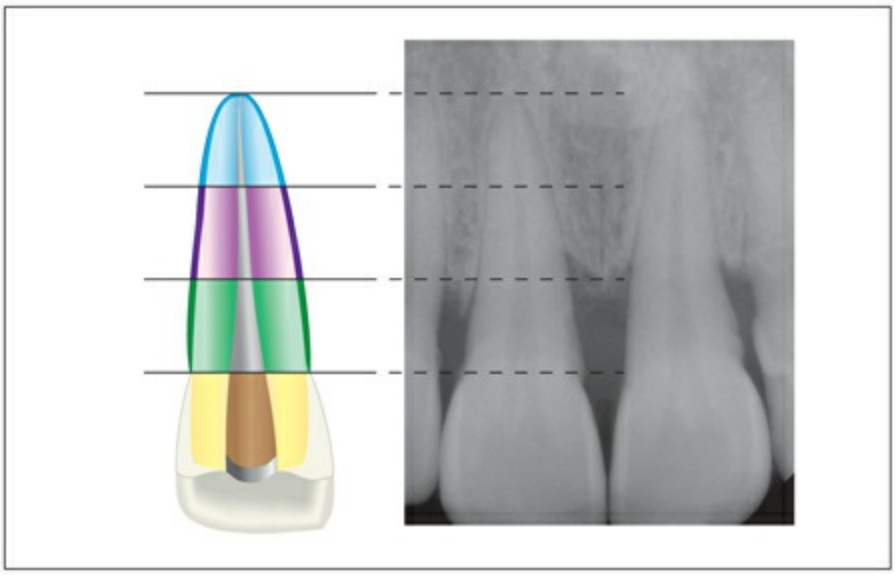


Fig 19-1 Division of root canal lengths into thirds is an important step in understanding the location and strategy for subsequent procedures.

CROWN-DOWN APPROACH

Locating the orifices

- Centered in their respective roots under their respective pulp horns (cusp heights).
- Symmetrically distributed over the root cross section.
- At the ends of pulp chamber tissue tracts (the road map).
- Enhanced visibility (light and magnification) is key in identifying orifices such as the elusive mesiobuccal (MB2) in maxillary first molars (≥70% incidence) • Copious flushing with sodium hypochlorite further improves visibility by controlling bleeding and removing overlying debris (see lesson 18).

Accessing the orifices

- Orifices should be exposed without removing an extensive amount of tooth structure (Fig 19-2). To accomplish this, you must remain constantly aware of the internal anatomy of the tooth being treated and anticipate the number of orifices that should be found.
- A careful observation of a cleared pulpal chamber floor should reveal the orifices. If more orifices are expected than are immediately visible, reassess and retrace the road map on the pulp chamber floor (see lesson 16).
- A sturdy and sharp endodontic explorer (eg, DG 16 [HuFriedy]), when "pushed and poked" into the direction of suspected orifices, not only can remove overlying dentin but also can penetrate a tiny blocked entrance. This desired "stick" with the endodontic explorer can function as the eye of the clinician.

- Depending on the mineralization caused by age, caries, multiple and repeated restorations, pulp capping material, and so forth, a canal orifice may be mineralized and thus not be immediately visible. In such cases, small surgical-length round burs and/or ultrasonically powered tips may be beneficial (with adjunctive loupes or microscope) in the removal of obstructing dentin and in uncovering the natural anatomic landmarks. Progress should be slow, methodical, and done with care to avoid perforating the chamber floor.
- A chamber floor treatment with 17% ethylenediamine tetraacetic acid (EDTA) solution for 30 seconds helps remove the smear layer and dentin debris that might obscure a small canal orifice. It leaves a dull surface texture that makes localization of the small canal orifice easier. Here again, a probing DG 16 explorer is helpful.

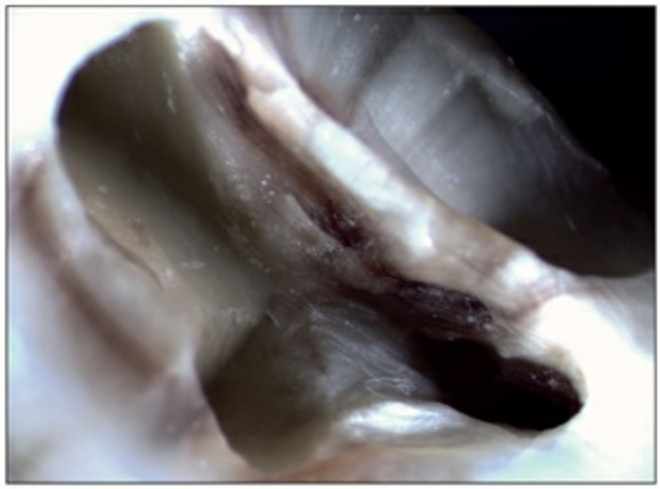


Fig 19-2 Magnified view into the access cavity and onto the developmental road map visible when accessing a maxillary first molar. The shape of the access cavity demonstrates a balance between visibility and conservation of healthy dentin.

Penetrating the orifice

1. Each root canal third provides its own unique challenge(s). Take one or more preoperative periapical radiographs (parallel) with a Rinn X-C-P film holder (Dentsply) and a bitewing radiograph to serve as a basis to estimate the pulp space and size of the chamber (see Fig 19-1).
2. Once you have found the orifice, slightly flare it with the No. 16 explorer, and insert a No. 10 K-file into the first few millimeters of the orifice. This will orient you to the direction of entry. If doubt exists with regard to being in the canal, take a radiograph for confirmation. The radiograph will not only determine the position of the file but also will exclude a perforation.
3. Another way to flare and enlarge the coronal third of a root canal is to insert and use a stainless steel Hedström file (see Fig 17-3) in a pulling motion directed away from any danger zone (eg, furcation). However, if you use this file aggressively, you can easily create a strip perforation. Therefore, restrict the use of this file to the first 2 to 3 mm of the coronal aspect of the orifice, and use only the Nos. 10 to 25 sizes.
4. Gates Glidden (GG) burs (Fig 19-3) are drill bits. They may be used sequentially from largest to smallest, but with caution. Restrict your use of GG burs to the coronal third, and never force one

into a curve. As such, straight-line access to the mid-root is essential. The No. 4 GG bur should be inserted 1 or 2 mm into the root canal orifice and followed in sequence with 2-mm advancements of the Nos. 3 GG and 2 GG burs.

5. Some manufacturers offer nickel-titanium (NiTi) rotary instruments (identified as orifice openers) specifically developed to flare the coronal canal portion. Typically these rotaries are stiffer, more tapered, and more cutting-efficient than the instruments recommended to prepare the full length of the canal:

- *Caution:* Before using any NiTi rotary file, it is best to create a "tap hole." This can be accomplished with any of the aforementioned techniques, including the No. 16 explorer. These instruments have noncutting tips and do not initially make their own path. By establishing a starting point and exposing inner canal tooth structure, the rotating instrument is able to grasp solid structure and begin to advance.
- *Caution:* Though the NiTi rotary file may grip the canal walls and quickly advance, you must respect any degree of curvature that it presents. To prevent the rotary instrument from creating a ledge or accumulating dentin shavings that may block the canal, it is advisable to intermittently use a nonprecurved Nos. 15 or 20 K-file and an accompanying water spray. If you cannot advance with minimal force, the canal anatomy is not likely to lend itself to continuing with a rotary instrument.

6. In addition to its clearing effect, frequent irrigation with sodium hypochlorite is advantageous from a disinfection standpoint. For the most part, the microbes that cause pulpal disease gain access coronally and are therefore found in greater numbers in the pulp chamber and coronal third of the canal. By eliminating the mass of bacteria at the canal entry, the instruments used to prepare the remaining thirds will be less apt to carry bacteria with them as they advance to areas of the canal that are more difficult to clean and disinfect. To increase antimicrobial efficacy, constantly maintain a reservoir of bleach in the pulp chamber.

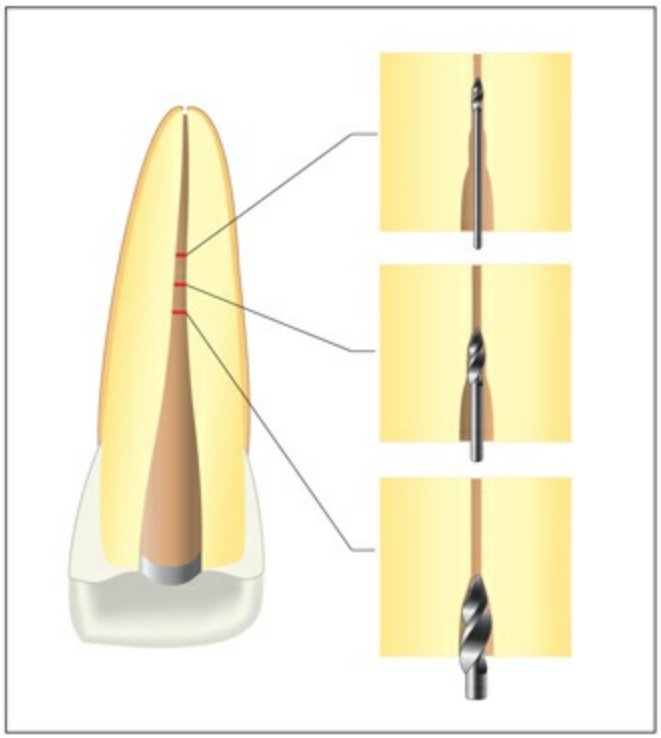


Fig 19-3 GG burs should normally be used in the coronal third to half of the root canal. When used deep in a narrow or fluted root, GG burs are dangerous and can create perforations.

Accessing the mid-root

While the entry into a canal may occasionally be challenging, the middle third of the canal is often relatively easy to prepare once the orifice has been sufficiently flared. Depending on the clinical situation (canal curvature and diameter), hand files Nos. 10 to 20 may be advanced to the level above the apical third. Coat the file with a gel-based lubricant (eg, ProLube [Dentsply]) to make file advancement easier (Fig 19-4). Endodontic hand files typically increase in size in 0.05-mm increments, except for very small and large files where increments of 0.02 mm and 0.10 mm, respectively, are used. The sizes are indicated by handle colors and numbers, and the file design is indicated by a symbol on the handle (see Fig 17-3). If the file does not progress easily with a watch-winding movement (see lesson 17), it is best to change the tactic as opposed to using more force. Force is never recommended, and its use invites ledges, perforations, and instrument fractures.

When resistance is encountered, you should immediately suspect that the canal is blocked by compacted pulp collagen and dentin shavings or that the file tip is bound by an aberration in the canal wall. This irregularity could be a curve, isthmus, groove, lateral canal, or even a ledge formed during the initial canal negotiation (Fig 19-5). In response, you must:

- Go back to the orifice entry and increase the coronal flare using the techniques previously described (see Accessing the orifices and Penetrating the orifice). However, care must be taken not to not overprepare the areas closest to the furcation of multirooted teeth.
- Insert a precurved No. 10 K-flex file, and with slight apical pressure, a watch-winding turn, patience, and frequent irrigation, you can pass most impediments.
- If the instrument fails to advance, a radiograph should be taken to determine the level of penetration and possibly the reason for the resistance (eg, ledge, broken instrument). If a ledge is confirmed, gently rotate a No. 8 or No. 10 lubricated K-flex file (sharply precurved) so that the curved tip of the file slides past the ledge and into the unprepared canal portion.
- *Tip:* Use the indicator line on the rubber stopper or use teardrop-shaped stoppers to designate the direction of curvature when precurved hand files are placed in the root and directional input is needed.
- If no progress is made, enlarge the coronal segment to the depth of the impediment with hand files (Fig 19-6). This so-called file cycling generates more space for the precurved file. Once the blockage is passed with the No. 8 file, the path is enlarged with Nos. 10 and 15 files.
- Determining apical working length (WL): The main goal in preparing the coronal two-thirds of a root canal is to set the stage for the safe and effective preparation of the apical third.

Fig 19-4 ProLube root canal conditioner.

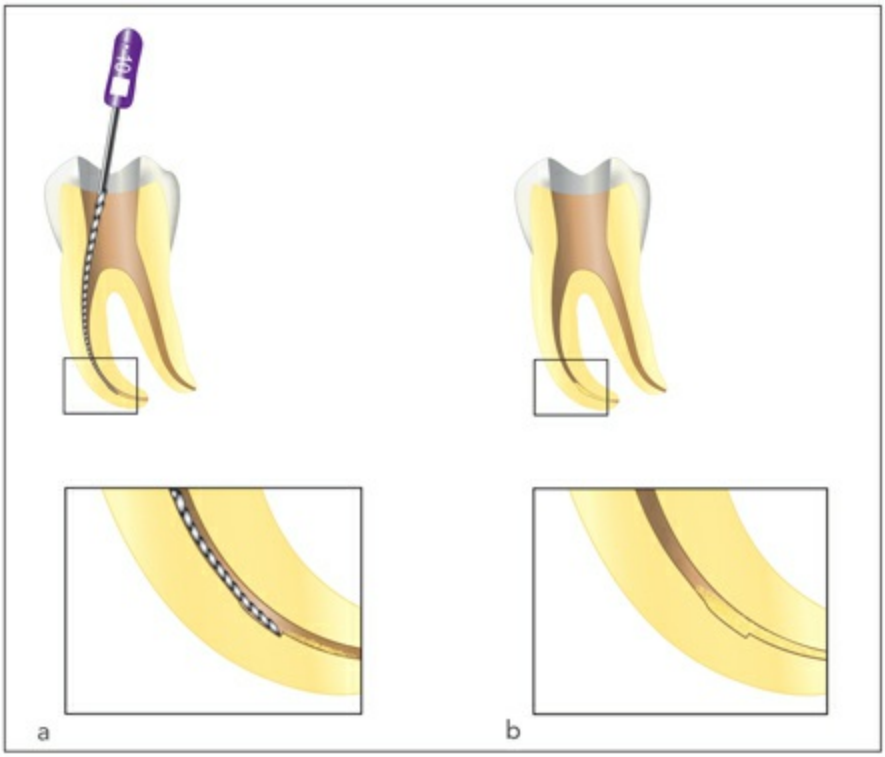


Fig 19-5 Any time a file does not reach working length, one has to ask why. There could be a ledge *(a)*, a blockage *(b)*, or the instrument could be too large for the canal.

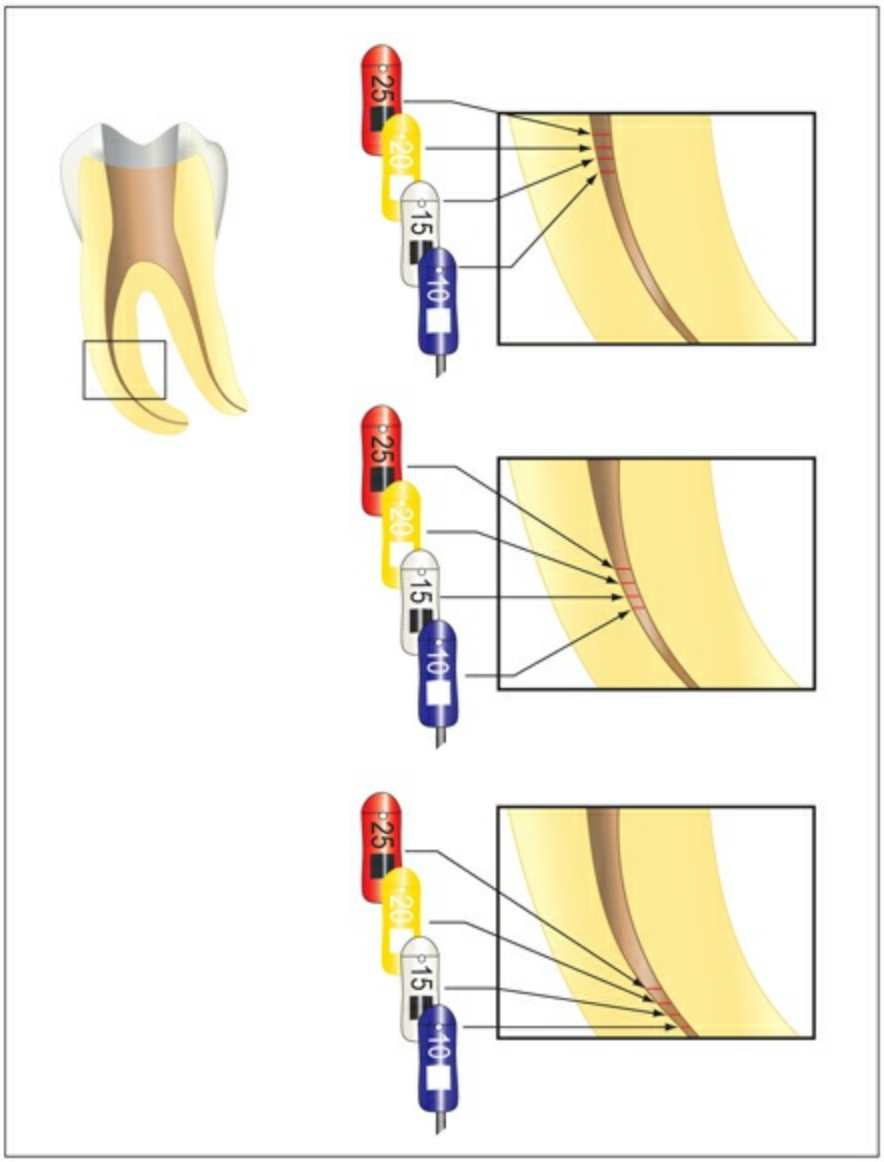


Fig 19-6 File cycling is a simple way to increase mid-root flare and allow apical preparations to commence with ease. It consists of one or more cycles of hand instruments used sequentially with larger instruments stepping back incrementally. Typically, K-files Nos. 10 to 25 are used.

Preparing the apical segment

Measuring the root canal terminus length

Various techniques have been proposed to accurately measure the length of the root canal terminus. A combination of several methods seems to be the most accurate way to calculate both the endodontic WL and patency length (PL):

- Measure from a radiograph taken parallel with the files placed in the canals.
- Electronically measure the length via an apex locator.
- Use tactile feedback (tug-back resistance) with files placed to estimated length.
- *Note:* It is strongly recommend to rely on the combination of an electronic measurement and a radiograph. This combination tends to give higher accuracy than does the radiograph alone. It virtually eliminates the potential for errors that sometimes occur by only using one or the other (Fig

19-7).

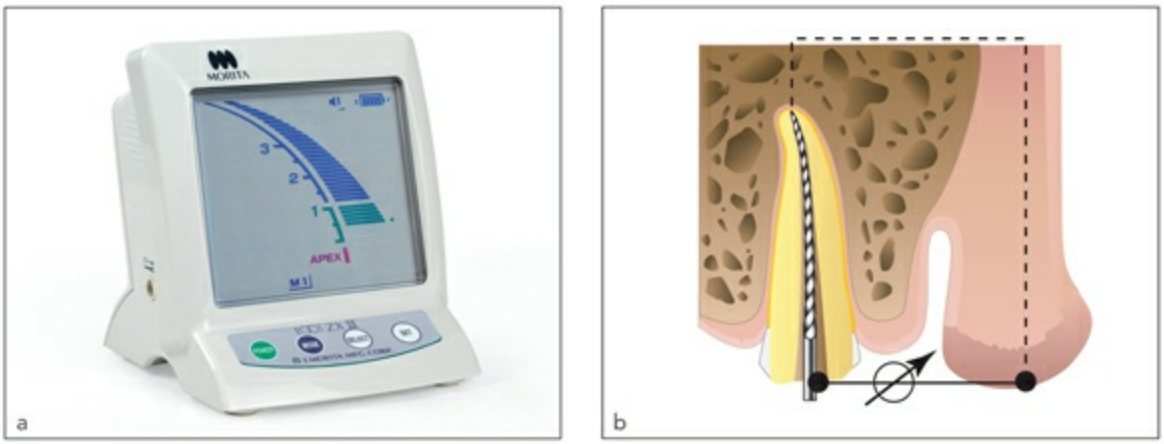


Fig 19-7 The use of an apex locator *(a)* allows the operator to determine WL much more accurately than do radiographs. Contact is made between the oral mucosa and the test file *(b)*. A measurement is then made of the resistance (or more correctly, impedance) between those two points, and the display shows the position of the apical constricture. (Image courtesy of J Morita.)

Appropriate preparation lengths

- WL is the distance from the most occlusal surface of the crown to the CDJ, commonly referred to as the *apical canal constriction*. Realistically, this distance is approximately 0.5 mm to 1 mm short of the root end. By maintaining WL, a new apical constriction is created that serves as a "resistance form" that controls obturation material from exiting the apical foramen during the condensation process.
- PL is the space immediately beyond the true apical canal constriction length and even beyond the true root length. Realistically, this length is approximately 0.5 mm to 1 mm beyond the root end. PL must and can be maintained throughout the preparation by intermittently passing a No. 10 file to PL throughout the preparation (Fig 19-8).

Achieving patency does not remove significant amounts of tissue or prepare the foramen; rather, it disperses apical dentin debris and allows access for irrigation solution to the apical foramen. A patency technique does NOT involve instrumentation beyond the apical foramen with large inflexible files.

PL should periodically be checked for moisture with a paper point. If moisture exists, it likely stems from the periodontal ligament. In this case, it is best to reduce WL by 1 mm and recreate a new apical constriction at this new length.

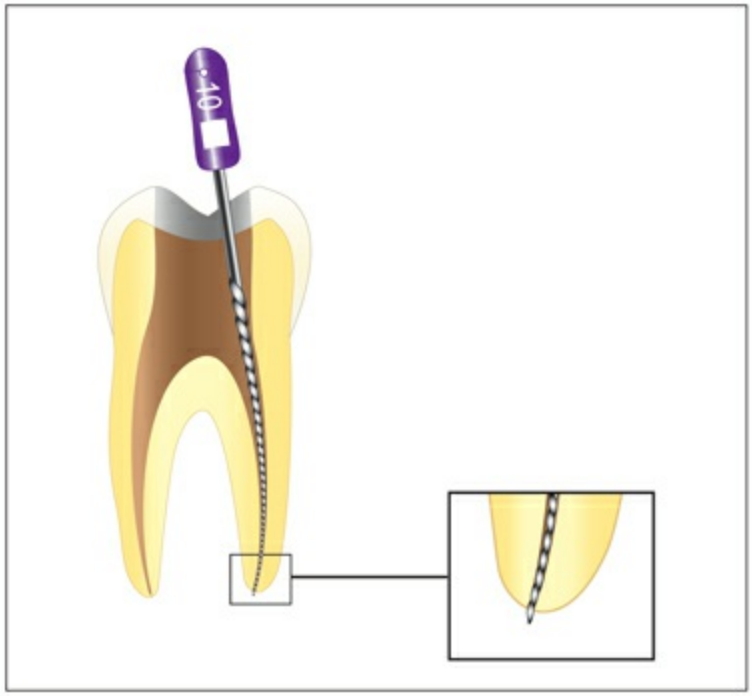


Fig 19-8 A patency file just protruding through the apical foramen. Note that no enlargement of the foramen is present.

Reaching the root apex

- Often a No. 10 K-file may reach the estimated WL with ease after the coronal and middle thirds of the root canal are enlarged as described. However, if impediments are encountered apically, the bypass procedures outlined for the middle third of the root canal can be implemented. Since curvatures tend to be more frequent and more abrupt in the apical third, ledging is also more frequent in this segment. Again, adequate precurving and additional file cycling can help you to deal with such problems.
- Before any rotary instrument should be used to prepare the apical segment, the canal should be explored and enlarged to WL with a No. 15 or No. 20 hand file (straight, non-precurved). This provides a glide path that ensures the safe use of a noncutting tip on a rotary instrument (regardless of the rotary system employed) to WL.
- To assure the preparation is clear, a No. 10 file should now be able to be negotiated to PL (see Fig 19-7). You can test patency in the same way that you can remove impediments—that is, with a small, precurved K-flex file.
- The diameter of the canal preparation at the CDJ can and should be predetermined based on the width and curvature of the root. Though factors such as apical canal curvature may force you to prepare the last millimeters of the WL to a smaller size, most canals can be prepared via hand files or NiTi rotary files to a comfortable No. 30 size.

LESSON 20

Shaping and Cleaning the Anatomically Uncomplicated Canal

OBJECTIVES

To perform a safe and effective approach to cleanse and shape root canals with anatomy of little complexity without creating iatrogenic damage.

INTRODUCTION

While an initial radiograph of a canal may give the appearance that the canal will be easy to treat, no case should be looked upon as being trouble-free. Difficulties may arise in the course of any treatment, including perforation, relocation of the apical foramen, and instrument fracture. Most cases in this lesson are considered class 1 or *minimal difficulty* as defined by the American Association of Endodontists (AAE) Endodontic Case Difficulty Assessment Form (see Fig 7-3). For a detailed discussion of more complicated cases, refer to lessons 21 through 23.

TAPER AND "STEP-BACK"PARADIGMS

The concepts of taper and step-back are critical for an efficient root canal shape, as they connect the coronal preflare with the apical preparation. Nickel-titanium (NiTi) rotary instruments offer a set tip size and a predefined taper to the shaping of a canal. Stainless steel instruments on the other hand

require meticulous use of increasingly larger serial tip sizes and "stepping" them back from the apical preparation (working length [WL]) to form an appropriate canal shape (Fig 20-1).

In endodontics, *taper* can be defined as an increase in diameter per millimeter of length. For instance, conventional stainless steel instruments have a 0.02 taper. That is, their diameter increases by 0.02 mm per 1 mm of cutting blade length (tip to shaft). If files are stepped back in 0.5-mm steps, a 0.10 taper is created, whereas step-backs of 1.0 mm produce a 0.05 taper. *Caution:* these steps are regulated by the International Organization for Standardization, whereas rotary instru ments do not necessarily follow those calculation requirements.

In many cases of uncomplicated anatomy, 0.5-mm steps are appropriate to ensure that disinfection of the apical third of a root canal is optimized and obturation materials can be adequately compacted without unwarranted extrusion (see lesson 30). Using the strategies described in this lesson, you can quickly and easily clean and shape canals in teeth with uncomplicated anatomy and create an ideal taper and apical shape that will facilitate good clinical outcomes—and all without technical error.

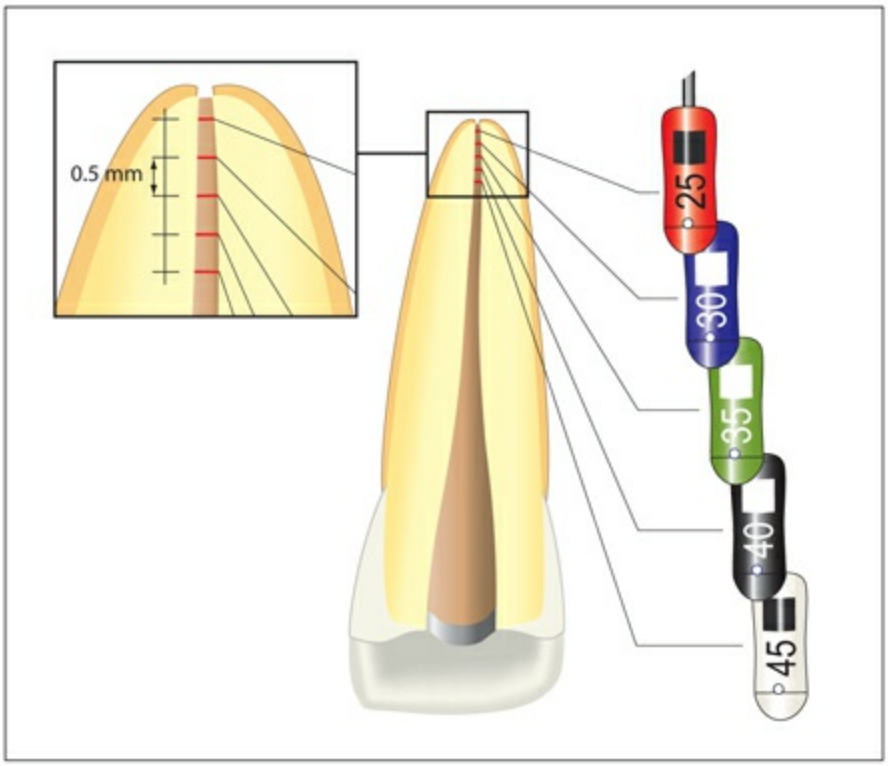


Fig 20-1 Preparation to WL determines the apical size. Then, the taper of the preparation should be increased to stay progressively short with larger files. Typical increment steps during the "step-back procedure" are 0.5-mm wide.

Philosophy and process

The first priority of effective therapy is to enter, shape, and clean the system in a manner that will allow efficient filling of the root canal space. The simpler the internal anatomy of a tooth is, the more straightforward the shaping procedures become. In today's world, the public is educated and demands root canal therapy. As such, the majority of teeth that require endodontic treatment must fall within the treatment scope of every dentist. As you build your experience and clinical skills, your confidence in your ability to treat more challenging cases will increase.

Purpose of canal enlargement

Historically, early research in endodontic therapy has revealed that small canal sizes, below 0.30 mm (No. 30 file), are of insufficient diameter to allow appropriate and effective canal irrigation. To increase the volume of irrigant used during the cleaning process, studies recommend that the coronal portions of a canal be opened at an early phase (enlarged first) and that the balance of the cleaning and shaping process follow in stages. This is a paradigm shift in endodontics, a departure from an "apex first" to an "apex last" approach. For lack of other terms, this method is commonly known as the *crown-down approach*.

By enlarging the coronal segment first, the increased canal diameter can hold and provide a greater volume of irrigant. As you carry the files into the next segment (the mid-root), its very presence will enhance the cleaning and shaping progress (Fig 20-2).

Review the initial radiograph to learn of the presence and degree of any root curvatures. Determine an estimated length to a curvature(s) and address and reduce that curvature with precurved flex hand rotary filing instruments. If experienced, you can use rotary NiTi files (with No. 20 tips) to follow the curve if and when a No. 20 (0.02) taper hand file has significantly reduced the degree of mid-root curvature. Never attempt to file around two curves at the same time, however. If a second apical curvature exists, approach it only after negotiating and eliminating the first curve (thus maintaining apical control).

Note: This lesson is dedicated to treating the less involved single-rooted tooth, such as a maxillary central incisor (Fig 20-3). While shaping and cleaning a maxillary central incisor is for the most part straightforward, the concepts that are presented should be followed for all single-rooted teeth, including premolars (see lessons 21 through 23 for more complex cases).

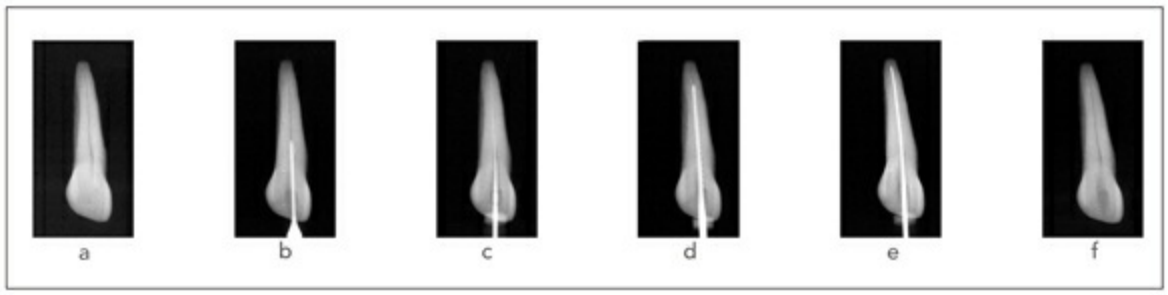


Fig 20-2 Preparation of a central incisor following the procedure outlined in this lesson. The tooth is accessed *(a)* and the coronal third of the root canal is first flared *(b)*. WL is then determined *(c)* and apical preparation is started *(d)*. Stepping back with larger files provides sufficient taper *(e)*, resulting in a harmonious final shape *(f)*.

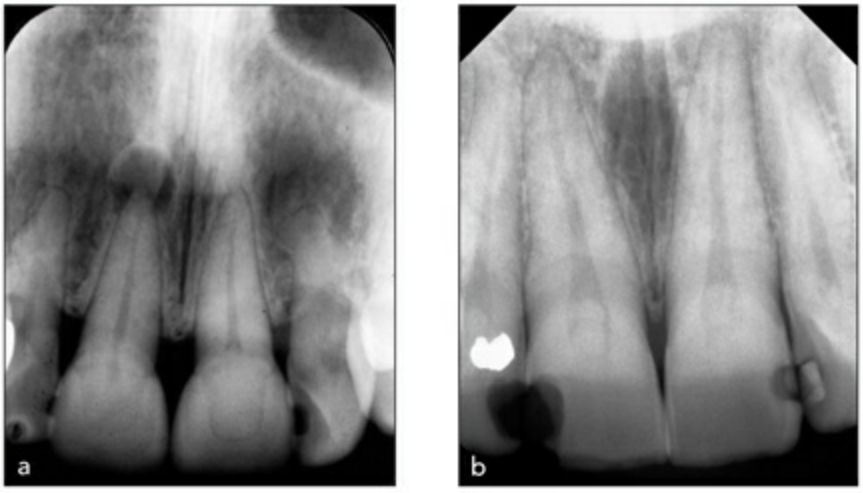


Fig 20-3 Examples of "simple" root canal anatomy. While there is always the chance for a surprise extra canal or a hidden curvature, root canals of central incisors are simple to prepare. *(a)* The maxillary right central incisor has a periapical lesion. *(b)* There are deep restorations in both maxillary central incisors.

CROWN-DOWN SHAPING STRATEGIES

Since the introduction of the NiTi rotary instrumentation systems, the cleaning and shaping process for root canals has evolved significantly. Clearly, adequate access to the apical third is a preparation design concept that is essential to ideal cleaning, shaping, and obturation; procedurally, the instrumentation strategy that allows the clinician to reach that goal has, for many years, been explained as "crown-down" shaping (Fig 20-4). This instrumentation protocol simply implies that:

- The coronal portion(s) of the canal should be cleaned and shaped first.
- Once the coronal preparation has improved access to the radicular or middle portion(s) of the canal, that segment should then be opened, cleaned, and shaped.
- Once adequate access to the apical third has been prepared, the important apical preparation of the canal is addressed, cleaned, and shaped.

The crown-down coronal strategy is designed to remove the most restrictive coronal dentin first, as one navigates and shapes the canal in an apical direction. To do this, complete the following steps:

- Estimate the full length of the tooth from a radiograph taken parallel to the tooth, that is, from the tip of the crown to the radiographic root terminus.
- Estimate the length of the three root segments (coronal, mid-root, and apical). Gates Glidden burs are very effective in preparing the coronal third of canals with uncomplicated anatomy. However, they are not flexible, and they are in fact drills. As such, their rigidity poses a significant potential for strip perforations when carried down invaginated canals and curvatures. To meet safety demands, restrict the use of these instruments to the coronal third of the root canal.
- Gates Glidden burs are most efficient at 1,000 rpm in a crown-down sequence going from large to small sizes: Start with a No. 4, progress apically (1 mm to 2 mm), follow with a No. 3 (1 mm to 2 mm), and follow with a No. 2 (1 mm to 2 mm).

- In large straight canals, these dimensions may be increased to include the mid-root area. In such a case, only the apical segment will be left to require special attention. In more complex cases (molars), the mid-root would require greater attention during the coronal preparation.
- Using a watch-winding motion, a small flexible (No. 10) 21-mm hand file (average length of incisors) may be slowly advanced apically. Because of the uncomplicated anatomy (straight), the file need not be precurved, and with lubricant (eg, sodium hypochlorite, Glyde File Prep [Dentsply]), it should progress toward the apex (the estimated root terminus) with ease. The actual canal diameter in the apical third is likely to be larger than a No. 10, but this size is sure to reach the estimated root terminus.

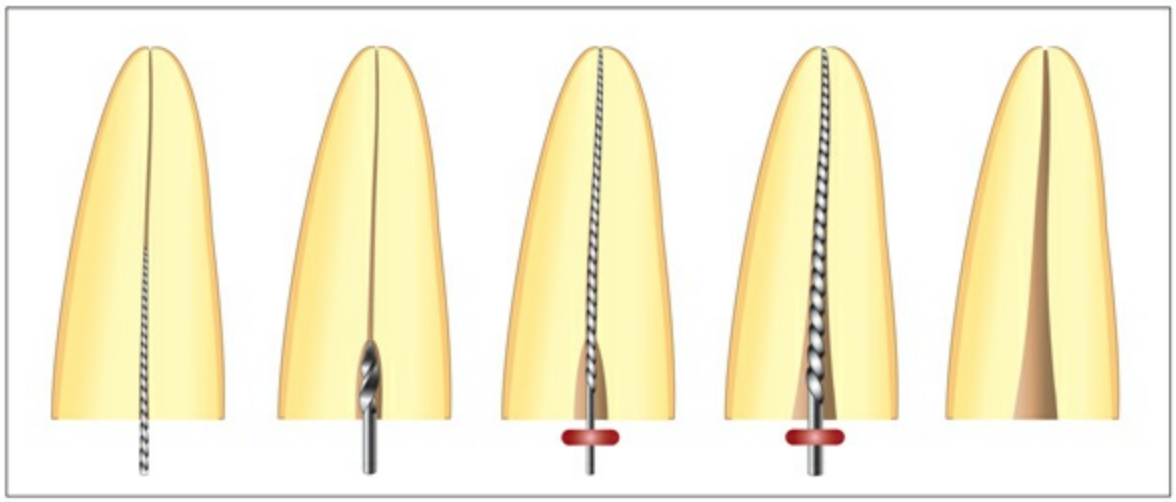


Fig 20-4 Root canal preparation for a simple canal, including *(left to right)* pathfinding, coronal flaring with Gates Glidden burs, and apical preparation.

DETERMINING WORKING LENGTH AND WIDTH

For consistent results, it is necessary to measure the root canal length, which is the radiographic length to the root terminus. This is the only true length that can be measured with any degree of accuracy against the radiograph. Various techniques (see lesson 19) have been proposed to achieve this goal, and the following methods are suggested:

- Use a ruler or periodontal probe to measure the distance from the crown tip to the apex on a parallel radiograph. This distance will be within 1 to 3 mm of the actual root length.
- The average lengths of teeth also provide a starting point for determining the root length. Maxillary incisors on average are 21 mm; maxillary canines on average are 23 mm; maxillary molars on average range from 19 mm to 21 mm; and mandibular incisors and molars on average range from 18 mm to 19 mm.
- It is recommend to rely on a combination of electronic measurement and a follow-up radiograph. Though the electronic measurement is probably the most reliable technique that endodontists currently use for measuring canals, combining this method with a radiograph tends to be more accurate than either technique used alone. It is essential that you positively identify the length to eliminate the potential for gross errors (see Fig 19-6).
- Many clinicians would like to set the limits of actual working length at the cementodentinal junction

(CDJ), where anatomists demarcate the periodontal tissues becoming pulpal tissues as they course up through the pulp space proper.

- The CDJ is considered by many to be the most ideally suited finish to the shaping and cleaning procedures of the canal as well as the termination point for obturation. Electronic apex location most often demarcates this position at the canal terminus.

MAINTAINING PATENCY

Importance

One of the most important reasons to use small hand files throughout the enlarging process is to preserve and maintain patency. While most clinicians think of apical blockage at the apical end of an extirpated and filed canal as a log jam of dentinal debris, it is more often caused by pulp remnants and/or collagen buildup from the shaping process. This collagen stump is compacted into the apical canal constricture (also the CDJ) by working files, and it generally is contaminated by organisms and is unyielding to instruments. If these contaminants are not removed from the canal, they may multiply, leading to postoperative symptomatic inflammation (pain and tenderness), even when the completed root canal treatment appears (radiographically) to be a quality fill.

Technique

- Use a lubricant early and often during the first stages of the canal negotiation and shaping process. These materials can have an emulsifying effect on the collagen plug and provide an effective way to avoid the compaction complication.
- Lubricants such as Gly-Oxide (GlaxoSmithKline), RC-Prep (Premier Products), and Glyde File Prep (Dentsply) are highly effective in removing smear and preventing the cohesion and packing of collagenous debris.
- Lubricants are best used early in the negotiation and shaping process and are critical in reducing cyclic fatigue and breakage of NiTi rotary instruments.
- Continue to use lubricants throughout the preparation process until you are satisfied with the canal enlargement and an established glide path (for gutta-percha sizing) has been established (see lesson 21).

ESTABLISHING WORKING LENGTH

Since patency length (PL) confirms that the canal has been passed through and this length can be verified with a radiograph and/or electronic measuring device (eg, Root ZX II [Morita USA]), there is no reason to enlarge this exit. Enlargement would simply increase the risk of exodus of the irrigating solution and obturation material. Therefore, the cleaning and shaping of the canal and the

more important apical segment should proceed at WL. WL is easily calculated as PL minus 1 mm. This length should be used for the balance of instrumentation.

With PL and now WL confirmed, the canal can be thoroughly cleaned, shaped, and alternately irrigated with sodium hypochlorite (short of WL during instrumentation). At this point, the mid-root of large canals may have already been shaped with either hand files or rotary files to an appropriate length, in which case the apical segment may next be shaped.

Apical preparation

- Shaping the apical segment by rotary or hand instrumentation is the last stage of the crown-down strategy and works in concert with the earlier coronal enlargement strategy.
- Apply a balanced-force motion (downward force and simultaneous reverse cut [see lesson 17]) to the apical WL wall with K-files of increasing sizes, or use a rotary GTX (Dentsply) tapered No. 30 or No. 40 file tip (original apical canal size will set the tip size) to complete the preparation.
- Deliver frequent irrigation deep into the canal (no closer than 3 mm to the WL) without locking the irrigation needle to allow the safe removal of debris and microorganisms from the canal.
- Periodically clean and remove the smear layer (an accumulation of debris on the walls and in the tubules) with a chelating agent such as ethylenediamine tetraacetic acid (EDTA), which can be irrigated into the canal during instrumentation.
- Provided that precoronal shaping is done well, irrigants can more effectively enter and clean the radicular portions of the root canal without requiring aggressive instrumentation.
- During the filing process, repeatedly insert a small No. 10 flexible file to maintain patency. This ensures a clean and open apical portal.
- With the use of effective irrigation, maintained patency, and the prudent use of endodontic instruments in a crown-down strategy, larger and stiffer files are not needed to clean the fragile region of the apical third. Thus the prospect of overenlarging the apical constriction is reduced.
- When coronal enlargement is done effectively, a gutta-percha cone corresponding to the last diameter file used will easily fit to the apical terminus, and the taper and snugness will help prevent extrusion of filling material during compaction.

Caution

When large instruments are aggressively used to WL, errors in length measurement are compounded. Stiff files straighten the original canal position from its center, destroy the apical constriction (at the CDJ), and invite the overextrusion of irrigating solution, sealer, and gutta-percha. The average clinician should utilize an approach that relies upon the use of a combination of instruments, thereby maximizing their strengths and minimizing their weaknesses. It is most prudent to:

- Always use hand instruments to explore and gauge canal levels before using rotary instruments.
- Preflare coronal canal sections before entering the apical third.
- Recapitulate with small K-files to loosen blockages.

• Always clean and shape in concert with the use of irrigants and/or lubricating agents.

Problems

While most experienced clinicians can routinely produce endodontic results that are clinically acceptable (Fig 20-5), even a seemingly simple root canal system can create problems. The following can occur even in the hands of the most practiced clinicians:

• Unfound or missed canals

• Underpreparation and insufficient disinfection

• Overpreparation and overextension of the filling material

• File breakage

• Perforation

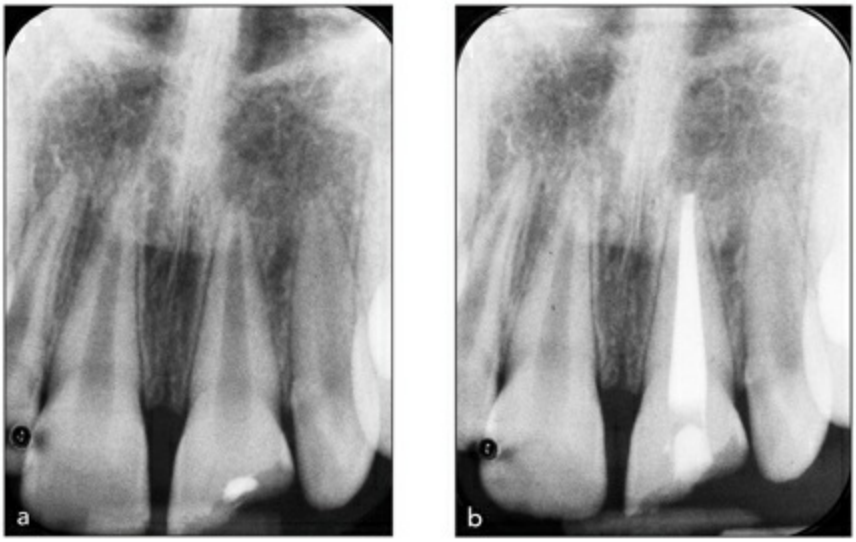


Fig 20-5 This case did not present any difficulties and was treated according to the principles described in this lesson. *(a)* Preoperative radiograph. *(b)* Radiograph taken immediately after removal of rubber dam.

LESSON 21

Shaping and Cleaning the Anatomically Complicated Canal

OBJECTIVE

To understand and master the specific challenges of shaping and cleaning complicated root canal systems.

INTRODUCTION

Root canal anatomy and the confounding nature of human pulpal systems provide the majority of key challenges in rendering root canal therapy. The first priority of effective therapy is to enter, shape, and clean the system in a manner that allows efficient and total filling of the root canal space. We have witnessed in the past two decades increasing innovation in the science and technology of endodontic therapy. These advances are helping to address the complex nature of the pulp space by safer and enhanced methods. These improvements have lessened the chances for iatrogenic problems but have not eliminated them.

COMMON PROBLEMS

Clinicians continue to encounter the problems associated with blockage, ledging, perforation, and transporting the canal systems from their original positions (see discussion in lesson 23 on treating

the obstructed canal). With so many challenges at hand, the practitioner is cautioned to approach the shaping and cleaning of root canal systems with the following general guidelines in mind and an understanding that most cases in this category fall within the class 2 category of moderate difficulty based on the American Association of Endodontists (AAE) Endodontic Case Difficulty Assessment Form (see Fig 7-3).

GENERAL GUIDELINES

Assume curvature in all canal systems

Often, a root canal that appears straight on a radiograph can have multiple curvatures in three dimensions that cannot be captured on a two-dimensional film. It is a fact that all root canals have some curvature, which can occur at almost any position within the root. Curvatures that are hidden from conventional radiographic imaging are susceptible to errors in length determination, overinstrumentation, and canal transportation by clinicians who are unaware of the possible complexities. Recognizing the potential for any instrument fracture around hidden curvature requires the careful clinician to pay serious attention to early pathfinding files that first explore unseen complications within the root canal space (Fig 21-1).

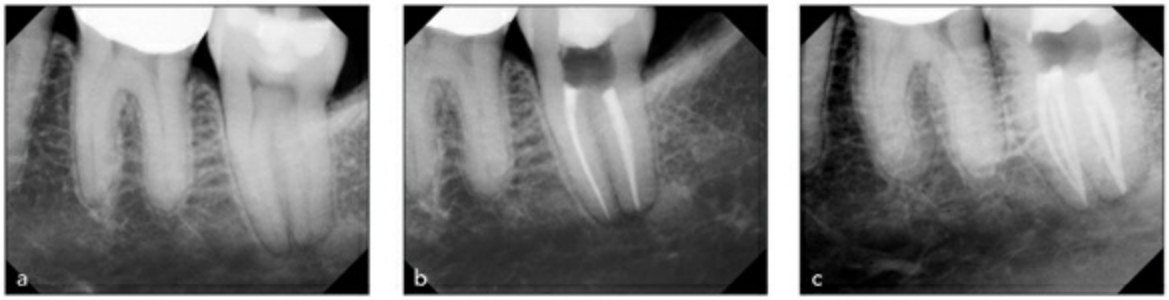


Fig 21-1 Clinical example of challenging root canal anatomy that reveals itself only during the course of the treatment. Such situations are often found in molars, both maxillary and mandibular. This preoperative image of a mandibular molar shows apparently straight roots *(a)* that are easily prepared and filled *(b)*. Only the angulated film *(c)* reveal the anatomic complexities in both roots. (Images courtesy of Dr Ali Rezai, Oakland, CA.)

Understand three-dimensional anatomy

Competent endodontic treatment requires a detailed knowledge of tooth and canal anatomy. The anatomic space presented by the root canal should dictate the course of the procedure. Building mental images and supplementing those images with the tactile feedback acquired during pathfinding helps clinicians to create images of the root systems they are shaping and to avoid preparation mistakes.

An adequate radiographic survey of the tooth or teeth in question is an important first step to gain a mental image of the required task. For any given preoperative evaluation, this would include at least

three radiographic angles. Multiple images such as this help build a three-dimensional picture of the roots and canal space.

Another significant aid in understanding three-dimensional pulp and tooth anatomy is the *3-D Tooth Atlas* by Brown and Herbranson (www.ehuman.com). This atlas has become an invaluable resource to the clinician who wants to understand three-dimensional and cross-sectional anatomy for all tooth morphologies. It also provides access to a library of cases completed by master clinicians worldwide. This information offers tremendous insight into an expert's approach to the instrumentation of variable root canal systems in all teeth.

Caution: Complex root canal systems can lead clinicians to face a multitude of complications:

- Canal transportation, strip perforation, apical perforation, ledge formation
- File fracture
- Root fracture as a long-term consequence of overpreparation or transportation
- Insufficient cleaning and subsequent failure of root canal treatment

Root canal anatomy is particularly significant in the apical third of the root canal. It is here where the most acute curves and lateral canals are found. Canals that merge, divide, curve, recurve, and dilacerate have been reported to be particularly problematic for nickel-titanium (NiTi) rotary instrument preparation. The following strategies will greatly enhance a clinician's ability to understand and resolve complexity in the apical third of root canals.

CORONAL CURVATURE

In an attempt to insulate the pulp space from a microbial challenge initiated by a carious lesion, a coronal layer of re-parative dentin is often laid down. This reparative dentin adds to the natural curvature many molar root canals already have upon exiting the pulp chamber as they course down the root. Mandibular molars often have a typical dentin triangle (Fig 21-2) over their mesial canal orifices. These triangles have to be removed for any file to have unrestricted access into the apical portion of the root canal system. Failure to remove coronal restrictive dentin often results in canal straightening or instrument breakage. Reparative dentin deposition and alterations in coronal canal pathways, as well as dentin bulges that produce acute entry pathways, require strategies for their elimination prior to shaping the canal. For more complicated canal systems, the importance of such a strategy cannot be overstated. Here are some points to remember:

Fig 21-2 Schematic of an important step in treating more complicated canals—the removal of dentin triangles. In this example, removal is accomplished using a laterally cutting nickel–titanium rotary file.

Illumination and magnification

Proper lighting and magnification can create a defining shift in clinician behavior. It is the difference between working in a small dark space hoping you have found all the anatomy versus operating with a complete command and understanding of your skills, seeing the complexity of a case, and identifying the challenges that face you (see lesson 13):

- Locating and negotiating canal spaces that would otherwise remain undiscovered far outweigh the argument to forgo incorporation of magnification in a clinical practice because of cost. The surgical operating microscope allows ideal visualization of any tooth needing therapy and the satisfaction of achieving long-term success from the improved quality of your root canal treatments.

Coronal enlargement

The philosophy of shaping root canal spaces has advanced in the recognition that adequate coronal flaring is an important first step in the negotiation and cleaning process. Once adequate coronal shape has been developed, important advantages are derived in irrigation and lubrication efficiency, apical control of instruments, cone fit, and condensation procedures. Developing adequate resistance forms apically, through coronal enlargement, sets the stage for reliable control of obturation materials.

Using this philosophy, instruments are used only where they can safely fit, with only the smallest files being used to create a glide path to the canal's terminus and the largest being used only at the orifice level. The coronal preparation of root canals is vital when the operator incorporates the rotary options for shaping that include NiTi alloy rotary files as orifice openers, Gates Glidden burs, and/or

Peeso reamers. The glide path now becomes an early tapered shape created by instruments that get smaller as they approach the apex (or larger as they move coronally to the orifice); the ideal early shape culminates in a minimum enlargement apically to a No. 15 to No. 20 hand K-file.

In constricted canals, the glide path to strategic levels within the root canal must be created by using smaller files in serial order from smaller to larger to create the initial space that can accommodate a rotary file. In most instances, Gates Glidden burs and/or rotary NiTi instruments will then follow this pathway. The larger the rotary instrument, the more it should be confined to the coronal levels. The main issue here is to avoid the structural weakening of the roots and the risk of lateral perforation caused by taking large radicular access instruments too deeply into the invaginated roots of posterior teeth.

MID-ROOT CURVATURE

The transition from coronal to apical third in the canal is often uneventful but presents some challenges of its own, most notably the potential for a strip perforation. Overzealous enlargement with Gates Glidden burs or Hedström files may lead to a vertical strip-shaped opening towards the furcation, which is difficult to repair. Of great importance is creating and maintaining the glide path, which in turn allows the safe progress of instruments to proceed apically (see lesson 19). Concentration and attention to detail are imperative if you are to avoid procedural errors by larger hand-held or rotary instruments.

Accurately prebending small apical files

When first negotiating curved canals, one of the most valuable instruments for negotiation and for enhancing tactile acuity of the operator can be the properly curved, pathfinding stainless steel file. An accurately prebent file is far more effective than a straight one in negotiating complex apical anatomy. The ability to prebend a small stainless file is a prerequisite skill that must be acquired to master the apical space in the last millimeters. The apical pathfinding end of the file must be curved smoothly, not kinked. It is bent at the tip in small flexible sizes such as Nos. 6, 8, and 10; it may even assume a C-shaped curvature in the last 2 to 3 millimeters of the instrument. If the canal anatomy is straighter than this bend, the file will flexibly accommodate the canal without improperly shaping it. If the apical anatomy is highly complex with multiple curvatures, it is now a file with the necessary adaptation to negotiate this unorthodox route.

APICAL CURVATURE

Acute curves concealed in the apical third of the root canal predispose the clinician to preparation errors. Blockage and ledge formation may result when a stiffer file is forced indiscriminately into an apical level of the canal. The consequence is loss of patency, short preparation, and short fill. Confirming and maintaining patency are important for successful shaping of complicated canal systems. Several apical strategies have been shown to be effective:

Work passively

Avoid aggressive apical instrumentation at all costs. It is an extremely important clinical paradigm to avoid the creation of ledges and the transportation of the original canal position.

When canals are blocked, control is lost, and the case is immediately in jeopardy. If clinicians can discipline themselves to shun pushing, avoid pressure, and spurn speed, they will circumvent the common pitfalls of aggressive instrumentation. This is neither an easy thing to do nor an easy habit to break. A common lapse is the natural desire to get the instrument into place as quickly as possible. Consequently, the constant temptation to push them is always there, even when they resist passive placement. Finesse *not force* is the recognized value.

Fortunately, once placed, the lightest manipulation easily cleans the apical regions. Tip modifications in both stainless steel and NiTi files decrease the inadvertent mishap of ledging, but they do not eliminate the error when a file is used inappropriately. In fact, the file may fracture unexpectedly (Fig 21-3).

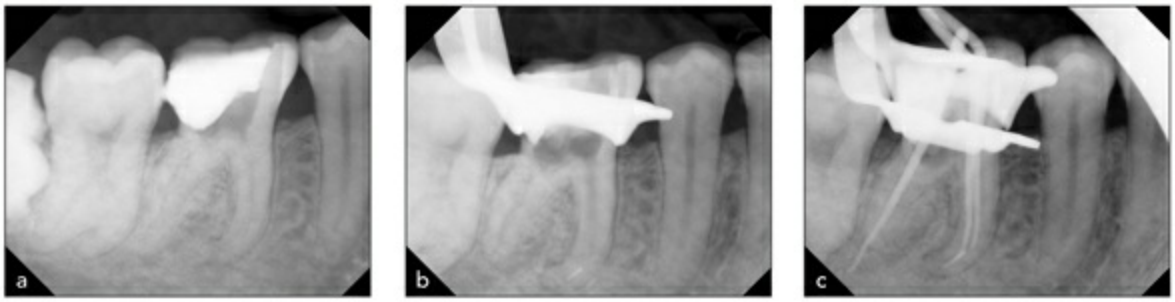


Fig 21-3 Aggressive canal preparation using a stiffer rotary file may create preparation errors but, more importantly, may lead to file fracture in the apical third. *(a)* After accessing the pulp chamber. *(b)* File fragment in the mesiolingual canal apical to the curve. *(c)* The fragment could not be removed, and an attempt is made to fill the canals around the instrument.

Practice patency

The connective tissues within the root canal space are the same tissues that constitute the periodontal attachment; they enter the apical foramen and become pulpal tissue. These tissues have the same embryonic origin and create a continuum from the attachment through the coronal space.

- Removal of the pulp is a surgical procedure at the level of the periodontal attachment, and accounts for the often-felt soreness after pulpal extirpation.
- Patency is the act of taking a small stainless steel file (Nos. 6, 8, 10) just past the apex of the tooth during length assessment to confirm communication past the terminus during shaping procedures. It is invaluable in the tactile feedback to feel the apical constriction where the clinician will develop the end point of a tapered preparation. The file by definition must be small and flexible and not enlarge the apical constriction (see Fig 19-7).
- Cleaning and shaping to the apical constricture most predictably eliminates the bioburden within the canal. Often this *terminus* is felt by the clinician; it can be verified by electronic apex location and

supported by radiographs and paper point measurement.

- The apical constricture becomes the narrowest diameter within the canal space—the optimum point to seal the space. As shape behind the constricture is created and cleaned with irrigants, it becomes appreciably easier to perceptibly feel the constricture and pass through it with precurved patency files. Again, patency should not be confused with overinstrumentation where larger instruments taken through the foramen can damage the constriction and produce the resulting discomfort and inflammation.

Note: Patency offers the clinician distinct advantages in addressing the biologic rationale for treatment:

- The apical portions of the canal are cleaner when irrigant is moved into apical areas by maintaining patency.
- Patency confirmation should precede irrigation, so fresh irrigant can displace existing irrigant when the patency file is withdrawn.
- Irrigant efficiency improves if patency is practiced frequently.
- Practicing continuous patency will alert the clinician when ledging or loss of center within the canal occurs. It is most important at that time to stop instrumentation and to regain patency to prevent shaping errors that may block the canal and contribute to the persistence of inflammation.

Controversy

The concept of apical patency and the resulting passage of patency instruments through the apical foramina of root canals is still controversial for a small minority of endodontic practitioners. They cite concerns about the extrusion of apical debris, inflammation, and postoperative pain. Yet good research over the years has shown that all instrumentation strategies cause the extrusion of apical debris even when filing is kept short of the apical foramen by at least 1 mm. Thus, the practice of apical patency has no direct or indirect association with increased exacerbations or interappointment flare-ups.

CONCLUSION

Anatomic difficulties call for a modification of strategy when preparing curved canals (Fig 21-4). The clinician should carefully:

- Assess canal configuration.
- Flare the coronal third of the root canal first.
- Prepare with flexible files, ideally NiTi rotary instruments, once the glide path is established.
- Utilize file cycling to create space when needed.
- Use precurved small K-files to verify patency.
- Lubricate with sodium hypochlorite and/or ethylenediamine-tetraacetic acid (EDTA)–containing gels

• Create a shape that is most conducive to shaping goals and produces minimal procedural error.

Note: While there are often unexpected anatomic variants and other issues that complicate treatment, following adequate specific instrumentation strategies allows most of the more difficult cases to be treated successfully (Figs 21-5 and 21-6). Lessons 22, 23, and 25 illustrate specific ways to deal with complex anatomic issues and mineralized and/or obstructed canals.

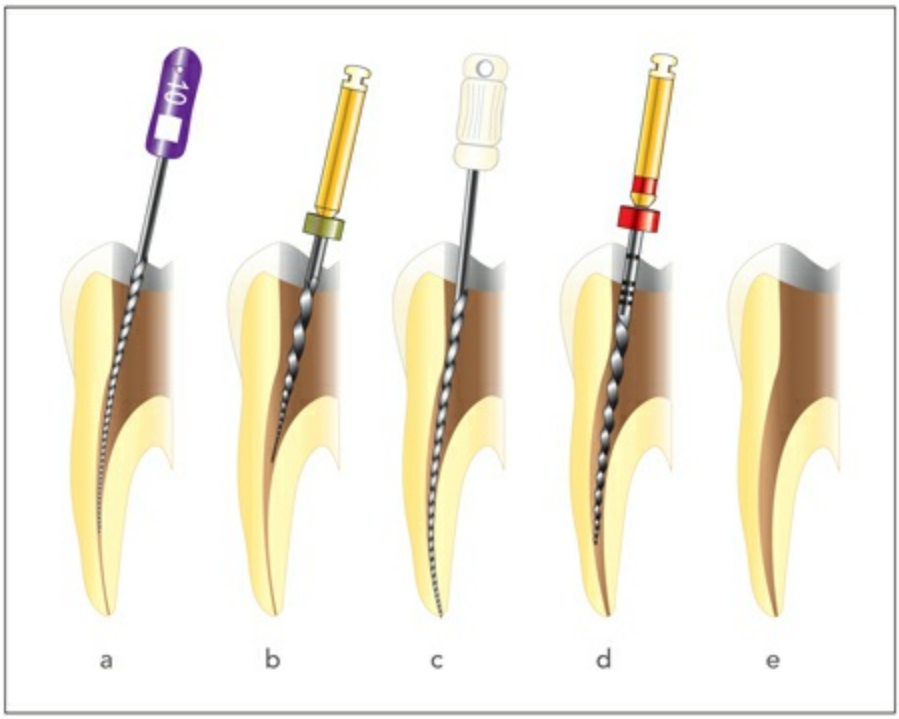


Fig 21-4 Step-by-step preparation of curved canals with a crown-down ap-proach. *(a)* The canals are first probed with a small file (No. 10 or sometimes smaller). *(b)* Rotary files are used to accomplish coronal flare. *(c)* Copious irrigation promotes debris re moval and helps avoid blockages. Then, patency is confirmed and working length determined. *(d)* After confirmation of a glide path with a No. 20 K-file, further crown-down steps with rotary files reach and prepare the apical third of the root canal. *(e)* The final canal shape is a continuous smooth taper.

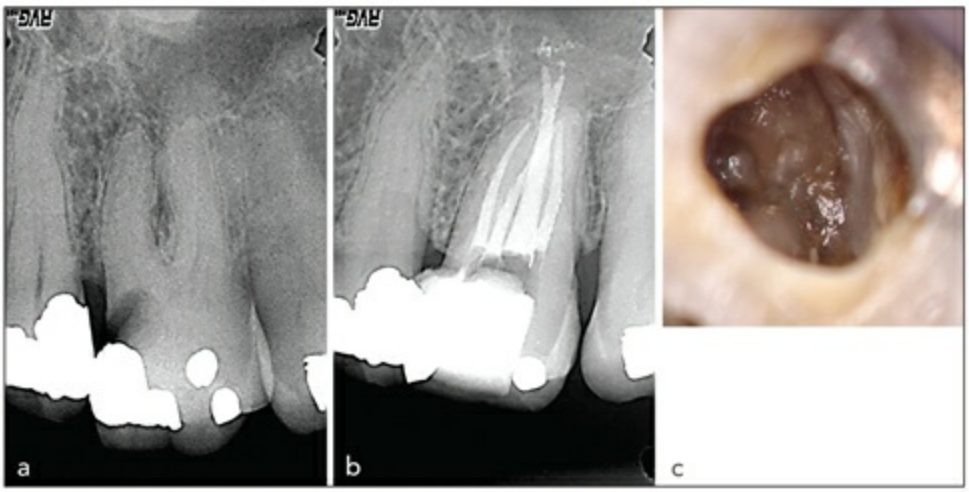


Fig 21-5 Maxillary first molar with four main canals and a bifurcating palatal canal. Diagnostic *(a)* and postoperative *(b)* radiographs are shown as well as a clinical photograph *(c)* depicting the two mesiobuccal canal orifices. (Images courtesy of Dr Tony Vera, San Leandro, CA.)

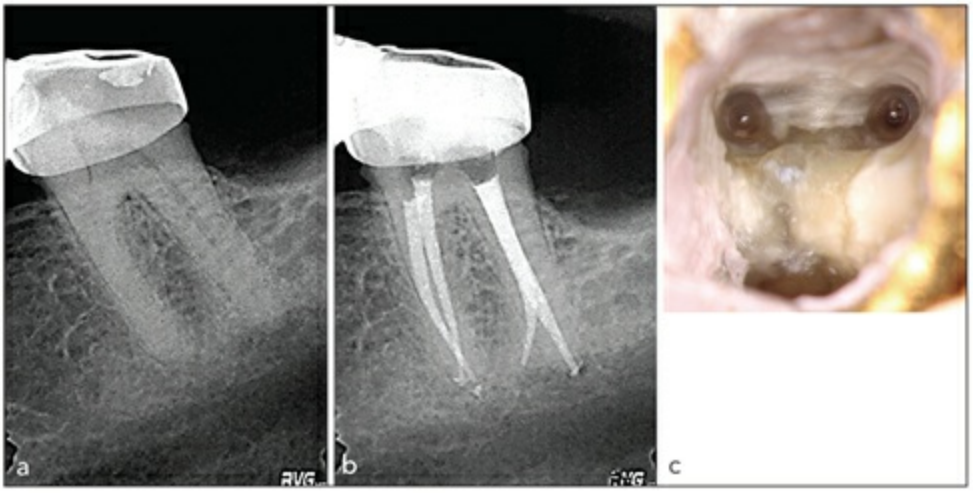


Fig 21-6 Mandibular molar with four canals, in which the second distal canal was not seen at the initial assessment. Diagnostic *(a)* and postoperative *(b)* radiographs are shown as well as a clinical photograph *(c)* depicting the access cavity allowing for the eventual demonstration of the second distal canal. (Images courtesy of Dr Tony Vera, San Leandro, CA.)

LESSON 22

Locating and Opening the Mineralized Canal

OBJECTIVE

To understand the physiologic and pathologic mineralization patterns for anterior and posterior teeth, and to locate and negotiate mineralized canals to obtain canal patency.

Most cases in this lesson fall within the class 2 to 3 categories of *moderate* to *high difficulty* based on the American Association of Endodontists Endodontic Case Difficulty Assessment Document (see Fig 7-3).

MINERALIZATION PATTERNS IN ANTERIOR TEETH

Physiologic mineralization occurs normally and progressively with age in all vital teeth. Mineralized teeth of mature adults are usually less sensitive to cold than are similar teeth in juveniles. Dentin is a good thermal insulator, and the deposition of mineralized dentin in the pulp cavity reduces responsiveness to average stimuli, particularly cold.

The formation of tertiary dentin is the defensive response of a vital pulp to irritation such as caries. The normal anatomy of the pulp is affected locally by this type of irritation.

Traumatic injury may result in generalized mineralization of a pulp that remains vital. This type of mineralization may require endodontic therapy if the pulp eventually becomes necrotic. A radiographic exam repeated over time (months or years) will reveal a less distinct canal in mineralized teeth compared with unaffected teeth. As mineralization proceeds, the cold tests become less reliable. Therefore, periodic vitality tests, especially electric pulp tests, should be conducted to

monitor the vitality of the pulp. These teeth may darken as mineralization progresses (see lesson 41).

Recognizing mineralized canals

The pattern of mineralization differs between single-rooted and multirooted teeth. In anterior teeth, mineralization of the coronal chamber is frequently seen on radiographs. The pattern of mineralization is directed from the coronal pulp horn area toward the radicular pulp. Concurrently, circumferential mineralization occurs in the radicular pulp (Fig 22-1). Commonly, no pulp chamber is visible on the radiograph, and the canal reduces in size until it is nonvisible. This clinical situation must be recognized during the pretreatment evaluation. The clinician must exercise clinical judgment with respect to starting endodontic therapy on an extensively mineralized tooth or referring the case to an endodontist. Specialized equipment and experience are necessary to conservatively locate and treat the mineralized canal without causing excessive removal of tooth structure or perforation.

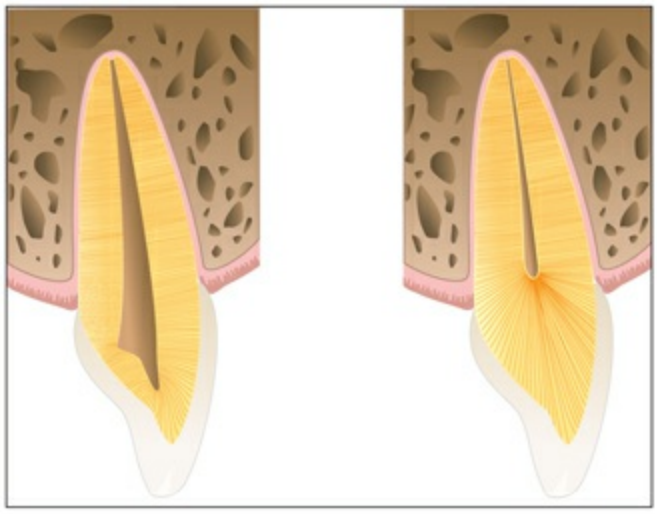


Fig 22-1 Mineralization of anterior single-rooted teeth initiates linearly in the pulp horn area of the coronal chamber and circumferentially in the radicular pulp.

Recommendations

- Whenever possible, a "split dam" without a metal clamp should be placed on heavily mineralized anterior teeth.
- Horizontally angled radiographs from the mesial and distal should be taken frequently during the access preparation to maintain proper orientation. The angled radiographs will disclose the labiolingual extent of the preparation.

Locating mineralized canals

The size and location of the outline form of the access preparation should not be altered for the mineralized tooth. If the clinician is properly equipped with magnification, preparing a larger than normal access opening is unnecessary in locating the opening of a mineralized canal. The outline form is established with the bur directed perpendicular to the tooth. After the dentin is penetrated, all

subsequent instruments are directed within the long axis of the root.

If the chamber appears to be mineralized on the radiograph, do not expect to "drop into the chamber" with the bur. The clinician must advance cautiously with the cutting instruments. A sharp No. 16 explorer may produce a slight catch as the chamber or canal opening is approached.

Recommendations

Specialized instruments are necessary:

- Magnification via microscope enhances vision and provides greater illumination.
- A fiber-optic transillumination device can be used on the external surface of the tooth to illuminate mineralized areas of the chamber and root. The light does not pass through mineralized areas because of the lack of open and continuous dentin tubules. Therefore, the mineralized dentin appears as a dark spot.
- A sharp endodontic No. 16 explorer can serve to chip out calcifications and to probe for the opening of the mineralized canal.
- Specialized ultrasonic tips are designed to remove dentin and to vibrate calcifications (Fig 22-2).
- Dyes may be used to stain residual collagen from the pulp, but the dark color of the dye may impede vision.
- Extended-length burs such as the LN bur or the M bur (Dentsply) are useful for access penetration into the apical third of the root.

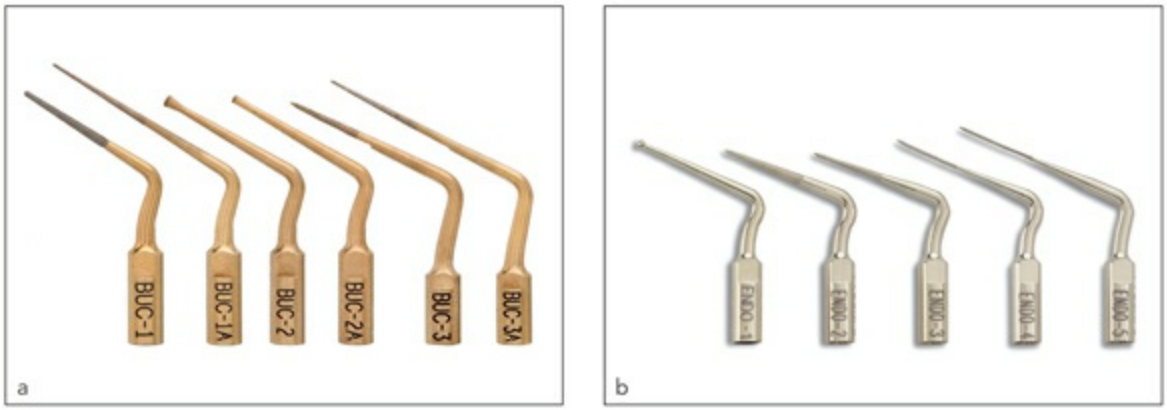


Fig 22-2 *(a)* BUC Ultrasonic Tips (SybronEndo). Tips 3 and 3A are recommended for mineralized canals and canal obstructions. *(b)* Ultrasonic Pro Ultra Endo Tips (Dentsply). Tips 2 through 5 are very effective in the conservative cutting of dentin. High magnification is recommended with the use of these ultrasonic tips.

Opening the mineralized canal

When the opening of the canal is detected as in the subtle catch of a sharp explorer, the canal may be approached more aggressively. If there is any doubt that the catch is the opening of the canal, place a small file in the opening and test it with an apex locator (or radiograph) to insure that the opening is, indeed, the canal. An "out" reading will be signaled on the apex locator if a perforation is present.

The safest rotary instrument to open a small canal is a 20/12 GT rotary file (Dentsply). The instrument is available in 17-, 21-, and 25-mm lengths. The 17-mm length is recommended for opening mineralized canals because the reduced length allows better visualization of the pulp cavity and better "feel" during initial negotiation. The short flute length and the greater taper of the file offer safety against breakage. Furthermore, the instrument is retrievable if it is broken in the canal because of the reduced flute length (only a short section of the file will break in the canal). An ultrasonic instrument can predictably remove any part of this file if it breaks and remove the dentin to facilitate entrance to the canal (Fig 22-3). The rotary instrument is used in an up-and-down "pecking" motion at 300 to 350 rpm. Lubricant should be placed on the flutes of the file. The file opens the original space and enlarges the canal opening to facilitate a pathway for a patency file. When the GT file penetrates to the depth of the flutes, you should irrigate debris from the canal and attempt to establish patency with a small file.

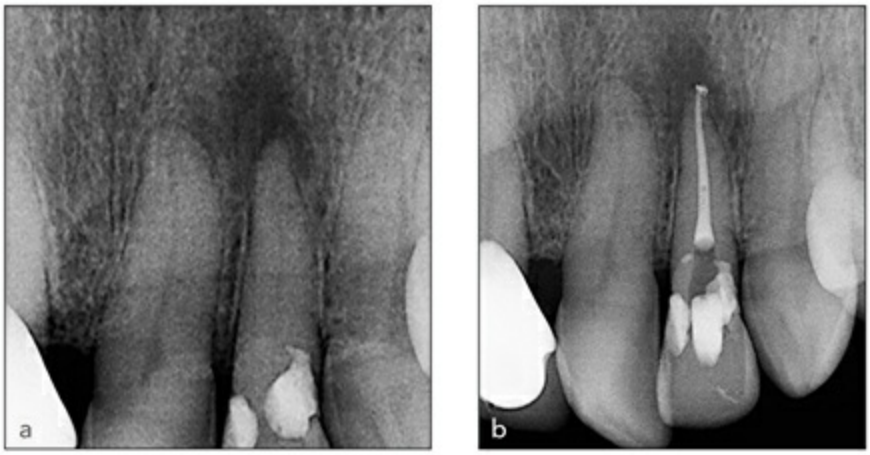


Fig 22-3 *(a)* Deep cervical restorations have contributed to the mineralization of the pulpal space in this maxillary lateral incisor. *(b)* Structural dentin is preserved by the conservative use of ultrasonic technologies in root canal therapy.

Establishing patency

The opening established by the GT rotary file serves as a glide path for small files. Patency files are No. 6, 8, and 10. The stiffness of the C-File (Dentsply) in these sizes is particularly useful for canal negotiation. If obstructions are encountered during attempts to negotiate the canal, the steel files can be precurved to bypass these obstructions. Each file should be lubricated and worked in a combined reaming and filing motion. The reaming motion advances the file apically. The filing motion planes the walls of the canal and develops taper. This combination usually allows space for each progressively larger file to advance. If a blockage is encountered, do not attempt to force the file apically by applying even greater force.

Recommendations

- The best response to blockage is to enlarge the existing space to the point of blockage with larger hand files, usually two to three sizes larger. Then return to the smaller patency files and attempt to bypass the blockage in a clockwise fashion.

- The best methods to gain patency of the canal are to pre-curve the steel files and to apply lubricating agents. In the most challenging of mineralized canals, multiple repetitions of the sequence of files —No. 6, 8, and 10—may be necessary to advance apically to the working length. Always examine the fluting pattern of the small files to look for fluting distortion. Discard worn files.
- Most clinicians agree that a canal should be enlarged to at least a No. 20 hand file to the established working length prior to using additional rotary files to enlarge and shape the canal. The No. 20 file provides a glide path for the rotary files.
- After patency is established and the canal is enlarged to at least a No. 20 hand file, any rotary technique can be applied to clean and shape the canal. The clinician must not lose patency during the cleaning and shaping procedure. Losing patency is considered an iatrogenic error.

MINERALIZATION PATTERNS IN POSTERIOR TEETH

The mineralization pattern for posterior teeth with multiple roots differs from the pattern encountered in those with a single root. Coronal chamber mineralization occurs on the roof and the floor of the chamber simultaneously (Fig 22-4). The radicular pulp mineralizes circumferentially, in the same pattern seen in single-rooted teeth:

- A bitewing radiograph is useful in determining the extent of mineralization in the coronal chamber of a multirooted tooth.
- Preoperatively, the clinician must study the radiographs. Horizontally angled radiographs should be taken in addition to perpendicularly angled radiographs.
- The distance from a cusp reference point to the chamber of the canal should be measured, and to prevent perforation of the furcation, the bur used for access preparation should be placed in the handpiece at this length.

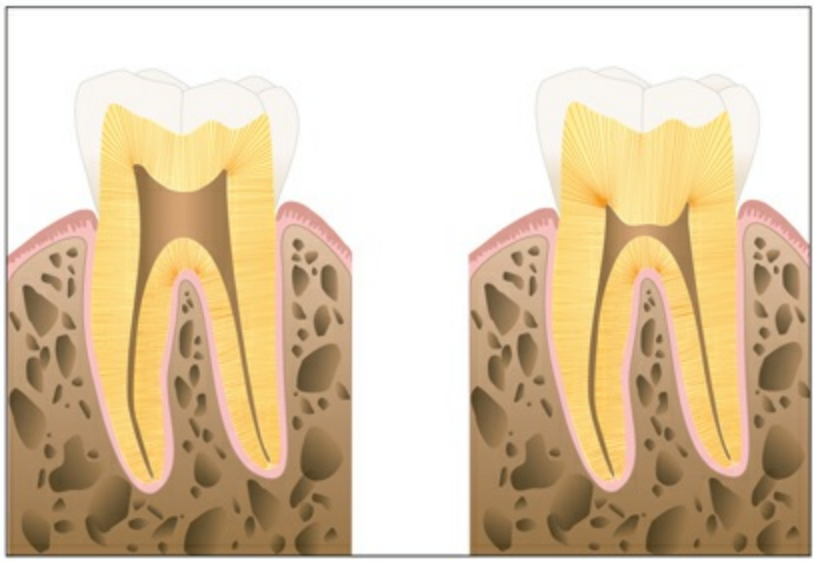


Fig 22-4 The mineralization of multirooted teeth occurs on the roof and floor of the coronal chamber. Radicular mineralization occurs circumferentially, as in single-rooted teeth.

Locating mineralized canals

The outline form of the access preparation is the same in teeth with mineralization as it is for teeth without mineralization. The bur used for dentin penetration should produce a flat surface of cut dentin. An end-cutting, crosscut fissure bur is recommended for this purpose:

- A flat dentin floor facilitates visualizing the "road map" on the floor of the chamber. Transillumination with fiber-optic light, dyes, and magnification are useful aids for canal location (Fig 22-5).
- As the floor of the chamber is exposed, the color of the dentin becomes darker. The darker color results from the entrapment of blood pigments within the dentin.
- The clinician should probe the road map areas with a sharp explorer until the opening of the canal is engaged. Usually, the larger canal in the system is located first.

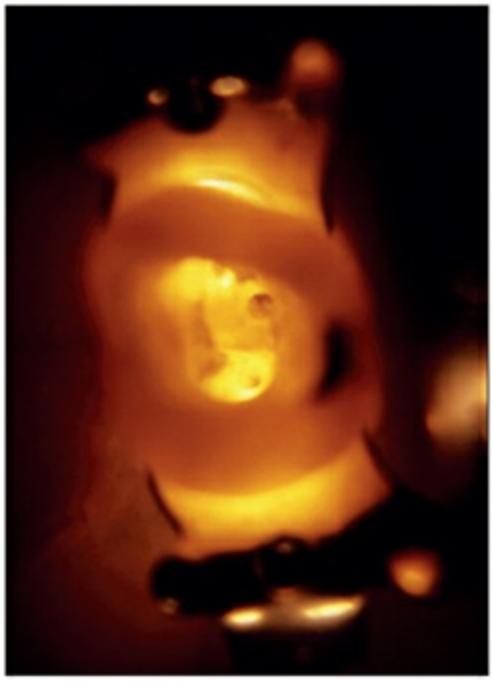


Fig 22-5 Fiber-optic transillumination may assist in the location of mineralized canals. The mineralized areas of the canal do not allow transmission of light. The high intensity light stops in an area of mineralization due to the lack of dentin tubules to conduct the light.

Recommendations

- Verify that the opening is a canal, and then proceed with establishing patency and cleaning and shaping as described earlier.
- In a mineralized canal system, fully clean any canal that has been found before attempting to locate other canals.
- As cleaning and shaping proceed and the canal is irrigated with 0.5% to 6.0% sodium hypochlorite, visualization of the chamber anatomy improves due to the bleaching effect of the irrigant. Follow the road map to determine the most likely location of other canals.
- Opening mineralized canals accelerates the wear of rotary files. To avoid natural fatigue, change the files frequently.
- During the access preparation, radiographs may be necessary to evaluate the depth of preparation

and the proper orientation of the access cavity.

- Use a split-dam application if the tooth being treated is not the terminal tooth. Otherwise, use a plastic radiolucent clamp to image the progress of access preparation without blocking the x-ray beam with a metal clamp.
- If a canal is not located after chamber access has been established, the clinician must exercise judgment with regard to continuing the procedure. Access should continue only as long as the clinician can visualize the canal space and landmarks.
- The rule, "proceed as long as you can see," should be followed.
- Magnification devices, such as an operating microscope, extend the depth of a safe access preparation.
- Refer problematic cases to an endodontist prior to creating an irreversible error.

Establishing patency

The same methodology should be used for posterior teeth as for anterior teeth. Because posterior teeth have more roots and canals than do anterior teeth, the clinician must be familiar with the normal and abnormal anatomy of the tooth being teated. Once access to the canal is confirmed, the clinician should proceed as follows:

1. Open the coronal third of the canal with a 20/12 GT rotary file. Lubricate the file as it is used in an up-and-down pecking motion. Direct the file in an anticurvature direction, away from the furcation.
2. Set the rotation speed in the range of 300 to 350 rpm. Clean the flutes often and lubricate the file frequently.
3. Use the patency files (Nos. 6, 8, and 10) as previously described.
4. If a hard blockage is encountered before patency is achieved, do not attempt to gain patency by applying more pressure to these small files. Clean and shape the canal to the depth of the blockage. Return to the patency files, and then attempt to bypass the blockage. Precurving the files improves the chances of successful bypass.
5. Once patency is established, continue cleaning and shaping with hand files until at least a No. 20 file is accommodated. Any rotary technique can be applied safely after this glide path has been established.

Recommendations

- Cleaning and shaping to the point of blockage enlarges the canal diameter at all levels and reduces the severity of curvature of the canal.
- Precurving the small files allows the clinician to feel around the circumference of the blockage, thereby increasing the chances of bypassing the obstacle.

LESSON 23

Managing the Obstructed Canal

OBJECTIVE

To identify the best evidence and retrieval strategies for managing a previously treated tooth that exhibits a metallic obstruction while ensuring the soundness of the remaining tooth structure and patient safety.

Most cases in this lesson fall within the class 3 category of *high difficulty* based on the American Association of Endodontists Endodontic Case Difficulty Assessment Document (see Fig 7-3).

INTRODUCTION

It is always necessary to make a pragmatic pretreatment assessment of the degree of difficulty involved in any attempt to reclaim the root canal space. The clinician must answer the following questions regarding the practicality of the retrieval of an obstruction:

- How accessible is the obstruction and what level of clinical skill or expertise is required (Fig 23-1)?
- What are the consequences if unexpected complications arise? In other words, what alternative treatments may be beneficial?

Note: The practitioner must always have a realistic notion of the challenges ahead and apprise the patient of the prognosis for any retreatment procedure. The following stages comprise the reclamation of a previously treated and now obstructed canal space:

1. Disassemble coronal restorations
2. Establish access to the root canal system
3. Retrieve or bypass the canal obstructions
4. Establish access to the apical third and patency
5. Reshape, clean, and obturate

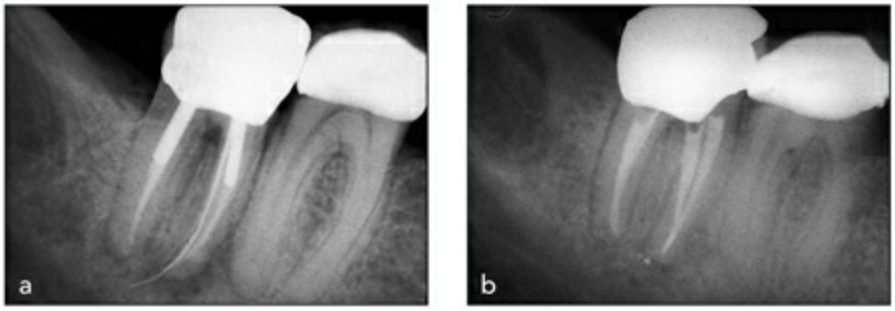


Fig 23-1 *(a)* Mandibular molar exhibiting prior treatment with multiple ob-structions including posts and silver cones. *(b)* Retrieval of obstructions and retreatment accomplished by an expert clinician. (Images courtesy of Dr William Goon, San Francisco, CA.)

CORONAL RESTORATIONS

Separated instruments, posts, and silver cones that are embedded below the root canal orifice present a formidable challenge when their removal is indicated. Accessing, exposing, troughing, and cutting away restorative materials surrounding an obstruction are features common to all retreatment techniques (Fig 23-2).

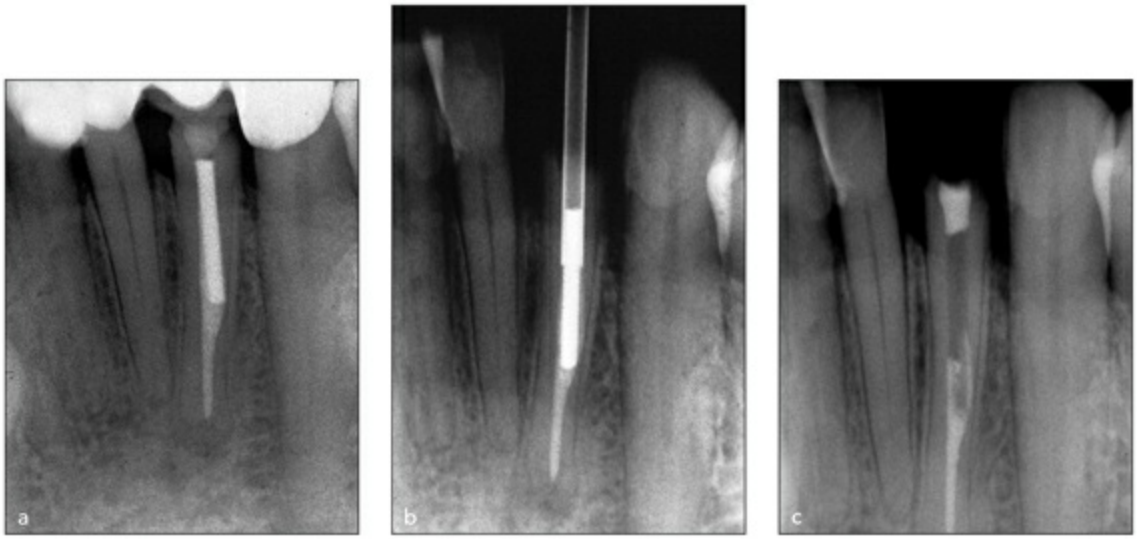


Fig 23-2 *(a)* Removal of a fixed partial denture required post removal to rehabilitate and re-treat a mandibular incisor. *(b)* After disassembly of the bridge and coronal restorative materials, a trephine bur surrounded the post fragment. *(c)* Removal of the post allowed for retreatment and definitive restoration of the tooth.

Accessing the pulp chamber

The pulp chamber is typically accessed through the existing restoration if it is judged to be functionally designed, well-fitting, and esthetically acceptable. Strategically, the decision to remove any restoration is based primarily on whether additional access is required to facilitate disassembly and revision of the prior root canal therapy. If the restoration is deemed inadequate and/or additional access is required, the restoration should be removed entirely. Situations requiring crown removal are made easier by a number of crown removal devices. In most circumstances, the clinician should objectively weigh the accepted benefits of cutting off the crown. Access to the canals, improved visibility, and enhanced coronal seal may make the step worthwhile.

Problems

While burs may seem the most expeditious route to reclaim the root canal space, the ability to safely accomplish this goal depends on the ingenuity and technical abilities of the dentist. Operative burs are indiscriminate cutting instruments and can be extremely destructive. A bur's potential for gouging, root perforation, and structural mutilation must be recognized.

REMOVAL OF POSTS

Clinicians commonly encounter endodontically treated teeth that contain posts. When endodontic treatment fails to achieve healing, you may need to remove the posts to gain access for retreatment. In other instances, the endodontic treatment may be judged successful, but restorative needs require the removal of an existing post to improve the function, fit, or esthetics of a new restoration.

Factors affecting post removal

Many factors influence post removal:

- Operator judgment, training, and experience.
- Choice of technologies and techniques.
- Interocclusal space.
- Existing restoration.
- Location of the most coronal aspect of the post, whether above or below the bone.
- Post type: Posts can be parallel or tapered, active or non-active, metallic or nonmetallic.
- Post cementing agent: Zinc phosphate ($Zn_3(PO_4)_2$) can generally be removed more predictably than can composite resins or glass ionomers.

Furthermore, clinicians should be knowledgeable about the anatomy of the teeth being treated and familiar with the typical range of variation associated with each tooth type. The clinician must consider:

- Three-dimensional tooth morphology
- Length of roots

• Circumferential dimension of any given root
• Curvature
• Depth of any external concavity

This information is best achieved by obtaining several well-angulated preoperative radiographs. These radiographs also assist the clinician in visualizing the length, diameter, and direction of the post.

In general, post removal becomes more challenging moving from anterior to posterior teeth. Once straight-line access into the pulp chamber has been accomplished, all core materials have been eliminated, and the post has been fully exposed, a variety of techniques are available to finally remove a post.

Post pullers and post extractors

Removal of an obstructing post can be facilitated by using devices such as post pullers and post extractors. The use of these devices should be restricted to the removal of dowels that exhibit significant supragingival exposure. A post extractor system requires the circumferential troughing of the cement interface between the dowel and the dentin wall after disassembly of all coronal restorative materials. Subsequently, the extractor is threaded securely onto the exposed post, and a post puller (vise) is then engaged to the extractor while protecting the remaining tooth structure. As the vise is opened, it lifts out the post along the root's long axis. Extractors work best when adjunctive techniques for loosening dowels are also incorporated, such as ultrasonics (Fig 23-3).

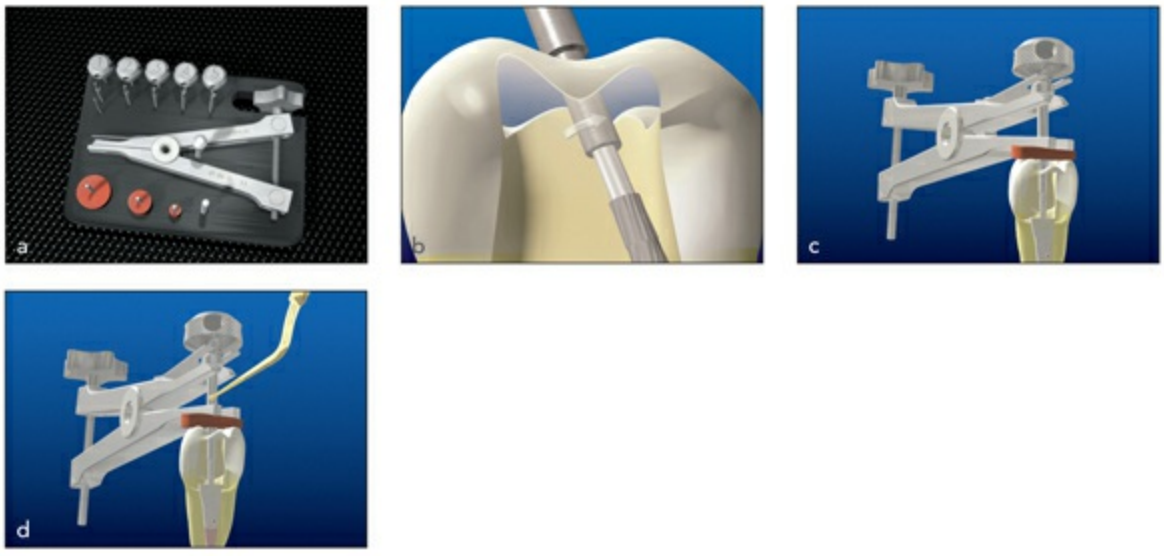


Fig 23-3 *(a)* Ruddle Post Removal System (SybronEndo). *(b)* Sized trephine bur machining the top several millimeters of the obstructing post. *(c)* Extracting pliers and tubular tap assembly prior to post extraction by the pliers. A bumper protects the tooth structure. *(d)* An activated ultrasonic instrument applied to the tap can enhance the retrieval effort. (Graphics courtesy of Advanced Endodontics.)

Ultrasonic applications

The active distal end of an appropriately designed ultrasonic instrument may be kept in intimate contact with the post to maximize energy transfer and promote cement or bond failure. The selected ultrasonic instrument is energized and moved around the post circumferentially and up and down along its exposed length. The use of these mechanical vibrations has emerged as a highly efficient method of dislodging solid objects from their cement bond to facilitate removal. A piezoelectric generator is utilized in conjunction with ultrasonic instruments to transfer energy and perform a variety of clinical procedures. When used with the superior lighting and magnification of an operating microscope, you can be certain that you are making use of the most effective means to accomplish a desired outcome.

Other uses

After removing all circumferential restorative materials, the majority of dowel posts can be safely and successfully removed within approximately 10 minutes. Certain posts may resist removal if only ultrasonic efforts are used. Therefore, it is recommended that you use a synergistic strategy that incorporates the use of adjunctive devices such as post extractors.

Current ultrasonic tips (Fig 23-4) and devices (Fig 23-5) expand the range of treatable problems to include:

- Disintegrating insoluble paste formulations
- Bypassing and dislodging separated burs and endodontic files (Fig 23-6)
- Disrupting amalgam shavings and instruments from deep within the root canal

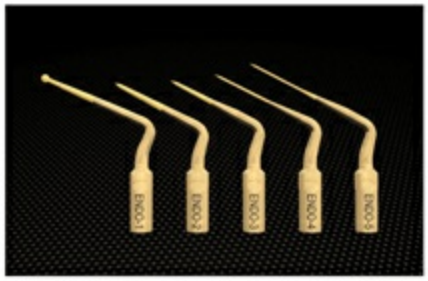


Fig 23-4 Series of ultrasonic Pro Ultra Endo Tips (Dentsply) uniquely designed for disassembly of restorative materials and cements as well as for troughing around obstructions. (Graphic courtesy of Advanced Endodontics.)

Fig 23-5 P-5 Newtron XS ultrasonic de-vice (Acteon Satelec). (Graphic courtesy of Advanced Endodontics.)

Fig 23-6 CPR tips titanium series (Dentsply). Nos. 6, 7, and 8, are ultrasonic instruments designed to be used with high magnification for deeper obstructions such as separated instruments. Power settings are at lower intensity for these more delicate instruments. (Graphic courtesy of Advanced Endodontics.)

Techniques

Access preparations should be thoughtfully planned and prepared to minimize the risk of inadvertently foreshortening silver points or other metallic obstructions:

- Initial access is accomplished with high-speed surgical-length cutting instruments.
- Ultrasonic instruments may be carefully utilized within the pulp chamber to cut away restorative materials and progressively expose a silver point while avoiding direct contact of the silver point with the ultrasonic tip.
- If large silver cones are first bypassed by hand-held stainless steel files, frequently the clinician will displace them by applying energy to specialized tips working around the periphery of the point, or by indirectly energizing a file that has bypassed the point.
- Smaller silver cones can often be grasped, levered, and dislodged with specialized pliers.
- Files can also be braided around the point and engaged in an outward pulling motion (Fig 23-7).

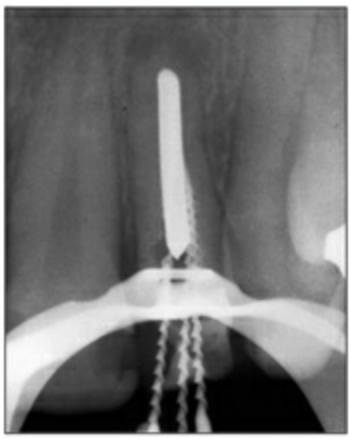


Fig 23-7 Three Hedström files surround a very large silver cone. The files are twisted around each other to bite into the softer silver cone and promote removal.

REMOVAL OF SEPARATED INSTRUMENTS

All clinicians who perform endodontic procedures experience procedural accidents such as the separation or fracture of an instrument. During root canal preparation procedures, the risk of instrument breakage or fracture exists. Instrument breakage is always stressful to the clinician. The term *separated instrument* could also apply to a sectioned silver point, a segment of a lentulo spiral, a Gates Glidden (GG) drill, a portion of a carrier-based obturator, or any other device obstructing the canal. The advent of rotary nickel-titanium (NiTi) files has resulted in an increase in the occurrence of separated instruments in the last decade. Today, separated instruments can often be removed because of the technologic advancements in visibility, illumiation, ultrasonics, and microtube delivery methods (Fig 23-8). With the increasing integration of the dental operating microscope into clinical practice, clinicians can visualize the coronal portion of most fractured instruments. These strategies have greatly improved the potential and safety of removing broken instruments. However, not all instruments can or should be removed, as the potential for a catastrophic mishap resulting in loss of the tooth is ever present.

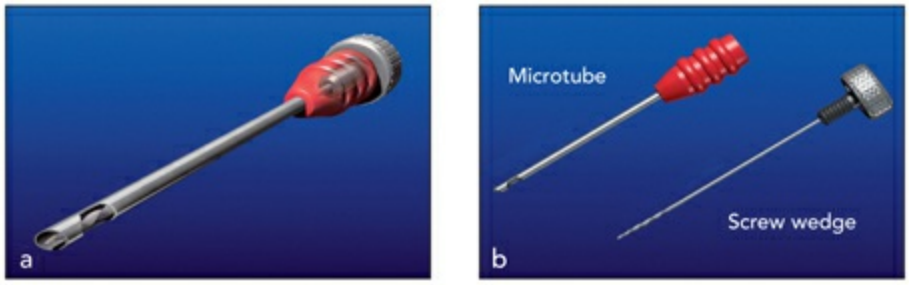


Fig 23-8 *(a)* IRS (San Diego Swiss Machining) instrument removal system offers sized microtubes and insert wedges that are scaled to work deep within the root canal space to grasp a separated instrument. *(b)* Each IRS instrument assembly offers a microtube with a cut-out window and an insert-threaded screw wedge. (Graphics courtesy of Advanced Endodontics.)

Do all broken instruments need to be removed?

When considering the best evidence, the answer is no.

In noninfected canals

- Cases involving separated instruments in noninfected vital teeth have the same prognosis as their counterparts that are appropriately filled.
- In situations where there is an apical separation of an instrument, some credence must be given for obturation to the coronal level of the instrument and then appropriate monitoring. The patient must be informed.

In infected canals

- The prognosis is much more problematic.
- Instrument separation or an obstruction in the apical third of a tooth with an obvious infection results in a persistence of that infection unless the instrument or obstruction can be bypassed or removed

(Fig 23-9).

- Instrument retrieval or bypass can be contemplated in the coronal third of canals as well as deeper retrievals above any curve in the root (Fig 23-10).

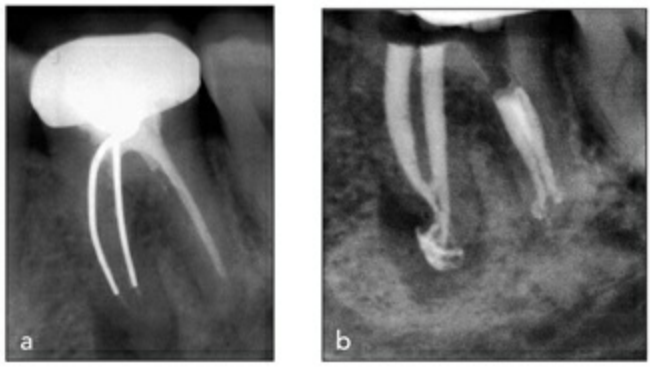


Fig 23-9 *(a)* Silver cones inadequately seal the mesial roots of a mandibular molar with evidence of persistent infection. *(b)* Retreatment with gutta-percha after silver cone removal. The successful obturation of the three-dimensional anatomy includes an unfound canal system in the distal root. (Images courtesy of Dr Ralan Wong, San Francisco, CA.)

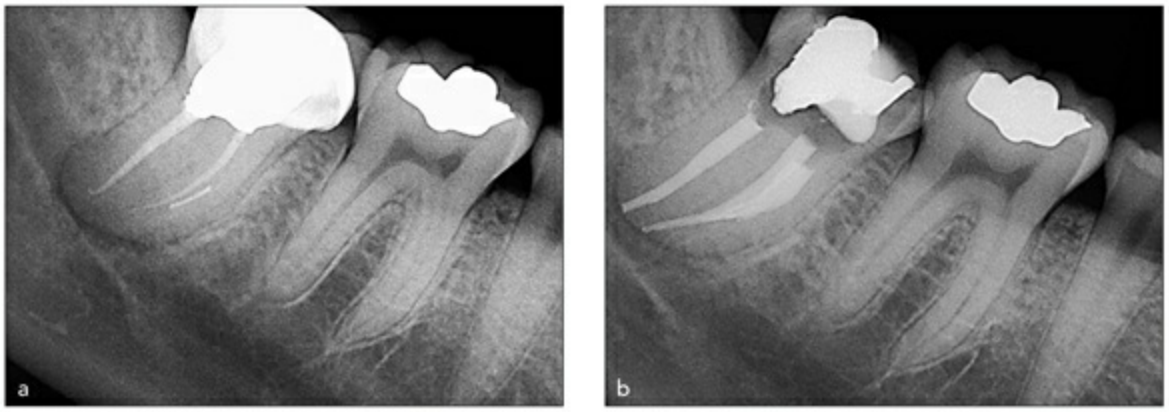


Fig 23-10 *(a)* Fractured instrument in the mesiolingual canal of a mandibular second molar. *(b)* After bypassing it with smaller curved instruments, shaping and obturation proceeded to the terminus. (Images courtesy of Dr Wyatt D. Simons, San Clemente, CA.)

Factors influencing removal

The factors influencing nonsurgical access and removal of a broken instrument include the diameter, length, and position of the fragment within a canal. Additionally, the chosen approach to safely remove a broken instrument is guided by the three-dimensional anatomy of the canal. Limiting factors include the circumferential dimensions and thickness of dentin and the depth of an external concavity. In most instances, if a third of the overall length of an obstruction can be exposed, it can usually be removed. Instruments that lie in the straight, more coronal portions of the canal can be removed more readily than can separated instruments that lie partially around canal curvatures. If the fractured instrument segment is apical to the curvature of a canal and access will compromise the structural integrity of the root, then removal should not be contemplated. In the presence of signs or symptoms, apical surgery or an extraction may be required.

Recommended instruments

When contemplating instrument retrieval, you must have, at the very least, the following instruments:

- A surgical microscope or high-powered loupes with effective illumination
- An ultrasonic unit and specialized tips
- An adjunctive microtube device
- Bypassing files and staging drills

Creating radicular access

A number of different techniques may be employed to flare the canal coronal to an intracanal obstruction.

A predictable way to create safe radicular access is to:

1. Initially use hand files—from small to large—coronal to the obstruction. Hand files create sufficient space to accommodate NiTi orifice openers, or preferably, GG drills.
2. Typically, size 4 to 1 GG drills are employed in the coronal third of root canals. In many cases, GG drills are used to create radicular access and a uniform tapering funnel to the obstruction. They are safely rotated at speeds of about 750 rpm. Increasingly larger GG drills are uniformly stepped out of the canal to create a smooth-flowing funnel that is largest at the orifice and narrowest at the obstruction:
   - To avoid strip-perforations, limit the use of GG drills to the coronal straight portions of the canal.
   - In the case of a fractured instrument in a larger root cross section, however, you can carry a small GG drill to the depth of the head of a separated instrument. Use the GG burs cautiously in approximating the obstruction with attention to cutting away from the furcation in multirooted teeth.
3. Deliberately relocate the coronal third of a canal away from the furcation to maximize the remaining dentin, produce a more centered preparation, and improve straight-line radicular access to the fragment.
4. If more lateral space is required, modify the cutting head of a GG drill and use it to create a circumferential "staging platform:"
   - To make the staging platform, select a GG drill with a maximum cross-sectional diameter slightly larger than the visualized instrument.
   - Alter the cutting portion of the GG drill by cutting it perpendicular to its long axis at its maximum cross-sectional diameter.
   - Carry this modified GG drill into the preenlarged canal, using a reduced speed of approximately 300 rpm and directing it apically until it lightly contacts the most coronal aspect of the obstruction. This clinical step creates a small platform that facilitates the introduction of an ultrasonic instrument or bypassing instruments to engage the obstruction (Fig 23-11).

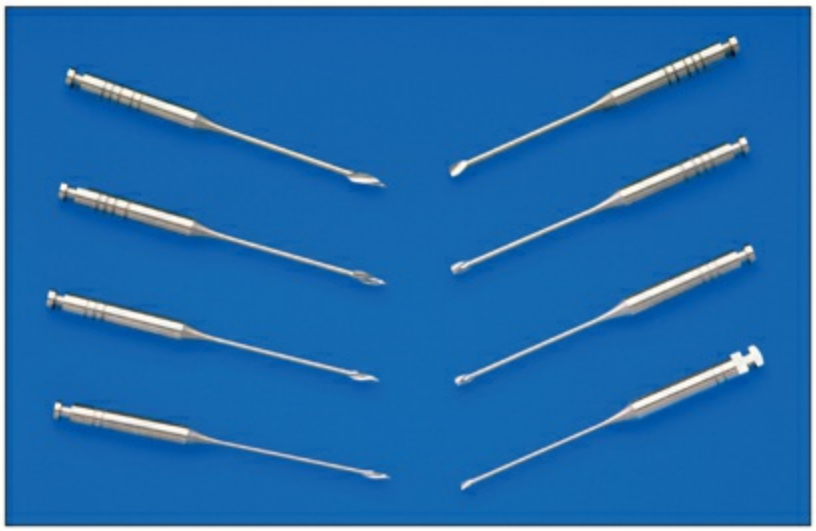


Fig 23-11 Modification of Gates Glidden drills to create staging platforms above broken instruments prior to retrieval efforts. (Image courtesy of Dr Clifford Ruddle, Santa Barbara, CA.)

Removing the obstruction

Twisted Hedström file technique

When adequate space has been created around a metallic obstruction such as a silver cone, GG drill, rotary instrument fragment, or file section, you can braid three Hedström files of sufficient size and grasping ability around each other to create a firm grip around the object. After several attempts, the use of applied directional leverage often dislodges the obstruction (see Fig 23-7).

Microtube devices

A number of devices and techniques have been utilized to remove an intracanal obstruction such as a separated instrument. As described, the most predictable and safest removal strategies in use today employ a microscope in conjunction with optimally designed ultrasonic instruments and/or a microtube.

1. Lightly move the selected ultrasonic instrument, in a counter-clockwise direction, removing dentin around the obstruction:
   - Conduct all ultrasonic preparation below the orifice with a compressed air stream so that visualization of the energized tip against the broken instrument is possible. If used correctly and cooled with water and air, these ultrasonic techniques do not generate sufficient heat during the removal of fractured instruments to become harmful to the attachment apparatus.
   - Gently placing the energized tip between the tapered file and canal wall may cause the broken instrument to move suddenly in the coronal direction (Fig 23-12).
2. In circumstances where a separated file tip is located further apically in a slender root morphology, ultrasonic procedures are restricted to a smaller space. Ultrasonic instruments with longer lengths and smaller diameters are designed specifically for this task and may be useful in promoting safe retrieval (see Fig 23-6).

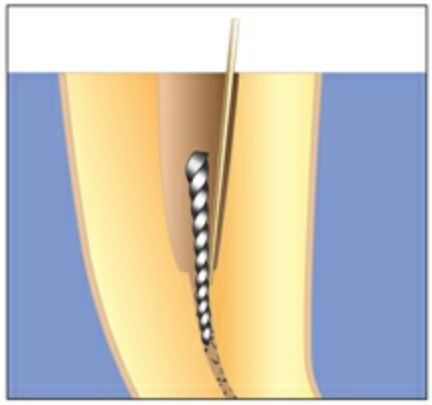


Fig 23-12 Ultrasonic tip circumferentially removing structural dentin to free a fractured instrument.

For difficult cases

Despite sufficient coronal and radicular access, exposure of the separated instrument, and ultrasonic trephining procedures, it may be impossible to loosen and extract an instrument from the canal. Reduced visibility or the presence of anatomic restrictions may make continuing efforts unsafe.

In this instance, small hand files are necessary to partially or completely bypass or remove an instrument fragment. The bypassing procedures should always be attempted in a canal well lubricated by chelation. As bypassing attempts continue, several microtube removal methods can be employed to mechanically engage an intracanal obstruction as dentin is negotiated circumferentially (Fig 23-13 and see Fig 23-8). These microtube systems are scaled to fit and work deep within the root canal space:

1. Ultrasonic instruments can only circumferentially trephine dentin, so they expose the portion of the obstruction that lies in the straight portion of a canal. To create the potential for microtube retrieval, therefore, expose 2 to 3 mm, or about a third of the total length, of a separated instrument.
2. If a microtube can be placed over a broken instrument such that the head of the obstruction lies within the tube, then the lumen of the microtube can be bonded with cyanoacrylate (Cancellier Kit [SybronEndo]), grasped (Endo-Extractor System) (see Fig 23-13), or wedged (IRS Superior Edition [San Diego Swiss Machining]) onto the fragment.

Fig 23-13 Endo-Extractor System (Royal Dental Products).

FURTHER CONSIDERATIONS

Microtube devices have become increasingly sophisticated in recent years to provide key adjunctive support in fragment retrieval. Removal of all manner of fragments such as silver cones, carrier-based obturators, or separated file segments is now possible within the dictates established by a tooth's anatomy. The best remedy for a separated instrument is prevention and the incorporation of clinical strategies promoting the safe and prudent use of canal filing systems that minimize separations. Because no technique for retrieval of an obstruction is universally applicable to every situation, the clinician who attempts retrieval should be thoroughly familiar with the entire spectrum of retrieval techniques and armamentarium. The ultimate goal of any retrieval attempt is not only to salvage the root canal but also to ensure the soundness of the remaining structure.

Ultrasonic energy and heat transfer

The prudent practice of dentistry dictates that the safe usage of ultrasonic devices is paramount. Expediency should not compromise proper procedural design to protect a patient's safety and welfare. Since dentists are taught to be cautious with heat-generating devices contacting hard and/or soft tissue, a reasonably careful dentist should always be mindful of the excessive heat potential of ultrasonic devices despite accompanying water coolants. Ultrasonic usage for obstruction removal should be coupled with monitoring intervals to assess overheating and to permit post cooling.

Ultrasonic energy can be harmful, since intense heat can be generated within a metallic object that has its distal end millimeters away from any cooling effects created by the operator or the device itself. The use of heat and the potential for injurious heat transfer to dentin and bone has been investigated for a number of different devices used in endodontics and associated restorative procedures. It is generally accepted that external root temperature increases exceeding 10°C produce irreversible bone and attachment damage. Intraradicular heat transfer and thermal injuries are a clinical reality when ultrasonic procedures are incorrectly performed without coolant and for prolonged periods of time (Fig 23-14).

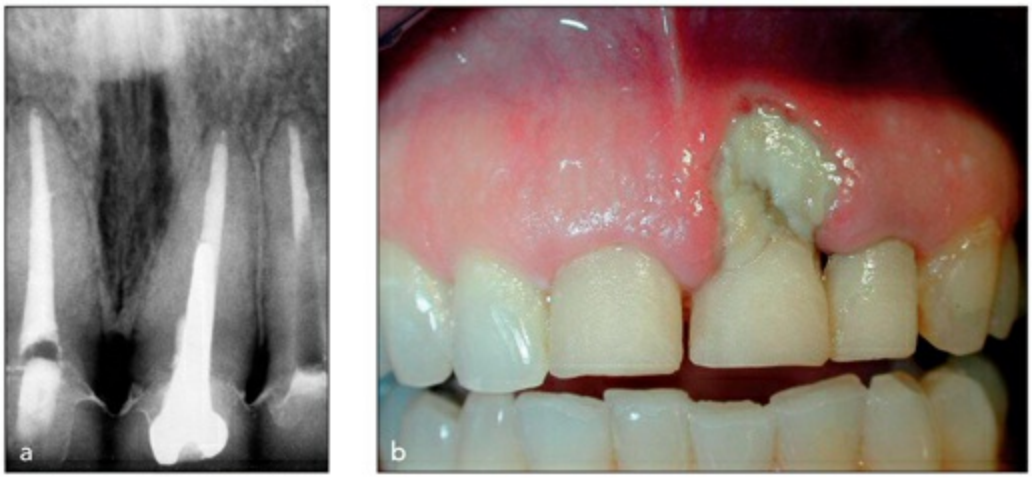


Fig 23-14 *(a)* Preoperative radiograph of a metal post in a maxillary left central incisor. *(b)* Postoperative ap-pearance of an ultrasonic burn after post removal. The tooth was extracted 48 hours after the injury. Bone loss was extreme and disfiguring in this case.

Suggestion

Based on the best available evidence to date, the following protocols are recommended to provide safe and effective therapy using ultrasonic devices in intraradicular obstruction removal:

- Attempt to radiographically image residual dentin thickness for the working level within the root. This will help you to judge heat transmission rates to the attachment. Thicknesses under 1 mm in combination with metallic or ceramic posts transmit heat rapidly (Fig 23-15).
- Use devices that allow water to reach the working end of the ultrasonic tip. This provides maximum cooling effect.
- Use copious water spray and effective suction at a continuous rate. Ample evidence indicates that heat generation occurs rapidly when the working end of any ultrasonic device is deep within the root.
- Monitor the post temperature at 1- to 2-minute intervals. This seems to be the most prudent standard given the evidence that extreme temperatures on the root surface, even while using coolant, can be reached in 5 minutes.
- Where physically accessible heat buildup in the post can be monitored by touching it. You can sense a post overheating with your gloved finger.
- Allow reasonable intervals between applications of ultrasonic energy. If post removal attempts are continued beyond 10 minutes, rest intervals between ultrasonic device applications should be at least 2 minutes. Consider using timers with beepers to monitor time intervals; heat buildup appears to be dissipated in stages, and recovery of physiologic temperatures occurs very slowly.
- Incorporate refrigerants (ethyl chloride [C_2H_5Cl] or Endo-Ice Refrigerant spray [Coltène Whaledent]) applied to a cotton tip or ice sticks to cool the post if necessary. The expansion and contraction effects of this strategy are minimal compared to the severe outcomes of a burn injury.
- Use post pullers and other microtube devices as adjuncts to ultrasonic energy.

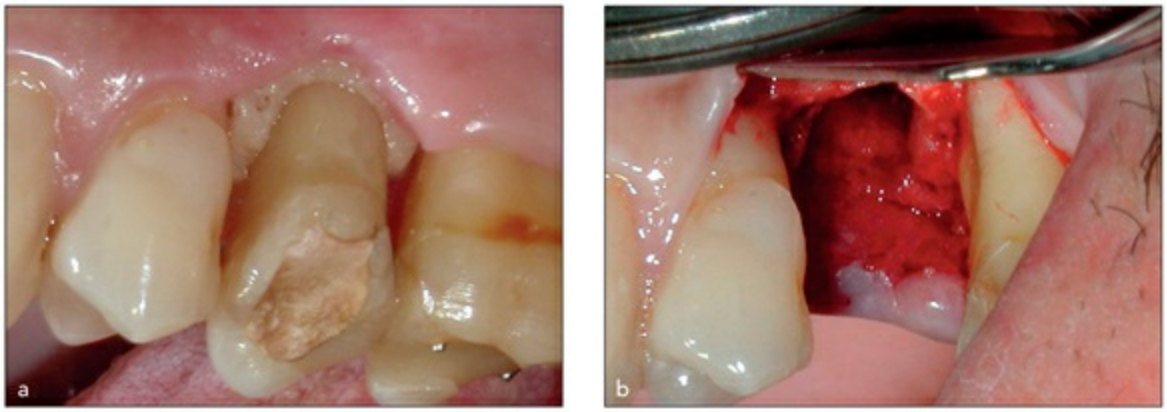


Fig 23-15 *(a)* Postoperative burn to surrounding attachment and bone due to heat transfer using ultrasonic instruments in the removal of two posts from a maxillary premolar. *(b)* Several weeks postinjury reveals the extent of the burn damage with resultant tooth loss and severe bony defects to both proximal teeth.

LESSON 24

Mishaps During Root Canal Shaping

OBJECTIVE

To discuss the treatment modalities for repair of mishaps that occur during access preparation and shaping procedures in light of newer materials, such as mineral trioxide aggregate (MTA), that have greatly improved the prognosis for repair and healing.

INTRODUCTION

The proper design, method of preparation, and size of access preparation for each type of tooth is described in lesson 16. Occasionally, perforation of the chamber or coronal third of the root occurs during access preparation. Perforation may be caused by misdirection of the access bur, by caries, or by resorption. The clinician must be aware of the prognosis for each of these situations and, if favorable, perform the repair procedure or refer the case to an endodontist. In determining a course of action, the following questions should be asked:

- Will the tooth be restorable after repair?
- Can endodontic therapy be completed adequately after the repair?
- Can the repair be completed immediately?
- What is the long-term prognosis after repair?
- Should the perforation repair be done by the dentist or referred to an endodontist?

The epithelial attachment of the periodontal ligament is damaged if the perforation occurs at or just below the crestal bone. Though the initial injury may not cause an immediate periodontal pocket to form, subsequent inflammation will cause further loss of attachment and result in pocket formation. Therefore, it is not the initial injury that affects the periodontal attachment as much as the subsequent inflammatory response and bacterial invasion after the injury. The epithelial attachment is fragile and does not tolerate an acute inflammatory response well. Pocket formation and/or recession are the usual outcomes. The prognosis for nonsurgical repair of injury to the periodontal attachment apparatus by bur perforation ranges from excellent to poor depending upon location, size, and length of time before repair.

Location

Furcation

In multirooted teeth, a perforation of the furcation may be better tolerated than the same size perforation on the external root surface. If properly treated, the furcation perforation responds to repair in the same manner as a three-walled periodontal defect. Bone repair usually occurs if the defect is repaired before periodontal communication develops (Fig 24-1).

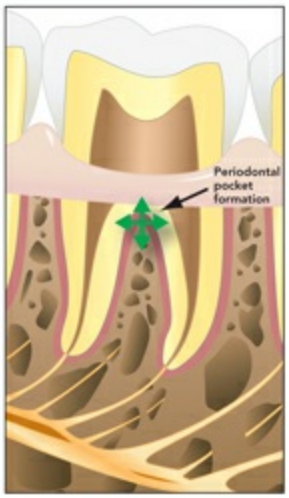


Fig 24-1 Epithelial attachment is fragile in the furcation area. An extended inflammatory process results in loss of attachment *(green arrows)* and contamination of the perforated area with oral bacteria. Immediate repair of a perforation in this area usually prevents a periodontal communication.

Coronal third of the external root surface

- On the external root surface, the perforation may be treated restoratively if the location is above the crestal bone. Repair of the defect is accomplished with a core material, such as an amalgam or composite, and then covered by a crown. Crown margins should not be placed on the restorative material. In some cases, periodontal crown lengthening must be performed to maintain biologic width.

- If the perforation is below the crestal bone, the periodontal prognosis is less favorable. This location presents challenges for nonsurgical repair. MTA does not have favorable physical properties for repair in this location. The material will wash away if a periodontal pocket forms.
- If there is no preexisting pocket, an immediate repair with MTA will occasionally prevent the formation of a pocket. A better choice of repair material for this location is Geristore (Den-Mat), a dual-cure hybrid ionomer composite. This material is well tolerated periodontally and will not wash out if exposed to oral fluids. Repairs of this nature require special instruments and materials. Magnification is required.

Middle and apical thirds of the root

As a general rule, the more apical the location of the perforation, the more favorable the prognosis becomes. This assumes that adequate cleaning, shaping, and obturation can be accomplished after the repair.

Bone tolerates the inflammation associated with perforation better than does the periodontal attachment apparatus. Therefore, perforation repair in the middle and apical thirds of the root does not generally result in a periodontal communication. The surrounding bone acts as a barrier to the inflammatory process and prevents the invasion of oral bacteria from periodontal communication (Fig 24-2).

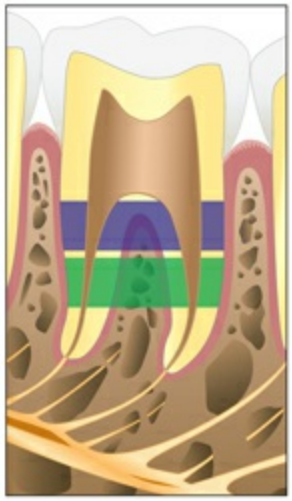


Fig 24-2 Location of perforation. A perforation in the furcation of a multirooted tooth may have a favorable prognosis because of the encasement in bone *(blue zone)*. A perforation on the external root surface *(blue zone)* frequently results in the formation of a periodontal pocket. A more apical location improves the prognosis *(green zone)*.

Size

The size of the defect affects the prognosis for repair: As size increases, the prognosis becomes less favorable. At any location on the root or furcation, a large perforation (greater than 3 mm in diameter) significantly lowers the chance of successful repair. A large perforation creates more inflammation of the bone and periodontal ligament than does a small perforation. In addition to increased physical injury to the soft tissues and bone, there is also more surface area for leakage due to the large size of

the defect.

As such, a large perforation presents challenges for adequate repair. Commonly, the bone encasing the periodontal ligament has been extensively damaged or is severely inflamed. Either situation presents challenges with controlling hemorrhage (to avoid contamination of the repair material) and controlling the placement of the repair material (to avoid over- or underfill and to seal the defect) (Fig 24-3).

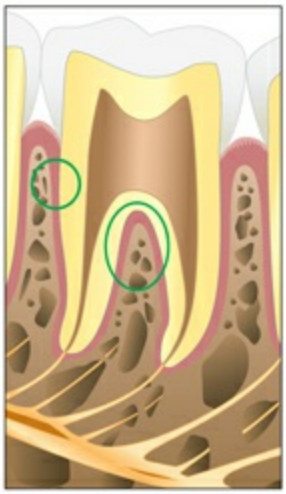


Fig 24-3 Size of perforation. At any location, as size of perforation increases, the likelihood of a favorable prognosis decreases because of the increased difficulty of sealing the defect.

Time

The prognosis for tooth retention drops in proportion to the length of time before perforation repair is completed. If a perforation is not recognized immediately and the clinician continues with nonsurgical endodontic therapy, the resulting inflammation becomes more severe.

Perforation into bone does *not* always result in immediate profuse hemorrhage. Bone is relatively avascular in the absence of inflammation. Thus, the clinician may be misled by the lack of immediate bleeding from a perforation. Within hours of the injury, however, the early stages of the inflammatory process produce extravasation of blood vessels.

Commonly, the clinician recognizes the perforation at the *second* appointment because of the presence of hemorrhage that was not seen at the initial appointment (when the perforation occurred). At this point, continuing endodontic therapy will result in further irritation to the periodontal ligament and bone surrounding the perforation. This additional inflammation is caused by such factors as sodium hypochlorite extrusion through the defect; physical trauma to the tissues from instruments passing through, and enlarging, the defect; medications such as calcium hydroxide; bacterial invasion; and extrusion of obturation materials into the bone and periodontal ligament.

In particular, irrigation with sodium hypochlorite through a perforation causes hemorrhage and intense postoperative pain. With sodium hypochlorite extrusion, the patient usually feels pain even though local anesthetic has been administered. Postoperative pain is usually severe for the first 24 hours and is accompanied by swelling and bruising (see lesson 18).

Extraction of the tooth may be the best recourse in some instances of perforation. Within a week,

the swelling and symptoms usually subside.

Recommendations

- Time is the most controllable variable associated with the treatment of perforation. The clinician should diagnose the presence of perforation by using an apex locator or by evaluating a radiograph with a file placed in the potential defect.
- If the clinician recognizes a perforation, repair should be performed immediately and should be considered the first treatment priority.
- If repair is delayed, bone loss will occur rapidly. If a periodontal pocket develops and communicates with the perforation defect, the prognosis is compromised by the invasion of oral bacteria and resulting inhibition of biologic repair (Fig 24-4).

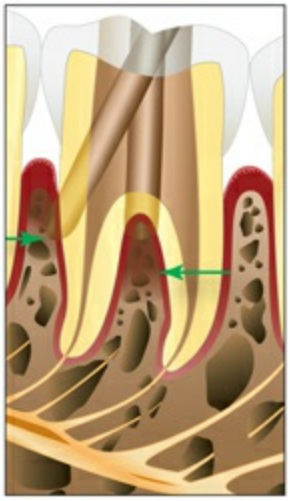


Fig 24-4 Length of time be-fore repair. Periodontal breakdown *(arrows)* occurs rapidly after perforation if the defect is not repaired.

Summary

Good prognosis factors

- Location: Furcation, middle to apical third of root.
- Size: Small (< 3 mm).
- Time: Immediate repair.
- Repair does not compromise cleaning, shaping, and obturation of the canal.

Poor prognosis factors

- Location: External root surface, coronal third of the root.
- Size: Large (≥ 3 mm).
- Time: Delayed repair, periodontal communication forms.
- Repair of perforation compromises cleaning, shaping, and obturation.

PERFORATION REPAIR

Mineral trioxide aggregate

MTA is the material of choice for most types of perforation repairs (see lesson 25). This material has greatly improved the prognosis for the repair of many types of perforation defects because of its biologic activity.

Set MTA has a pH of approximately 10. In this alkaline environment, calcium ions are available for the formation of hydroxyapatite, which is the basic building block for biologic hard tissues. Cementum and bone have been demonstrated to form against the surface of set MTA, which explains the excellent biocompatibility associated with this material.

MTA continually releases calcium ions when exposed to fluids. Over time, the material "washes out" if exposed to saliva or abrasion from a toothbrush. Therefore, repair of a perforation with MTA is contraindicated if any portion of the defect is located on or coronal to the gingival sulcus. As mentioned earlier, repairs in this location should utilize Geri-store. MTA is recommended for all other locations on the root surface.

Because of its "sand-and-water" consistency, the handling characteristics of freshly mixed MTA differ from all other materials in operative dentistry:

- The mixture of MTA and water does not flow (without vibration) and cannot be condensed.
- The initial setting time is 3 to 4 hours.
- Because the mixture is hydrophilic while setting, it can be placed in a wet environment, which is ideal for perforation repair.
- After the initial set, MTA has excellent sealing properties due to its minimal expansion as moisture is imbibed into the core of the material and the formation of a hydroxyapatite precipitate on the surface margins.
- The material continues to harden for weeks, but a high percentage of total hardness occurs by 28 days.

Recommendations

The original suggestions for hardening MTA required laying a wet cotton pellet over freshly placed MTA to provide the moisture necessary for continued setting. After a week of additional hardening of the MTA, the tooth could be restored. Subsequent research indicated that MTA repair of perforation defects could be restored immediately after placement of the material as long as there is at least a "single-side" hydration source. Therefore, the hemorrhage from the perforation site can provide enough moisture to allow the MTA repair to eventually set. A permanent restoration or an endodontic obturation can be placed immediately after MTA repair in most situations. Only when there is an inadequate single-side hydration source or a large volume of MTA to be cured is the wet pellet indicated.

A common method of restoration is to place glass ionomer cement directly over wet MTA when

space and access conditions allow. The glass ionomer adheres to dentin and can tolerate some moisture. The glass ionomer provides adequate strength to place a core restoration immediately. This method is particularly useful for furcation perforations or vital pulp caps.

Need for a matrix

Even a biocompatible material like MTA must not be grossly extruded into the bone during the repair procedure. Physical irritation of overfilled material can delay or prevent biologic repair. Therefore, like restoration of a Class II operative preparation, a matrix is necessary to control the placement of the repair material. However, the matrix material used in perforation repair cannot be removed and must be biocompatible and/or absorbable. Additionally, the material should be capable of controlling, but not eliminating, all moisture (if MTA is to be used). For example, if hemorrhage is profuse from a perforation, the matrix material must reduce the bleeding, not eliminate it. MTA requires moisture to set properly.

An ideal matrix material should:

- Be biocompatible
- Be absorbable after placement
- Not block patency of the canal system
- Control the placement and prevent the extrusion of repair material
- Not inhibit the setting properties of repair material
- Induce hemostasis

Matrix placement

A recommended matrix material to use prior to MTA delivery is bovine collagen, for example CollaCote or CollaTape (both by Integra Lifesciences) (Fig 24-5). The material is difficult to deliver but satisfies most of the other ideal qualities. Increments of the collagen are packed through the perforation with an appropriately sized endodontic plugger or paper point until profuse hemorrhage stops and there is slight resistance of the material to packing pressure. This slight resistance allows gentle placement of MTA without extrusion of the material into the periradicular tissues. Since the collagen remains wet, the MTA can properly hydrate during the setting process (Fig 24-6).

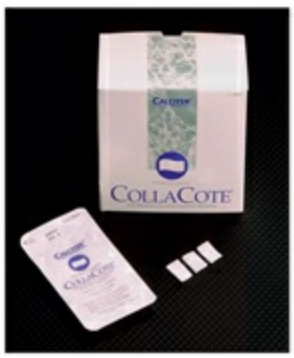


Fig 24-5 CollaCote controls bleeding, stabilizes blood clots, and fully absorbs in 10 to 14 days.

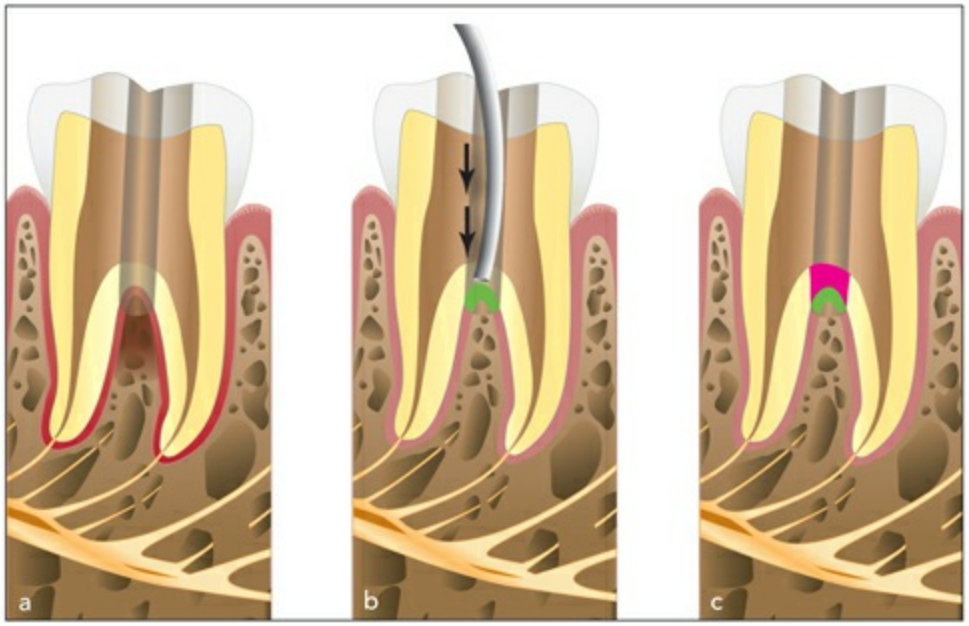


Fig 24-6 A furcation perforation *(a)* is repaired by placing an internal matrix (usually collagen), removing excess matrix material to the level of the periodontal ligament *(b)*, and placing MTA as the repair material *(c)*.

MTA placement

The recommended water-to-powder ratio for mixing MTA is 3 to 1. The goal of mixing is to wet all of the particles of the MTA to form a sand-and-water emulsion.

Since this mixed material handles differently than other dental materials, nontraditional delivery instruments are necessary. The manufacturer recommends a nonclogging, plugger-type carrier with a sliding plastic sleeve. MTA tends to clog most types of "piston-and-cylinder" devices, such as amalgam carriers. If these devices are used to carry MTA, thorough cleaning is necessary both during and after use.

ADDITIONAL CONSIDERATIONS

Before a clinician attempts to repair a perforation, several factors should be considered. Repair with MTA requires different levels of skill depending on the location and size of the defect and the availability of specialized equipment. In order to place MTA properly, the clinician should evaluate the following:

- Can the perforation be seen? Visualization is mandatory in this repair process. Some small furcation perforations may be easily visible and repaired without magnification, but most locations require a surgical operating microscope for adequate visualization.
- Can the perforation be manipulated? In addition to magnification, the clinician must be able to control hemorrhage, place a matrix if indicated, and deliver and place MTA into the defect. Special equipment may be necessary to accomplish this critical part of the procedure (Fig 24-7).
- Can the canal patency be maintained during the repair process? Frequently, perforation occurs prior

to completion of the cleaning and shaping procedure. A single gutta-percha point or silver point can be placed in the canal without sealer to preserve the space while the perforation is repaired. Collagen matrix material will not block the canal, but set MTA can cause loss of patency.

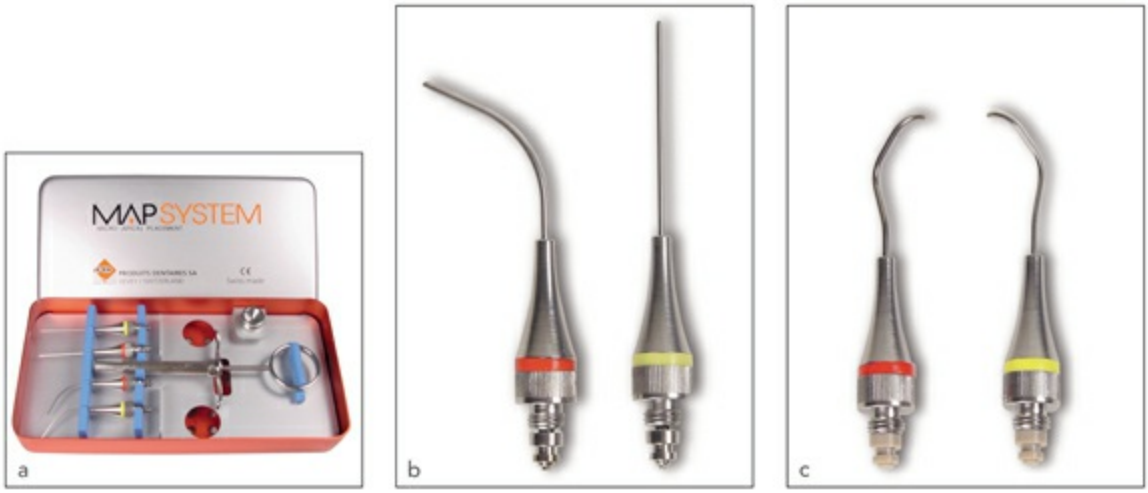


Fig 24-7 *(a)* Micro Apical Placement System (MAP System [Roydent Dental Products]) allows placement of MTA deep within the canal. *(b,c)* Variations in the carrier types are also shown.

Root perforation in the middle or apical third

Only an endodontist should attempt to repair a perforation in this inaccessible region of the tooth. Often the perforation can be visualized, but without special instruments, the perforation cannot be adequately sealed, and patency to the remaining canal space can be lost. Analysis of each situation is necessary, and innovation may be required.

Post space perforation

Generally, this type of perforation is located near a curve in the middle or apical third of the root. If obturation of the canal is acceptable, MTA can be packed into the canal to seal the defect. A collagen matrix may or may not be indicated depending on the size and accessibility of the perforation. MTA should extend to the coronal extent of the defect (Fig 24-8).

If the obturation is not acceptable, the perforation should be sealed with MTA and then a channel created with files to connect to the obturation material. A single gutta-percha cone is placed in this channel to preserve access while the MTA sets. After a week, the point is removed, and retreatment of the canal can proceed.

The prognosis for this type of perforation repair is generally good. Root fracture is a more frequent cause of failure than is perforation repair failure.

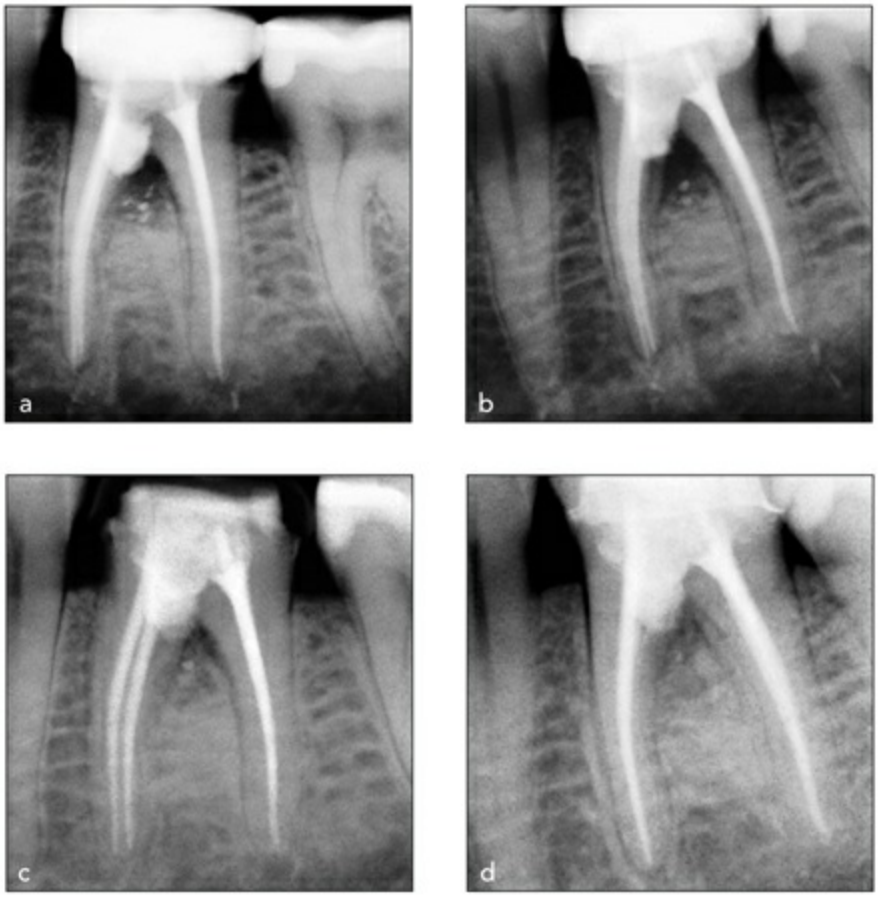


Fig 24-8 Clinical case involving a post space perforation. *(a)* Radiograph of a long-standing perforation repaired with IRM (Dentsply). Note the coronal leakage that must also be addressed. *(b)* Removal of the IRM filling and restoration of the perforation with MTA. *(c)* Radiograph taken 6 months postoperatively. *(d)* Two-year postoperative radiograph. (Images courtesy of Dr Ralan Wong, San Francisco, CA.)

Cleaning and shaping perforation

Attempting to establish patency in a mineralized canal or to forcefully enlarge a canal around a curve can produce perforation. If the canal has been adequately cleaned apical to the perforation, the canal can be obturated normally unless moisture contamination cannot be controlled. If moisture cannot be controlled, MTA is used to obturate the apical third and seal the perforation. Paper points are used to determine the moisture content of the canal.

The prognosis for this type of perforation repair is mixed. It depends upon the level of success with cleaning and then sealing the canal. Generally, a periodontal communication with the defect in this location rarely occurs because of the thickness of the surrounding bone. However, a sinus tract that communicates with the apical area of the root may form.

If nonsurgical repair fails, a periapical lesion will be seen on radiographs in a few months, and/or symptoms will persist. Periapical surgery can be considered to correct this failure to heal. A more comprehensive discussion of problem solving in the apical third is included in lesson 25.

LESSON 25

Mishaps in Shaping the Apical Third

OBJECTIVE

To understand and rectify or refer apical shaping errors.

INTRODUCTION

It is important to understand the biologic rationale and mechanical objectives for shaping and cleaning root canal systems. Forty years ago, Schilder identified the biologic objectives for shaping root canal systems, and they are still highly valid:

- Develop a continuous taper.
- Make the canal narrower apically.
- Make the preparation "flow" in multiple planes.
- Never transport the foramen.
- Keep the apical foramen patent and as small as practical.

Lapses in adherence to these objectives predisposes the clinician to needless complications such as blocks, ledges, apical transportations, and perforations. Quality outcomes in endodontic therapy require attention, practice, and persistence.

BLOCKED OR LEDGED CANALS

Managing blocked canals

- Choose the shortest file that can reach working length (WL). Shorter instruments provide more stiffness and greater tactile control.
- If the block is in the apical 3 mm, use a small-sized file with a preformed J-shaped curvature and light pecking strokes to negotiate or penetrate the dentin blockage above the canal terminus. Use short amplitudes to ensure safety, carry irrigant deeper, and increase the possibility of canal negotiation.
- Never excessively rotate a file whose tip is engaged, as the stresses over length will predispose the instrument to separation.
- If the apical extent of the file "sticks" or engages, move the handle with a minimal back-and-forth reciprocating movement to break through or bypass the blockage.
- Take radiographs to provide evidence as to root direction.
- Employ ongoing copious lubrication and chelation while attempting to bypass a ledge or blockage.
- Use viscous chelators such as RC Prep (Premier Products), Glyde File Prep (Dentsply), and ProLube (Dentsply), which are indispensable in bypassing a block or ledge.
- Use a No. 10 file to negotiate through the debris that constitutes the blockage. When the instrument reaches WL, gently move its tip to and minutely through the foramen to establish patency (Fig 25-1).
- Direct the No. 10 instrument to WL and PL to carry more chelator deeper into the canal, keep debris in suspension, and lubricate the file so it will more readily reach the desired length. Aspirate frequently.
- If a blocked canal is not negotiable and if clinical symptoms, periodontal breakdown, and/or infection are present, treat and obturate the root canal system to the blockage as efficiently as possible. Advise the patient of the importance of follow-up visits and that future treatment options may include apical surgery, replantation, or extraction.

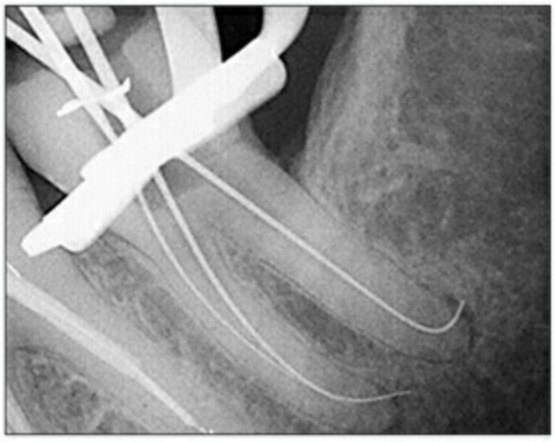


Fig 25-1 Establishing patency in a mandibular molar with curved roots and periradicular pathosis.

Managing ledged canals

An internal transportation of the canal is termed a *ledge*, and it results from engaging and overenlarging a curved canal and working short of full canal length. The failure to assess canal patency at routine and regular intervals is also a significant precipitating event. Once patency is lost, the instrument's position in the canal's center is at risk, predisposing the shaping to the formation of a ledge. Many ledges may successfully be bypassed using the techniques described previously for blocks. Once a ledge can be predictably bypassed, efforts should be directed toward establishing patency with a No. 10 file.

Moving the position of the canal's anatomic terminus to a new iatrogenic location within the canal or on the external root surface equates to a transportation of the foramen. Apical zipping or tearing is that damage done directly to the terminus by using progressively larger and stiffer files to WL. If apical transportation has occurred, the canal exhibits a shape that is open at the terminus and no longer provides resistance form for obturation of gutta-percha. Often these cases are vertically overextended, while at the same time, internally underfilled. Canals whose foramina have been significantly transported are not amenable to a conservative treatment approach and will require additional steps (ie, apical surgery and root end fill).

MINERAL TRIOXIDE AGGREGATE

Mineral trioxide aggregate (MTA) (ProRoot-MTA [Dentsply]) (Fig 25-2) is a biocompatible material for managing radicular repairs, and it can be used both in canals that exhibit severe apical transportation and in appexifying immature roots. Additionally, MTA is used for nonsurgical and surgical perforation repairs or as a surgical root end filling material.

MTA has been reported to be an ideal material of choice for furcal and root perforations. It is a cement composed of tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferrite, calcium sulfate, and bismuth oxide. It is, in a generic sense, medical grade Portland cement.

In patient studies with extensive follow-up, MTA demonstrated normal tissue healing and no pathologic changes adjacent to repair sites. Cementum grows adjacent to and onto this nonabsorbable, radiopaque material, thus allowing for a normal periodontal attachment apparatus to heal adjacent to the material.

Figs 25-2 *(a and b)* ProRoot-MTA is packaged in powder form and then mixed with sterile water to a heavy "cake-like" consistency.

Recommendations

In severe apical transportation, the goal is to place a dense 4- to 5-mm zone of MTA in the apical third of the canal. This MTA plug should be confirmed both radiographically and clinically. MTA is hydrophylic and therefore sets when it comes into contact with moisture. Fluids present in periradicular tissues external to the canal provide sufficient moisture for the apical aspect of the positioned MTA to set:

1. Place a presized cotton pellet moistened with water against the coronal-most aspect of the MTA within the canal.
2. Temporize the tooth, and dismiss the patient. At a subsequent appointment, remove the temporary filling, and re-move the wet cotton pellet.
3. Probe the MTA cement with a sharp explorer or large file to determine its hardness. Typically, the material has hardened and you can safely obturate the canal against this barrier.

Severe apical transportations that cannot be treated conservatively with MTA must be treated surgically either by apical surgery or by intentional replantation. If a surgical alternative is not possible, then tooth removal is the only alternative.

APICAL AND RADICULAR PERFORATIONS

Endodontic therapy is often complex and challenging. Some procedures carry an inherent risk for complications or procedural accidents, such as the access opening to initiate therapy or shaping procedures to debride the canal systems. An endodontic perforation is an artificial opening in the tooth or its root created by the clinician during entry to the canal system or by a biologic event, such as pathologic resorption or caries, which results in a communication between the root canal and the periodontal tissues. A *furcation perforation* refers to a mid-curvature opening into the periodontal ligament space and is the worst possible outcome of any cleaning and shaping procedure in root canal treatment.

- Except for resorptive defects or caries, furcation or root perforations are iatrogenic in nature and are a key cause of endodontic failure.
- An apical transportation as severe as those previously described must be included in this category. Apical perforation usually occurs during instrumentation as a result of using large inflexible files in curved canals and by violating the apical constricture. These perforations are often managed with the obturation material, MTA, or by surgical root end correction.
- When there is a perforation and the canal has not been fully prepared, the defect should be repaired prior to completing endodontic treatment. Repairing the perforation will enable the clinician to control bleeding into the canal, confine irrigation, and achieve a controlled obturation.

Perforations can be categorized by location: subgingival, mid-root, and apical. The four defining characteristics of a perforation always occur in combination, which complicates treatment outcomes (see lesson 24).

- *Level:* Perforations may occur in the subgingival, mid-root, and apical third of roots. Furcal perforations have similar considerations as those in the coronal third. Perforations at this level threaten the sulcular attachment, and due to communication with oral flora, they pose different

treatment challenges than do more apically occurring perforations.

- *Location:* Perforations can occur circumferentially on the buccal, lingual, mesial, and distal aspects of roots. The location of the perforation is less important when nonsurgical treatment is selected, but its position is critical and may preclude surgical access if a surgical approach is considered.
- *Size:* Perforation size greatly affects the clinician's ability to establish a biologic seal. Therefore, the perforation size contributed by any bur or instrument significantly increases the surface area to seal. Clearly, many perforations are ovoid in shape due to the nature of occurrence and represent enormous surface areas to effectively close.
- *Time:* Regardless of etiology, a perforation should be repaired as soon as possible to discourage further loss of attachment and to prevent periodontal pocket formation. Chronic perforations exhibiting a loss of sulcular attachment pose treatment challenges that potentially require surgical correction and tissue regeneration procedures.

Recommended repair technique

1. To apply MTA, mix the cement powder with anesthetic solution or sterile water to a heavy viscous consistency. Use a gauze square if needed to absorb surplus moisture and achieve the ideal viscosity.
2. Introduce a small measure of this cement into the prepared canal with a specialized microtube carrying device (Micro Apical Placement [MAP] System [Roydent Dental Products]) (see Fig 24-7a) or on the side of a specialized instrument (West Perforation Repair instruments [SybronEndo]) (Fig 25-3).
3. Gently pack the MTA down the canal to approximate length using a customized nonstandard gutta-percha cone as a flexible plugger.
4. If needed, trim a gutta-percha cone to a sufficient apical diameter and effectively condense the MTA. In straighter canals, use an ultrasonic tip to vibrate the MTA, moving it into the defect as well as to length.

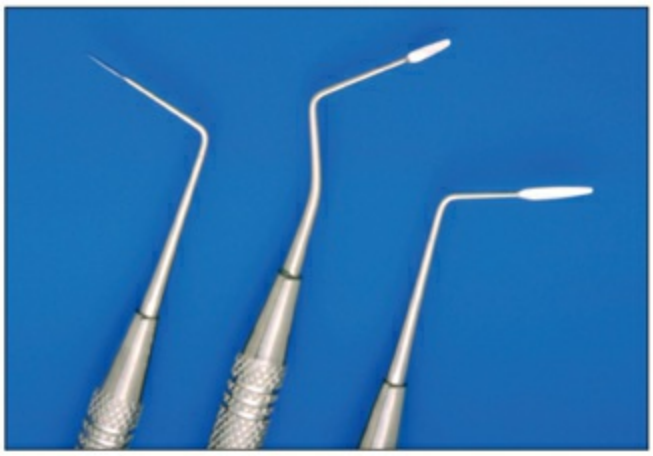


Fig 25-3 West Perforation Repair instruments provide thin flexible trowels angled at different orientations for placement of MTA.

CONCLUSION

Magnification loupes, headlamps, and transilluminating devices facilitate vision and are important adjuncts in addressing perforations, especially when the defect is in the middle and apical thirds of canals. However, the dental operating microscope has become a new standard for vision enhancement and is used to more predictably repair perforation defects nonsurgically, thus reducing the need for surgical intervention and its associated risks.

Central to success when repairing a perforation is to select a restorative material that is easy to use, nonabsorbable, and biocompatible, and that provides a fluid-tight biologic seal. The choice to use MTA should only be made when there is no sulcular communication. For mid-root and apical repairs adjacent to bone, MTA has proven to be a superior and well-suited material.

LESSON 26

Pain After Cleaning and Shaping

OBJECTIVE

To understand the etiology and biologic parameters in endodontic flare-ups and mid-treatment pain.

INTRODUCTION

An endodontic flare-up can be considered as the onset, persistence, or exacerbation of pain, swelling, or both during the course of root canal treatment. The development of interappointment pain and swelling, while quite rare, has been universally accepted by dentists as an expected part of endodontic treatment. The clinician who undertakes endodontic treatment must be prepared to manage these infrequent but painful complications.

CONTRIBUTING FACTORS

The causes of flare-ups are numerous and multifactorial. To render effective intervention, the clinician should understand the factors contributing to the flare-up and effective strategies for its management and prevention. Contributing factors include inadequate debridement, debris extrusion, overinstrumentation, necrosis and periapical pathoses, high occlusion, and host factors.

Inadequate debridement

Persistent pain or a severe exacerbation of pain often signals the presence of residual pulp tissue remaining in inadequately instrumented or unfound canal systems. Often these cases present symptoms consistent with irreversible pulpitis, especially with regard to intensity. The best way to resolve or prevent a flare-up is thorough debridement of all pulpal tissue, as this is the most direct way to stop the inflammatory response. Thorough debridement of the entire root canal space is a reasonable goal in the initial management of all pulpless teeth.

To achieve this goal, it is imperative that you understand *(1)* canal complexities that could be present in a particular tooth and *(2)* pulpal anatomy, including the likelihood that second, third, and fourth canals might exist. Furthermore, you must be adept in properly using instruments such as broaches, files, and rotary technologies, in conjunction with effective irrigation, to remove inflamed or infected tissue.

Debris extrusion

Despite strict length-control precautions in the use of instruments during root canal instrumentation, pulp tissue fragments, necrotic tissue, microorganisms and their toxins, dentinal debris, and canal irrigants may be inadvertantly extruded beyond the apical terminus. This may result in periradicular inflammation and pain. Debris extrusion is a problem with all instrumentation techniques. However, some techniques cause less extrusion than do others:

- Conventional hand instrumentation, especially involving push-pull filing, causes the most debris extrusion.
- Shaping the canal in a crown-down strategy is associated with less debris extrusion, since the coronal portions of the canal are cleaned prior to entering the apical third.
- Rotary manipulations of hand files (balanced-force technique) and the use of gear-reduced rotary nickel-titanium files are also associated with less extrusion.

Irrigation solutions may also be extruded during instrumentation. In most instances, the extrusion of small amounts of irrigation solution incorporated with dentinal debris is no more or less complicating than any other extrusions. However, forced irrigation of sodium hypochlorite beyond the confines of the root causes violent tissue reactions and unbearable pain. Irrigation mishaps are discussed in lesson 18.

Overinstrumentation

There is a correlation between endodontic overinstrumentation and mid-treatment or postoperative pain. With care and attention, gross overinstrumentation can be avoided.

A careful assessment of all preoperative and working radio graphs as well as the results of electronic measuring devices should allow for instrumentation to be contained within the confines of the canal space. Apical overinstrumen-tation in vital cases causes an acute apical periodontitis as a result of tissue damage and associated inflammation.

In treatment scenarios where infection is present, the over-instrumented case may exacerbate with

pain and swelling as noxious bacteria and their by-products are continually inoculated into periapical tissues, thereby compounding the chronic problem. There is a strong association between certain microorganisms and clinical signs and symptoms of exacerbation and flare-up. Chemical mediators, immunologic response by the patient, and a patient's psychologic profile can all contribute to an extreme reaction that can test the doctor-patient relationship.

Necrosis and periapical pathoses

Teeth with necrotic pulps are generally more prone to mid-treatment flare-ups than are teeth with vital pulps. This is universally attributed to the presence of microorganisms and other toxic substances in the root canal systems of pulpless teeth. Many of the same conditions found in necrotic teeth exist in retreatment cases.

A broad range of factors influence the biologic variability that can be present in producing a flare-up outcome. These include host factors, mechanical factors, the presence of virulent microorganisms, and whether the tooth in question was vital or necrotic at the time of therapy:

- The pain may be due to an alteration—caused by therapy—in the balance of irritants in the existing root canal and in the periapical tissues, which often adds organic solvents and anaerobic organisms into the equilibrium.
- It is not clear what relationship periapical lesions have to the occurrence of exacerbations in root canal therapy. Some researchers have found apical radiolucencies to be associated with a higher incidence of flare-ups whereas others have reported that an apical lesion or sinus tract presents fewer problems. Researchers in this latter group speculate that a lesion or sinus tract might provide a pressure release for the system that lessens pain. The contrast in thinking about this issue certainly underscores the changeability associated with the disease.

High occlusion

Occlusal reduction need not be a routine practice for all endodontic cases. However, it may be of value in the following selected cases:

- Patients with severe pain on biting
- Patients whose therapy is predicted to develop significant postoperative periapical inflammation (overinstrumentation)
- Patients with weak cusps or cracked teeth

Teeth with periapical inflammation after treatment may be exquisitely sensitive to occlusal forces. Occlusal reduction or selective adjustment of cusps is indicated as a palliative measure.

Host factors

The intensity of preoperative pain and the amount of patient anxiety and apprehension often directly

correlate to the degree of postoperative pain.

• If there is significant pain associated with an endodontic problem, patients need to understand that even with expert endodontic care the pain may require 24 to 72 hours to decline (see lesson 10).

• For difficult-to-treat patients with dental phobias and low psychophysiologic tolerance, presedation or other therapies may be required to help them cope (see lesson 6).

• A history of preoperative pain is an excellent predictor of pain after treatment.

MANAGEMENT AND PREVENTION OF FLARE-UPS

It is generally recognized that postoperative pain will diminish to tolerable levels within 72 hours. This is a stressful time for the patient who is consumed by pain and for the doctor whose job it is to alleviate the patient's suffering. During this critical period, clinicians must know how to quickly and effectively improve the patient's condition and prevent a recurrence. Although many preventive measures have been suggested in the endodontic literature, no specific method has been universally embraced as effective in the prevention or therapy of posttreatment pain. However, several important principles and strategies in root canal therapy are strongly aligned with trouble-free endodontics.

Cleaning and shaping

Symptomatic pulpless teeth and retreatment cases may be predisposed to interappointment exacerbations. The single most effective way to reduce flare-ups and their sequelae is by the thorough cleaning and shaping of the root canal at the time it is entered. The principles of crown-down cleaning and shaping and the practice of apical patency to eliminate a contaminated dentinal or tissue plug from the apical foramen are significant strategies in the strategic management of teeth most likely to exhibit midtreatment flare-ups. A crown-down shaping strategy removes the bulk of infected organic debris from the tooth, and apical patency not only removes that debris from the foramen but also helps place it into irrigation solution where it can be suctioned away. Apical patency can also provide a measure of tactile control during instrumentation that helps the operator stay centered in the canal and attentive to working within length.

Incision and drainage for swelling

Treatment of interappointment or postoperative swelling requires the establishment of drainage and, if indicated, the prescription of an antibiotic. If the root canal has not been obturated or is inadequately obturated, reinstrumentation through the root canal should be attempted to achieve drainage.

In the case of an adequate obturation with swelling, drainage may be achieved through incision and drainage alone. Often a combined approach through the root canal and via a soft tissue incision provides the most effective resolution.

Leaving teeth open

When a tooth is opened and purulence escapes, the exudates should stop after just a few minutes. The clinician should alert the patient that the tooth will be allowed to drain for 15 to 20 minutes while the rubber dam is left in place. On the rare occasion when exudate continues to well out of a tooth and prevents closure, the tooth may be left open to the oral environment with a cotton ball or similar barrier to prevent food (canal) impaction. The tooth can usually be closed without incident the next day after additional cleaning of the root canal (Fig 26-1). However, it is best to close all teeth immediately after treatment to prevent contamination by the oral cavity and to prevent future problems. The longer a tooth is left open, the more frequently it is involved in mid-treatment flare-ups.

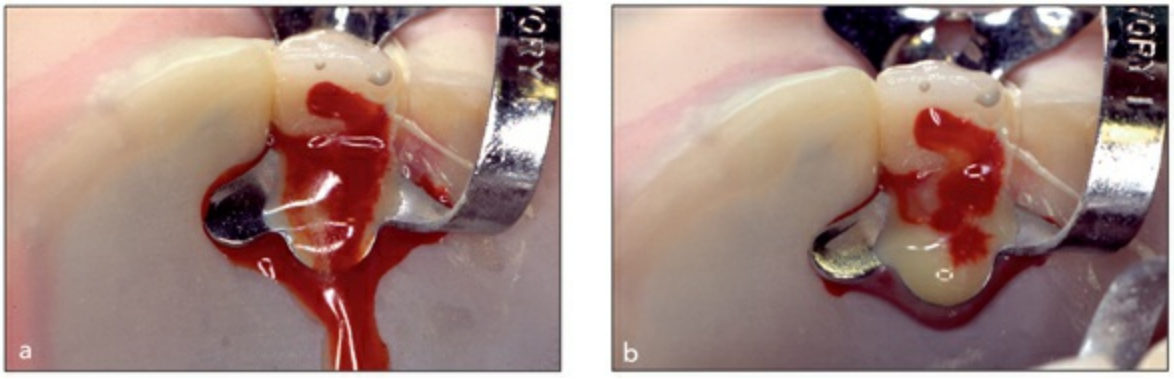


Fig 26-1 *(a)* Accessed central incisor with copious drainage of pus and blood. *(b)* Initial pus flow should abate within minutes to be replaced by blood and serum. Only an unremitting flow of pus that does not stop within the allotted chair time for the patient warrants leaving the tooth open for additional drainage.

Intracanal therapies

Within root canals that require more than one visit to complete, there frequently remain sufficient bacteria to grow and reinfect the canal space between appointments. Historically, the coronal placement of intracanal medicaments became a popular method of preventing bacterial regrowth. However, increasing evidence has suggested that many intracanal medicaments are unsuccessful in reducing exacerbations. The decision to use an intracanal medicament should be guided by antibacterial efficacy, toxicity, and specificity of the drug.

Calcium hydroxide and chlorhexidine (CHX) gluconate are the two most commonly used medicaments today. CHX is safe and easily delivered by syringe directly into the root canal. Calcium hydroxide is also considered a safe and effective intracanal medicament that can be potentiated by mixing it with CHX or iodine potassium iodide (Vitapex [NeoDental International]) (Figs 26-2 to 26-4).

Calcium hydroxide intracanal dressings may be therapeutic in the treatment of flare-ups. While there are numerous reasons for flare-ups, surely one of the critical factors is the presence of viable bacteria remaining within the root canal system. The application of calcium hydroxide reduces

bacterial populations and levels of their toxic metabolites. Studies have shown that calcium hydroxide should remain in the root canal for at least a week to achieve the greatest antimicrobial effects. Furthermore, its penetration into the dentin is aided by smear layer removal via chelating liquids. Calcium hydroxide's high alkalinity helps to neutralize toxins, dissolve tissue remnants, and temporarily obliterate the pulp space, thereby hindering regrowth.

There are numerous methods by which calcium hydroxide can be applied to the canal system. Acceptable techniques include the use of a specialized gun or injection device often supplied by the manufacturer, condensation pluggers, paper points, files, and/or a lentulo spiral. A lentulo spiral has been shown to most consistently place calcium hydroxide to length with maximum density (Fig 26-5). Placement of calcium hydroxide is advised between appointments, when cleaning is incomplete, when teeth are symptomatic, when interappointment time is lengthy, and when periapical rarefaction exists.

Some newer antimicrobial irrigating solutions and techniques are as effective against a range of bacteria encountered in root canal cases that have been previously treated. These retreatment protocols include (Fig 26-6):

- 2% CHX
- MTAD Biopure (Dentsply), a mixture of tetracycline (doxy-cycline, 3%), citric acid (4.25%), and a detergent (Tween- 80 [(Akzo Nobel)], 0.5%, with a pH of 2.15)
- Calcium hydroxide and CHX paste combinations (also see lessons 18 and 27)

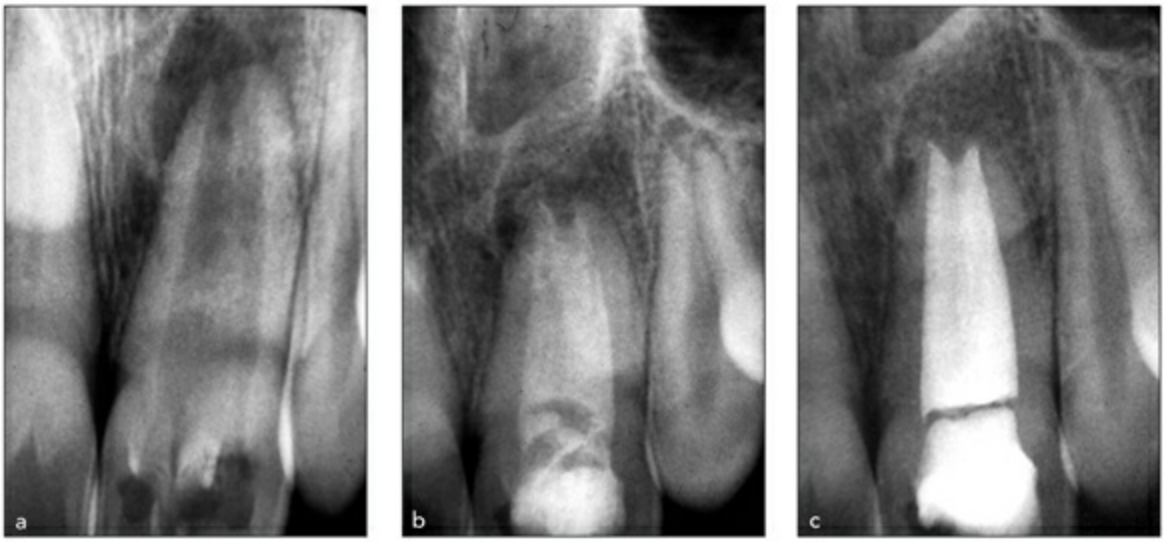


Fig 26-2 *(a)* Geminated central incisor with a large periradicular infection. *(b)* Calcium hydroxide was used in conjunction with irrigation as an interappointment medicament to reduce the intraradicular bioburden in such a large pulpal space. *(c)* Three-dimensional obturation with gutta-percha.

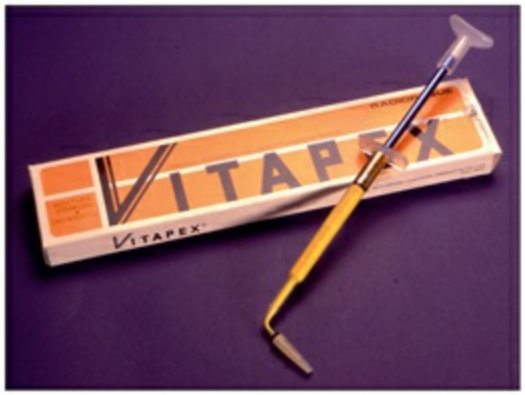


Fig 26-3 Vitapex is a calcium hydroxide medicament mixed with iodine.

Fig 26-4 Calcium hydroxide is mixed with saline or sold in a methylcellulose base as in Pulpdent Paste (Pulpdent).

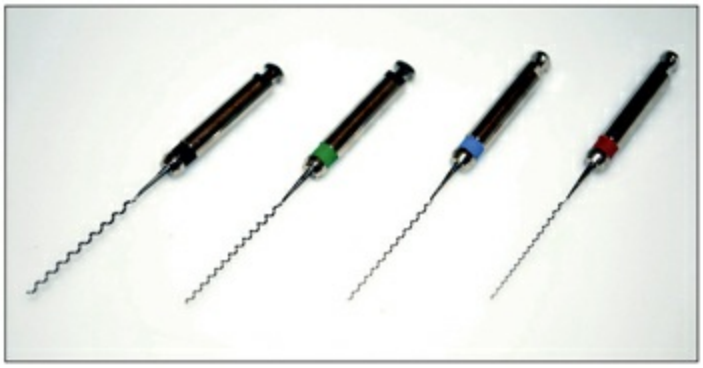


Fig 26-5 A lentulo spiral allows a dense condensation of calcium hydroxide within the canal.

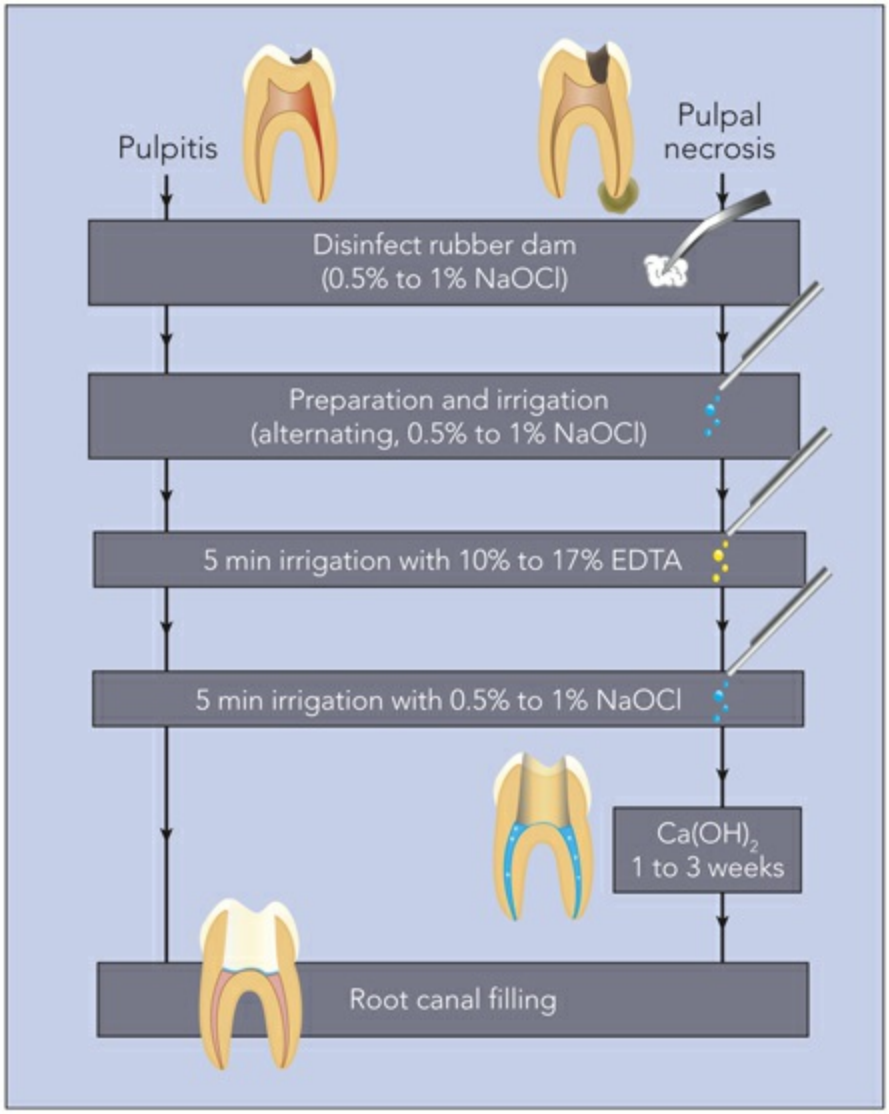


Fig 26-6 A sample disinfection protocol for a two-visit, or more, scenario. In general, a canal should be rinsed with 5 to 10 mL of ethylenediamine tetraacetic acid (EDTA) for at least 1 minute. Sodium hypochlorite (NaOCl) should be used in copious amounts throughout the preparation phase. $Ca(OH)_2$ = calcium hydroxide.

DRUG INTERVENTION

Nonsteroidal anti-inflammatory drugs

The use of pretreatment and posttreatment analgesics can significantly reduce the incidence of flare-ups, especially in patients who present in moderate to severe pain. Because endodontic pain results from numerous inflammatory and immunologic pathways, most endodontists prefer to prescribe nonsteroidal anti-inflammatory drugs (NSAIDs) over narcotics for interfering with this process and reducing pain symptoms.

Corticosteroids

The inflammatory process is a highly complex mechanism involving many mediators and pathways. Corticosteroids can either directly or indirectly interfere with this process by suppressing the formation of the precursors of these mediators. Because of this interference, corticosteroids can significantly decrease the severity of posttreatment pain, reduce the incidence of flare-ups, and decrease the need for analgesics throughout the course of treatment. Of all the oral steroid medications, dexamethasone in moderate to low dosages may have the greatest anti-inflammatory efficacy for root canal therapy, and it has a strong history of safety.

Corticosteroid therapy is *contraindicated* in instances of:

- Periapical infection
- Viral or fungal infections
- Medications for systemic disease (eg, diabetes, hypertension)
- Pregnancy, ulcer, and/or allergy to corticosteroids

The successful clinical effects of corticosteroids are well documented. However, they have yet to gain universal acceptance. Nevertheless, the fact remains that this class of drugs is an excellent way to preempt the moderate to severe pain of periradicular inflammation, and their use should not be ruled out for patients who present no contraindications.

LESSON 27

Single-Visit vs Multiple-Visit Therapy

OBJECTIVE

To provide guidelines on the number of treatment appointments required to maximize successful outcomes.

INTRODUCTION

While general recommendations regarding treatment are made in this lesson, each case needs to be evaluated individually, based upon the patient's medical and dental history and current signs and symptoms, to determine the number of necessary appointments.

SINGLE APPOINTMENTS

Single-appointment root canal therapy involves completing the entire endodontic treatment in one appointment. Dentists base their decision to complete therapy in a single visit on the principle that vital caries-exposed or inflamed teeth without apical periodontitis are for the most part sterile at the apex. With a lack of infection at or near the periapex, there is justification for completion of this therapy in a single appointment.

The latest evidence does not support the viewpoint that all necrotic root canals need 1 or more weeks of intracanal dressing to ensure adequate disinfection and healing of apical pathosis. Recent research has shown that when the cleaning, shaping, and antimicrobial treatment are thorough,

comparable healing takes place regardless of whether or not the treatment was performed in one or two appointments. However, it must be noted that when the disinfection process is not adequate, less than half of the lesions heal. A case-by-case decision has to be made after all available information about the history and diagnosis of the tooth is taken into account.

Advantages

- Faster procedure.
- Convenient for the patient.
- Usually associated with no compliance problems from the patient.
- Eliminates the potential of recontamination during temporization.
- A permanent restoration, that will ensure long-term success, can be placed sooner.

Disadvantages

- Hastened completion may be at the expense of quality.
- Infected, necrotic root canals may not be properly or adequately disinfected.
- Retreatment cases with difficult bacterial flora may not be decontaminated.
- Unwarranted incidents may occur when clinicians are under pressure. Root canal instruments may fracture, and gutta-percha may be poorly condensed (under- or overfilled), thereby disposing the canal to latent bacterial infiltration and making the endodontic treatment more likely to fail.
- Success rates may be lower in infected teeth that are treated in a single visit.

MULTIPLE APPOINTMENTS

Nonvital teeth (ie, teeth with apical periodontitis or periapical lesions) are contaminated by myriad microorganisms. As successful healing will occur when these teeth are disinfected, proven strategies for disinfection are required, and the components of that disinfection strategy include:

- Mechanical preparation and shaping with sequentially sized filing instruments to a confirmed working length (WL).
- Chemical disinfection with antimicrobial irrigation fluids, which are used intermittently with the mechanical instrumentation process, that effectively decontaminate the root canal space.
- Dressing the canals with intracanal medicaments. Research has indicated that cases should be divided into infected or noninfected cases. The debate centers on the question, “Can adequate disinfection be accomplished in one appointment when a canal is contaminated with microorganisms?”
  - Infected cases might include teeth with necrotic pulps and failed endodontic treatments in teeth experiencing posttreatment disease. These cases may be best treated with an interappointment

dressing of calcium hydroxide that neutralizes toxins and kills microorganisms. Materials that are used as dressings between appointments are discussed in lessons 26 and 28.

- In emergency situations, which often include unscheduled endodontic appointments, inadequate time may also be reason to postpone completion of the treatment.

INFLUENCE OF THE LITERATURE

Before 1995

- According to a number of authors, it is impossible to eliminate all of the bacteria that harbor in the fins, grooves, and tubules of infected teeth via a chemomechanical system of instrumentation.
- Several researchers claim the microbes that remain in a canal following the instrumentation of infected teeth are the prime reason for the continued aggressiveness of an apical periodontitis.
- A number of researchers have recommended eliminating the remaining bacteria by treating the canals with an interappointment compaction of calcium hydroxide for 14 to 28 days.
- Others have reported that flare-ups after single-appointment endodontics are inevitable.

Current research

A number of articles published in the last decade have challenged many of the conclusions of the classic literature that have been abided by for years:

- Calcium hydroxide is not an effective antimicrobial against the large range of bacteria involved in endodontic infections as evidenced by the fact that viable bacteria are still detectable after as many as four 30-day calcium hydroxide treatments.
- Modern cleaning, shaping, and disinfecting techniques are more capable than previous techniques of reducing the bacterial count in root canals to levels that cannot sustain life.
- Antimicrobial irrigating solutions and techniques available today are far more effective than previous solutions against the range of bacteria encountered in root canal therapy:
  - 2% Chlorhexidine (CHX), an effective endodontic antimicrobial, is commonly used to eliminate the bacteria that resist sodium hypochlorite.
  - MTAD BioPure (Dentsply) is a mixture of tetracycline (doxycycline, 3%), citric acid (4.25%), and a detergent (Tween-80 [Akzo Nobel], 0.5% with a pH of 2.15). This antimicrobial/antibiotic disinfecting solution has been added to the arsenal of endodontic cleaning agents.
  - Superior disinfecting results with calcium hydroxide and CHX paste combinations have been reported.
- There are a number of studies that report no differences in healing between one- and two-visit root canal therapy. The following statement in the March 2008 issue of the *Journal of Endodontics* is the representative conclusion of most authorities: “There was no statistically significant difference

in radiographic evidence of periapical healing between one-visit or two-visit therapy with an interim calcium hydroxide/chlorhexidine paste dressing of necrotic teeth with apical periodontitis at either the immediate postoperative examination or the 12 month evaluation."

CLINICAL SITUATIONS

Indications for single-visit treatment

- Asymptomatic vital teeth with healthy periapical tissue: This includes inadvertent mechanical pulp exposures and elective root canal treatment (on healthy vital teeth) for restorative or periodontal reasons.
- Irreversible pulpitis: The pulp tissue is inflamed but still vital and does not appear to be contaminated by oral fluids (diseased tissue is sequestered beneath nonleaking restorations).
- Necrotic pulps with apical periodontitis and an absence of acute spontaneous pain symptoms: This includes an absence of exudate or pus in the canal during instrumentation of the complete root length, and if the meticulous instrumentation and irrigation (disinfecting solutions) are able to eliminate any detection of a putrescent odor.
- Necrotic or partially necrotic root canals without apical periodontitis or an associated lesion.
- An asymptomatic tooth with an apical periodontitis and a patent (traceable) sinus tract.

Indications for multiple-visit treatment

- Lack of clinical skill and experience: Postoperative pain is not infrequent in this clinical scenario and may be caused by treatment mishaps or an incomplete debridement of the canal space. Irritated pulpal tissue may be left behind, a canal may be overlooked, periapical tissue may be injured and infected by overinstrumentation beyond the apical foramen, and irrigants or necrotic debris from the canal may be introduced into periapical tissues, causing inflammatory exacerbations.
- Highly symptomatic teeth: Treatment for the relief of postoperative pain and inflammation is more easily resolved through a patent and unfilled canal. A patent canal can act as a vent for the release of periapical pressure due to accumulating fluids; the canal and pulp chamber can serve as a reservoir for accumulation of periapical exudate. In the absence of periapical infection, the pain of inflammation will dissipate within 48 to 72 hours. The canal can then be obturated safely.
- Acute periapical infection (acute apical abscess, phoenix abscess, cellulitis): Opening the access cavity may be necessary to allow pus to drain through the root canal. Treatment for pain relief in a prematurely root-filled canal, on the other hand, requires the removal of the filling material. In this treatment step, periapical tissue can be damaged by leakage of caustic solvents used to remove the material from the canal.
- Asymptomatic or symptomatic teeth with periapical lesions that constantly drain fluid through the canal (weep) after instrumentation: A canal that cannot be dried should not be filled. The filling materials (sealer and gutta-percha) will not adhere to the canal walls. This creates voids, which

are subject to leakage, and results in an inadequately sealed apical exit. Leakage is invited, and failure is imminent.

- Retreatment cases contain microflora that are particularly difficult to control. In addition, studies indicate that during the cleaning and shaping process, the filling material that is being removed—and its associated bacteria—are pushed out the apical exit and into the infected area, which amounts to an invitation to exacerbation (Fig 27-1).

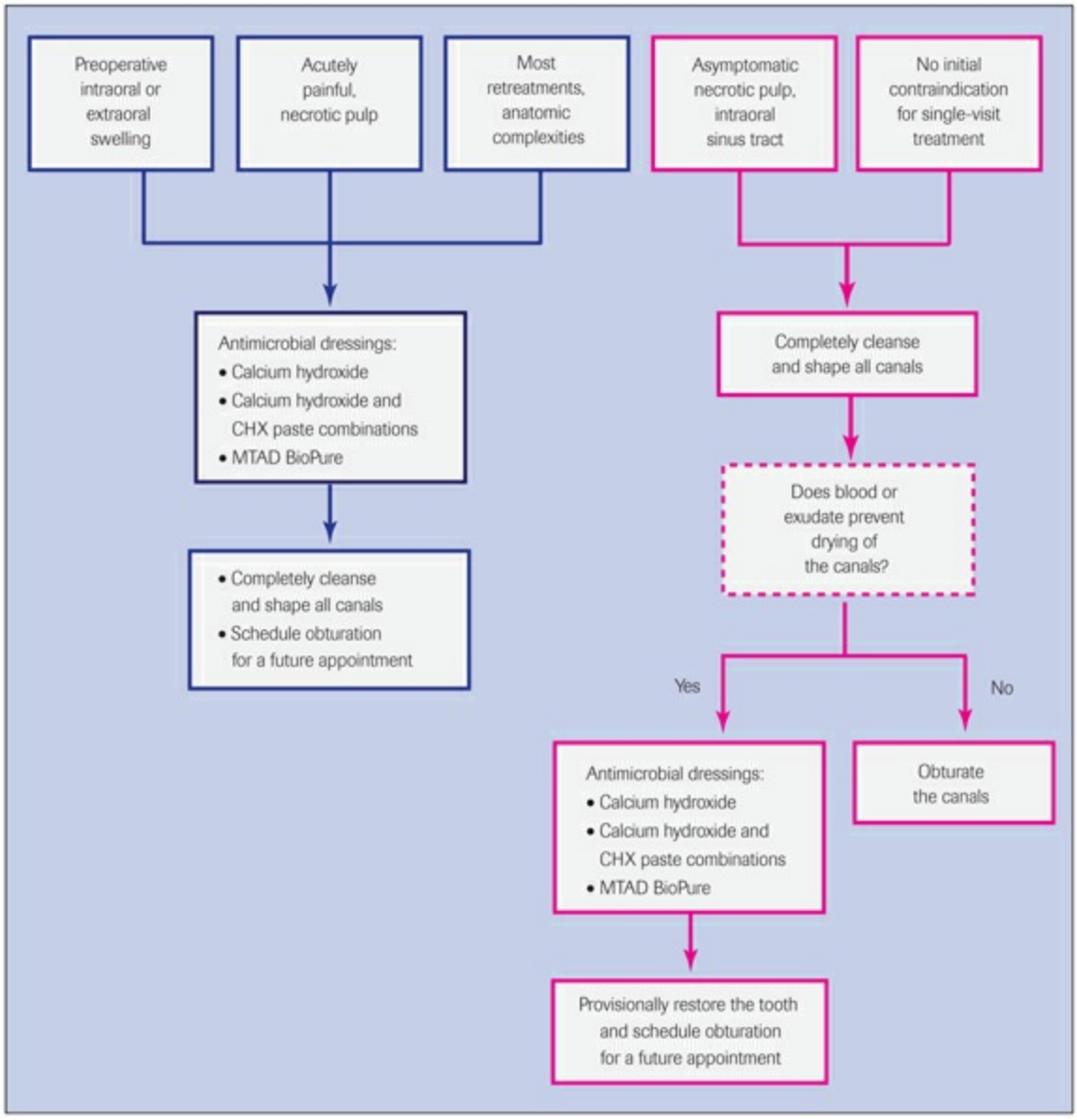


Fig 27-1 Algorithm for making a decision to do single-visit *(red)* or multiple-visit *(blue)* endodontic treatment.

Recommendation

Cases should be carefully assessed before initiating treatment. They should be selected based on the degree of difficulty and the skill level of the clinician. If accomplishing the goals of successful endodontics within a reasonable time frame is difficult for a practitioner, the treatment should be completed at a subsequent appointment. If the case is too difficult, it should be referred.

CONTRIBUTING FACTORS

Adequate disinfection

Protocols from studies that showed good healing after treatment in one appointment emphasize the following factors in approaching aseptic treatment:

1. Use of rubber dam, tooth isolation, and disinfection of the tooth access site surface.
2. Instrumentation to an adequate apical size that allows proper cleaning and irrigation of the apical portion of the infected canal. Apical diameters (adequate instrument sizes) vary and are discussed in lessons 20, 21, and 22.
3. Abundant irrigation (throughout the mechanical instrumentation process) with 0.5% to 6% sodium hypochlorite, a 2% solution of CHX, and/or a combination of 30% hydrogen peroxide and 10% iodine potassium iodide.
4. Irrigation with ethylenediaminetetraacetic acid (EDTA) for 60 seconds (or intermittently during the instrumentation) to remove the smear layer from canal walls prior to obturation:
   - While sodium hypochlorite and EDTA are the most commonly used disinfecting agents, it is beneficial to have an arsenal of other effective irrigation fluids to obtain the broadest spectrum of disinfection. This is especially true in cases with refractory lesions and retreatment cases. It has been recommended to soak the canal for 10 minutes in 5% iodine potassium iodide or 2% CHX solution.

Criteria for filling a canal

Before filling a canal, you must be certain that you are able to do the following:

1. Navigate an instrument to patency length(s) (PL) and accurately measure WL.
2. Properly clean and shape the canal to WL while preserving PL throughout.
3. Disinfect and free the canal(s) of pulp tissue, smear layer, and debris via the copious use of sodium hypochlorite, CHX, EDTA, and/or MTAD BioPure after instrumentation.
4. Dry the canal(s).

Recommendation

If all of the above criteria can be met for the patient within a comfortable time frame, the tooth is an excellent candidate to complete (obturate) in a single appointment.

Diagnosis

A number of studies report no significant differences in the incidence of flare-ups and/or success rates regardless of pre operative symptoms, gender, age, diameter of a lesion, or prescription of

analgesics and antibiotics at the time of treatment.

Informed Consent

Regardless of the number of appointments a practitioner deems necessary to complete a particular case, no treatment should be initiated until the patient has been told the benefits, options, and potential problems associated with the treatment, and has signed an informed consent (see lesson 10).

CASE EXAMPLES

Case 1: Irreversible pulpitis

The tooth in question is sensitive to cold; sporadic pain is spontaneous; caries is evident; electronic and thermal pulp tests are positive; and no periradicular pathosis is apparent radiographically. Though the pulp tissue is inflamed, it is vital and not completely contaminated by bacteria. The diagnosis is irreversible pulpitis.

Treatment

- If all of the treatment criteria can be met and time is available, a tooth diagnosed with an irreversible pulpitis should be treated in one appointment.
- Treating complex canal anatomy and multiple canals in a single treatment session will depend on the skill, confidence, and efficiency of the clinician.
- Regardless of the diagnosis or the effectiveness of the cleaning, shaping, and disinfecting process, an endodontically treated tooth may experience a mild to severe postoperative flare-up (pain). However, flare-ups following one-appointment endodontic therapy have been reported to occur less frequently than following multiple-appointment endodontics. Patients must be informed of that possibility prior to treatment.

Visit recommendation

Under ordinary circumstances, a tooth diagnosed with an irreversible pulpitis may be treated in one appointment.

Case 2: Pulpal necrosis

Thermal and electric pulp tests are negative; an apical periradicular lesion is radiographically apparent; and a draining sinus tract exists. The diagnosis is pulpal necrosis.

Treatment

- Attention should be focused on using a high volume of irrigating solution.
- In certain cases, once the cleaning and shaping procedures are completed, the root canal(s) may be washed free (saline rinses) of all disinfecting solution and flooded every 30 seconds for a period of 3 to 5 minutes with a fresh 2% CHX solution. Note that the presence of any sodium hypochlorite will dilute the effect of CHX.
- The canal(s) are dried to WL with paper points.
- If all of the endodontic treatment criteria were met and there is no constant canal drainage (seepage of fluids from the canal) or visible drainage on the paper points, the tooth may be completed (obturated) at this appointment.

Visit recommendation

A necrotic tooth, particularly a case with a sinus tract, may be treated in one appointment. Attention is focused on meticulously cleaning (volumes of irrigating solution), shaping (clean dry shavings on the last files), and disinfecting the canal (with alternating agents: sodium hypochlorite, EDTA, CHX):

- It is possible that a patient might experience pain and swelling even after appropriate and efficient instrumentation of a necrotic tooth (studies report 13% to 17%). In this case, however, the pressure that might build postoperatively would be released (drain) through the sinus tract.
- If the cleaning, shaping, and disinfecting procedures were done well, the lesion should heal and the sinus tract eventually close (disappear).

Case 3: Pulpal necrosis

The patient has a facial swelling. Thermal and electric pulp tests are negative, and an apical periradicular lesion is radiographically apparent. The diagnosis is pulpal necrosis.

Treatment

- Treatment should proceed as described in Case 2, except that the tooth should not be obturated.
- If the canal(s) cannot be dried or drainage and/or an odor are continuously detectable on paper points, medicate the root canals and complete the treatment at a subsequent appointment.
- As such, mix a combination of calcium hydroxide powder and 2% CHX (liquid) to a toothpaste consistency, apply it into the root canal(s) with a lentulo spiral, and compact it with assorted Schilder pluggers.
- Schedule the patient for a follow-up visit (2 to 4 weeks).
- If the patient has a fever or develops a fever, prescribe an appropriate regimen of antibiotics.
- Upon the patient's return, remove the calcium hydroxide and CHX mix and verify PL and WL. Irrigate the canal(s) with sodium hypochlorite and EDTA, and if needed, prepare the canals to one file size larger than the last file size used during the initial visit.
- Dry the canals with paper points:

- Option 1: If the patient is asymptomatic and the tooth can be dried, complete the treatment at this appointment.
- Option 2: If the patient is symptomatic and/or drainage and the odor are still detectable, look for an additional source of the problem. There might be an additional canal(s), a perforation(s), a nonodontogenic issue, the presence of resistant bacteria (eg, actinomycosis), and host problems (eg, immune deficiency, untreated diabetes), among other reasons.

Visit recommendation

If no other problem is diagnosed, repeat the calcium hydroxide and 2% CHX paste fill, but discuss the possibility of surgical intervention or referral with the patient.

Case 4: Pulpitis with pulpal necrosis

The patient presents for endodontic therapy on a tooth that has severe loss of coronal tooth structure (eg, decay, cracks, or trauma). The tooth presents both isolation and interappointment contamination risks. The diagnosis is partial necrosis.

Treatment

• Isolating (clamping) a tooth damaged to a level below the gingival crest, possibly even below the crest of bone, requires gaining access to solid tooth structure via crown-lengthening procedures and innovative rubber dam approaches (see lesson 15).

• Interappointment contamination and reinoculation is a major risk regardless of how well temporization is done.

• Structurally deficient teeth may be temporarily restored with dentin bonding and a composite or glass ionomer cement. The teeth should be isolated with rubber dam and accessed from the occlusal aspect of the composite restoration.

Visit recommendation

• Considering the difficulty in isolating the tooth, preventing contamination and reinoculation between visits, and possibly having to repeat the temporization process at a second appointment, it is better to resolve these difficult structural situations by completing the endodontic procedures in one appointment.

• Studies show that teeth treated in one appointment with a pretreatment diagnosis of pulpitis or necrosis with an apical periodontitis have a reasonable prognosis for complete healing. Though reports show that the flare-up potential is 13% to 17%, the rewards and benefits of completing these cases in one appointment far outweigh the risks The patient must be informed of the risks and the reasons and benefits of taking the risk (ie, informed consent).

CONCLUSION

The decision to endodontically treat a tooth in one or two (or more) appointments may depend on tangible issues such as the patient's medical and dental history, the amount of remaining tooth structure, the current pain symptoms or signs of infection and inflammation, and the complexity of the canal anatomy. However, the final decision to treat a case (regardless of the number of appointments) is the doctor's and must be made on a case-by-case basis.

LESSON 28

Interappointment Temporization

OBJECTIVE

To provide a quality access opening seal that will prevent microbial contamination between endodontic treatment appointments.

INTRODUCTION

The purpose of a temporary filling between appointments is to create a seal over an endodontic access opening that is impervious to the ingress of the oral flora. Leaking restorations, whether provisional or permanent, are responsible for endodontic post-treatment disease and can generally be attributed to technical deficiencies of the restoration. Studies indicate that a tooth with a quality root canal treatment that is restored with a poor restoration will fail from 50% to 70% of the time.

CORONAL SEAL DURING AND AFTER ENDODONTIC THERAPY

Most teeth that require root canal treatment have lost considerable amounts of coronal tooth structure to caries, poor restorations, and/or trauma. Though this lesson focuses primarily on sealing the canal, your patients will be best served in the long run if you repair the structure before the pulp chamber is accessed. Consequently, it is recommended that all caries and unsupported restorative material be removed and that the tooth be rebuilt with a tight-sealing provisional filling that will withstand occlusal forces and prevent leakage throughout the treatment phase.

Because the pulp might be exposed during the excavation process, it is best to isolate the tooth with

rubber dam. However, a structurally deficient tooth may defy clamping and prevent the application of a secure nonleaking dam. In such a case, isolate the tooth with cotton rolls as best as possible, and excavate without a dam. If during the excavation process the roof of the pulp chamber is exposed, remove the pulp tissue, locate the orifices, and flush the chamber free of blood and debris. Then, place cotton pellets over the orifices, and place a temporary restorative material (eg, zinc oxide–eugenol, IRM [Dentsply]) over the cotton pellet.

Once the temporary material has set, the balance of the reconstruction process can take place. Amalgam, composite, or glass ionomer cements are suitable materials to rebuild tooth structure. This provisional restoration not only helps orient the operator to the long axis of the tooth but also enhances the placement of the rubber dam. You can now prepare an ideal access through the new restoration. The access preparation should be well directed and should not undermine the provisional restoration. Remove the cotton pellets, and with the orifices already exposed, focus your attention on the canal(s).

PROVISIONAL RESTORATIVE MATERIALS

Criteria

Since many clinicians prefer to leave a cotton pellet in the pulp chamber between endodontic appointments (to make reentry to the canals easier), it is important that the layer of provisional filling material be thick enough to withstand occlusal forces and prevent a compression collapse into the cotton. For safety reasons, the thickness of the occlusal provisional filling should be at least 4 mm. When more than three walls of the crown are missing, it is wise to provisionally crown the tooth and provide access through the crown.

Common materials

- Cavit (3M ESPE) is a composite of zinc oxide, calcium sulfate, glycol, polyvinyl acetate, polyvinyl chloride, and triethanolamine. It is a soft material incapable of withstanding excessive occlusal forces when only two or three walls of the crown remain. Cavit provides a good marginal seal for nonvital teeth. It is dimensionally stable, easily placed, and easily removed. However, Cavit should not be used as a restorative material on vital teeth. It is hydrophilic, and as the material sets, it absorbs fluid from the pulp and aspirates the odontoblasts into the dentinal tubules, inciting a latent pulpitis.
- IRM is resin-reinforced zinc oxide–eugenol cement that can withstand occlusal forces in large cavities. Though a provisional crown works better when replacing two or more walls, this material combined with a second material-seal works well if the interappointment time is short. If this is the case, Cavit or IRM can be placed as the first (deepest) layer and an overlying layer of harder cement—such as glass ionomer cement, zinc phosphate, or the more recognized and stronger restorative materials such as amalgam or composite—can follow.

• Glass ionomer cements are calcium fluoro-alumino-silicate glass powders that are mixed with acrylic acid. Conventional and resin-modified glass ionomer cements have been used both as provisional fillings and as orifice barriers (Fig 28-1). They adhere chemically to dentin, display antimicrobial properties, are biocompatible, and release fluoride ions. Setting shrinkage is related to the thickness of the material. The thicker the layer of material, the greater the degree of shrinkage. Though shrinkage may cause the material to pull away from the walls and allow leakage, this consideration is not a problem for short-term interappointment situations. If glass ionomer or resin is used as a temporary material, all traces (residual) of sodium hypochlorite must be removed (rinsed) from the walls of the access cavity, since it interferes with the bond of a composite resin.

The placement of glass ionomer cements over the pulp chamber floor and canal orifices after completion of the root canal filling has been tested in vivo and in vitro, and the reports are favorable, indicating that glass ionomer cements resist leakage.

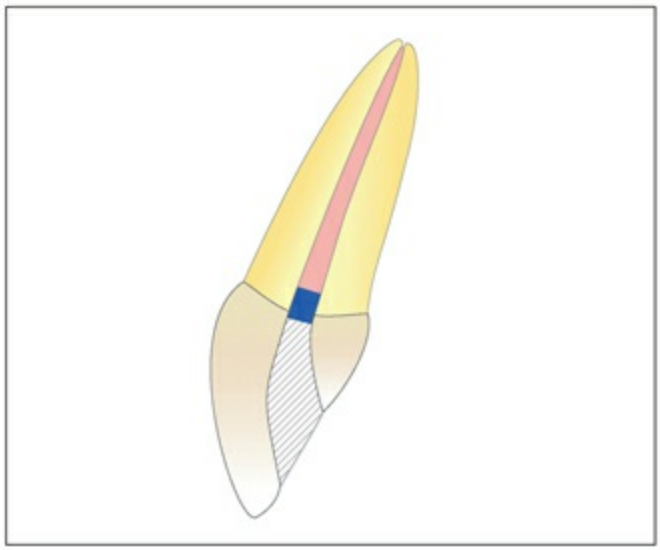


Fig 28-1 Completed root canal filling of an anterior tooth. The canal orifice is sealed with an orifice barrier of glass ionomer cement. The access cavity is sealed with composite.

COTTON PELLETS

Many clinicians place cotton pellets (medicated or dry) inside the pulp chamber between endodontic treatment appointments. However, cotton fibers have been reported to emerge through restorations and cause wicking and leakage. Instead of a cotton pellet, a solid sponge (eg, the sponge material used to package endodontic instruments or commercially available sponges) offers several advantages: It may be cut into an appropriate size and sealed in the pulp chamber, it does not attach itself to the walls, it offers resistance to the provisional filling material that follows, and it is easily found and removed. If a cotton pellet is preferred, care must be taken to use a small noninterfering size to allow for a sufficient thickness of at least 4 mm of the provisional filling.

ORIFICE BARRIERS

Once the canal has been accessed and instrumented, some clinicians place a paper point (either dry or

saturated with a medicament) into the canal in an attempt to supply an additional level of protection against contamination and to prevent temporizing material from entering the orifice. This practice is *not* recommended. If anything is placed in the canal, it should be a mix of calcium hydroxide.

INTERAPPOINTMENT ROOT CANAL DRESSINGS

An intracanal interappointment root canal dressing should be placed under the following conditions:

- When the complexity of the case is difficult and there is insufficient time to complete the case in one appointment
- When at least one canal of an infected tooth continues to weep fluid throughout the instrumentation process
- When mineralization-inducing procedures are necessary (eg, apexogenesis, apexification)
- When the doctor does not believe in treating endodontic cases in one appointment

Many different materials have been used as root canal dressings. Some newer medicaments, including bioactive glass, seem promising but have not been proven more effective than the following preferred agents.

Calcium hydroxide

The most frequently recommended interappointment medication for root canals is calcium hydroxide. Due to its slow hydrolyzation at body temperature, calcium hydroxide is most efficient when left in the canal space for 1 to 4 weeks. Calcium hydroxide has a high pH (approximately 12.5) and so creates an environment that kills most bacteria and inactivates most bacterial toxins. A large body of literature supports its efficacy in substantially destroying endotoxins that are rarely, if ever, affected by the instrumentation techniques or irrigating solutions used today. When left behind these endotoxins are capable of promoting and perpetuating inflammation.

Calcium hydroxide is available in ready mixed form (gel or paste), or the powder (available at any pharmacy) can be mixed into a soft paste with sterile saline or anesthetic solution. The paste can be injected, spun into the canal with a lentulo spiral (preferred method), or (less effectively) placed with a hand file or paper point.

Phenolic preparations

Derivatives of phenol, including camphorated phenol and cresol, are highly toxic to human cells and fail to eliminate microbial contamination in a third of the cases treated. The toxicity of these compounds outweighs their antimicrobial effect, so their use is *not* recommended.

Formaldehyde

Formaldehyde is highly toxic, mutagenic, and carcinogenic. It is absorbed and distributed to all organs in the body. Formaldehyde has been used mainly in the form of formocre-sol or tricresol as a pulpotomy remedy in primary teeth. Presently, there is no justification to use formocresol in adult endodontic treatment.

Halogens

Chlorine (eg, as sodium hypochlorite) and iodine (eg, as iodine potassium iodide) are effective disinfectants. Both substances may be used to disinfect rubber dam and tooth surfaces before accessing a tooth. Iodine potassium iodide is an effective antimicrobial agent and acts by producing antiseptic vapors. It may also be used as an interappointment dressing. Allergic reactions to iodine and iodine derivatives can occur but are rare.

RECOMMENDED CALCIUM HYDROXIDE TECHNIQUE

1. Mix the calcium hydroxide dressing paste to the consistency of toothpaste:
   - Some have suggested mixing calcium hydroxide with phenol derivatives, formaldehyde derivatives, or other substances. However, most clinicians feel this renders the calcium hydroxide less absorbable and more toxic. This practice is *not* advised.
   - Studies have shown that pastes are best delivered (inserted) by a slowly rotating (1,000 rpm) lentulo spiral.
2. Insert the paste a number of times and, between insertions, apically compact the material with dry cotton pellets.
3. Remove excess material from the cavity margins with a slightly moistened cotton pellet.
4. Place a provisional filling, with or without the insertion of a cotton pellet or sponge, into the access opening over the calcium hydroxide–filled canals (Fig 28-2).

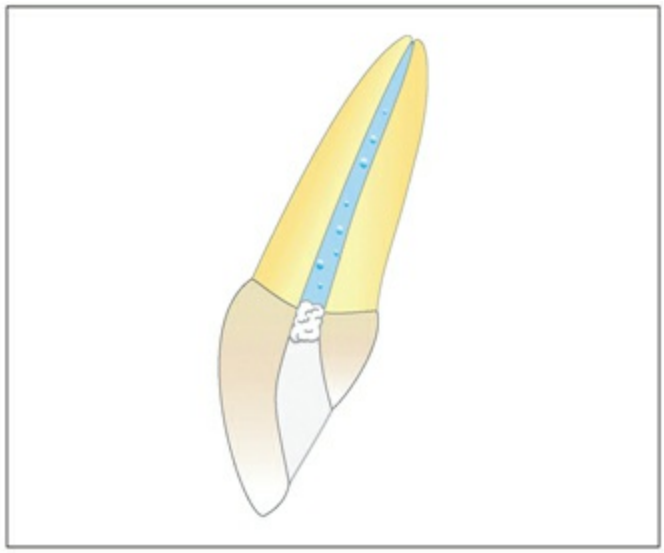


Fig 28-2a Root canal of an anterior tooth containing calcium hydroxide. A cotton pellet is placed over the dressing, and a provisional filling seals the access.

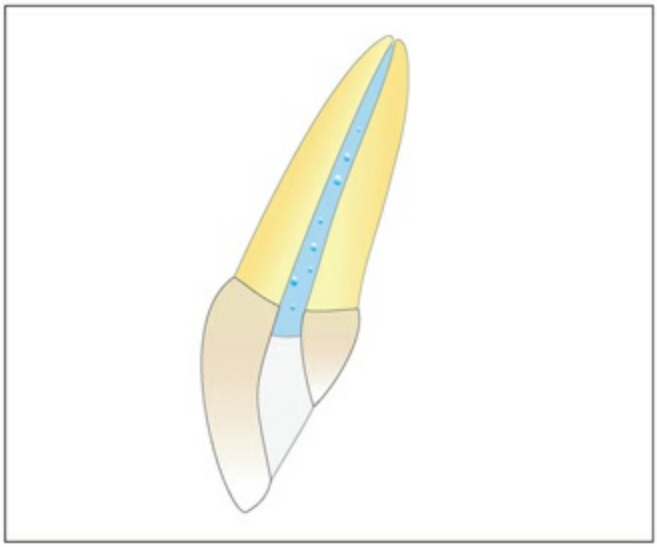


Fig 28-2b Root canal of an anterior tooth containing calcium hydroxide. Instead of a cotton pellet, the dressing is filled to a higher level, and the cavity is sealed with a provisional filling.

CONCLUSION

- Whenever possible, a single-visit treatment should be considered (see lesson 27).
- Most teeth are considered innocuous after careful and thorough instrumentation.
- For multiple visits, dress the canal with an interappointment dressing of calcium hydroxide if *(1)* it is infected, *(2)* it has an associated periapical radiolucency, or *(3)* a doctor is uncomfortable completing the case in one appointment.
- The dressing should remain in place for at least 1 to 4 weeks.
- All retreatment cases should be treated in two or more appointments, and the canals should be dressed with calcium hydroxide between sessions. These teeth may be contaminated with bacterial flora that are even more difficult to eradicate than in primary necrotic cases.
- Current clinical research in patients with asymptomatic teeth with apical periodontitis where careful aseptic treatment protocols were applied (ie, rubber dam isolation, disinfection of rubber dam, disinfection of the root canals with 1% to 6% sodium hypochlorite during and after root canal preparation, smear layer removal with ethylenediaminetetraacetic acid, and a final disinfection wash with 2% chlorhexidine) have shown similar healing results with single-visit or multiple-visit endodontic treatment.

LESSON 29

Final Steps Before Obturation

OBJECTIVE

To provide a preobturation checklist to ensure the root canal is clean, shaped (prepared), and disinfected.

INTRODUCTION

A root canal is ready to fill when it is prepared to an adequate apical size and continuous taper, free of debris, free of smear, disinfected, free from acute symptoms, and dry.

ADEQUATE APICAL SIZE AND CONTINUOUS TAPER

Each canal must be shaped to a size that will accommodate the individual apical diameter and taper of a core material (solid or semisolid). To effectively obturate a canal, you must locate and maintain a working length (WL) that reflects the terminus of the canal itself. The length of a prepared canal should extend from the orifice to the apical constriction of the canal, considered the *cementodentinal junction*.

The position of this constriction varies and is influenced by a number of factors. Determining apical canal anatomy is not easy. For instance, the apical constriction is frequently absent, the apex may have multiple constrictions, and inserted instruments may bind anywhere along a canal wall, leading an operator to a tactile misinterpretation. Therefore, it is recommended that the canal length

be established with an electronic apex locator (electrometrically) and/or with a radiographic estimation and adjustment from the root terminus.

Under normal circumstances, most authorities accept an adjustment from 0.5 to 1.0 mm from the radiographic terminus. For infected root canal systems, the best healing results are achieved when the WL is no more than an estimated 0.5 mm from the tip of the root terminus. In a comprehensive review of healing outcomes, therapeutic procedures that were either longer than the radiographic apex or shorter than 2 mm from the root tip showed significantly reduced success rates:

- If the canal is actively infected, it should be treated with a calcium hydroxide paste dressing.
- When the patient returns for a follow-up appointment, check the canal for moisture and excessive bleeding. The decision to obturate will be based on this evaluation and any remaining symptoms.
- Repetitive problems require alternative solutions, such as surgical intervention.

DEBRIS REMOVAL

Step 1: Irrigation

Thorough irrigation with a combination of irrigating solutions (eg, sodium hypochlorite, ethylenediaminetetraacetic acid [EDTA], MTAD BioPure [Dentsply], chlorhexidine [CHX]) and competent aspiration effectively clean and remove tissue remnants, dentin debris, and microorganisms from the biofilm on the root canal wall.

Step 2: Recapitulate a master apical file to patency length

1. During the step-back preparation of the apical segment, the last shaping file used to WL should show clean shavings (if any) in its flutes when it is withdrawn from the canal.
2. Since it is possible that dentin filings and debris may have accumulated in the apical constriction area, gently rotate the No. 10 nickel-titanium or stainless steel flexible hand file to patency length (PL) (0.5 to 1.0 mm beyond WL). Upon its removal, inspect the file for cleanliness. It should be visually clean.
3. If you observe debris on the file, irrigate (flush) the canal with a sodium hypochlorite solution. With solution still remaining in the canal, reinsert the No. 10 file to PL. If the file tip still shows debris, the apical segment has not been prepared and/or cleaned appropriately:
   - Gutta-percha cone tips are usually thin and fragile, particularly the classic tapered cones (eg, medium, medium-fine, fine). If the PL is not clear of debris and a master cone is chosen with the belief that vertical condensation will drive the point to WL, it is more likely that the remaining debris will buckle the tip and leave the final fill short of the desired length or that the vertical force will drive both the debris and the gutta-percha beyond the foramen and into the periapex.
   - To prevent these mishaps, insert a No. 15 or No. 20 file to the previously accepted WL, and reconfirm that measurement (preferably electronically).

4. Once WL is confirmed (or adjusted), repeat the filing series, and give particular attention to increasing the flare of the coronal and mid-root segments. By increasing the taper (flare) of the upper segments of the canal, the irrigating needle can penetrate the canal deeper and more efficiently deliver the sodium hypochlorite and EDTA (chelating agent) to the apical segment.
5. Again insert the No. 10 or No. 15 file to PL; no filings should be apparent upon the file's removal. This assures the glide path to WL is totally clear and ready to accept the gutta-percha master point.

SMEAR REMOVAL

If left on the canal walls, a smear layer will inhibit the sodium hypochlorite from penetrating and removing tissue remnants, debris, and microorganisms from the dentinal tubules. It also prevents the gutta-percha and sealer from adhering to the canal walls and infiltrating the dentinal tubules. As such, the seal will be inadequate and subject to leakage.

The smear layer can be removed from the finished preparation with a series of intracanal rinses (in the following order): sodium hypochlorite, EDTA, saline, 2% CHX. This combination of solutions (in series) has been shown to be more effective than any one of the solutions used alone.

DISINFECTION

Sodium hypochlorite is a tissue solvent and is the most effective and popular root canal irrigating solution. The recent literature suggests that it should be employed between the use of each filing instrument. Sodium hypochlorite can be used in varied strengths (from 0.5% to 6%), and it is most effective when heated to body temperature or slightly above and left in the canal for extended periods of time (ie, from 3 to 5 minutes). When sodium hypochlorite is used alternately with EDTA, the combination is highly effective in removing both organic and inorganic debris from the canal wall.

Reports suggest that the canal and pulp chamber be rinsed in the final stages before obturation with saline to remove residual sodium hypochlorite and EDTA, followed by a 2% CHX antimicrobial rinse. The literature clearly shows that the presence of sodium hypochlorite affects the curing of composite resin. As such, the final rinse with saline or CHX is particularly important if a resin filling technique will be used to obturate and seal the canal and/or if a composite resin will be used to fabricate a core.

ABSENCE OF ACUTE SYMPTOMS

Percussion (biting) pain at the time of filling is a symptom of apical periodontitis. Teeth displaying this symptom should be reaccessed to explore the possibility of:

- Coronal or root fracture
- A residue of debris and microorganisms and inflamed tissue at the WL or PL
- Additional canals that have been overlooked

It is also possible that a once quiet periapical pathosis has been exacerbated by irrigant, debris, and bacteria that have been pushed out of the apical foramen during instrumentation. In response to this insult, the patient's immune system might have responded with fluid (pus) and pressure at the periapex. Highly symptomatic teeth should not be final filled with gutta-percha but should be treated with a calcium hydroxide dressing and reevaluated in 1 to 4 weeks (see lesson 9).

DRYING THE CANAL

Sealers and/or resins will not set or adhere to the root canal wall in the presence of moisture. Drying a canal with compressed air must be done with great caution, and the pressured air must be confined to the access pulp chamber. A forced air stream directed into a root canal is capable of causing an air embolism that will provoke serious, potentially life-threatening, consequences for the patient (eg, immediate pain, swelling).

Paper points, from coarse to fine (depending on the size and taper of the last working file), are effective in safely soaking up the bulk of canal fluid(s). To prevent bleeding in the apical tissues and/or stimulating a foreign body reaction by leaving fragments of cellulose beyond the apical constriction, premeasure the paper points to WL. When removed from the canal, test the point on the back of a gloved hand to determine if the tip is (visually) dry. Cases that continue to show moisture (ie, fluid, pus, or blood) may require reconfirmation and reinstrumentation to WL. If after reinstrumentation the canal continues to weep moisture, then the canal is actively infected, and should be treated with a calcium hydroxide paste dressing. Schedule the patient for a follow-up appointment (1 to 4 weeks), at which time you should retest for moisture. The decision to obturate should be based on that evaluation. If this problem persists, surgical intervention may be necessary.

PART FIVE
Endodontic Obturation

LESSON 30

Guidelines for Sealers and Solid Core Materials

OBJECTIVE

To facilitate the decision-making process as to whether a given root canal can be safely obturated with biocompatible sealers and solid core materials.

ENSURING DRY CANALS

Root canals must be dry at the time of obturation. Moisture interferes with interface adhesion among the canal wall, sealer, and gutta-percha. As mentioned in lesson 29, avoid compressed air drying. Rather, use a series of sterile paper points (large to fine) set to working length (WL), and allow sufficient time for fluid to be absorbed from within the canals. This method is both the safest and most efficient way to dry canals.

If upon their removal the paper points are repeatedly wet or stained with blood, the paper points are obviously passing through the foramen and into the patency zone. In this case, you must determine if WL is correct. To do so, consider whether the terminus may have been transported and whether a new WL needs to be reestablished electronically with an apex locator.

SEALERS

Sealer acts as an adhesive filler that binds the dentin interface to the solid core filling material only when and if the canal walls are dry.

Zinc oxide–eugenol

Eugenol is a phenol derivative that is a major component of the most popular formulations of sealer pastes. It is typically combined with zinc oxide powder. Zinc oxide–eugenol sealers have been used for many decades. They provide good long-term results and perform well in clinical studies and laboratory tests. However, most zinc oxide–eugenol sealer cements are toxic to cells in the connective tissues and invoke an inflammatory response that, fortunately, dissipates within 48 hours. Patients should be forewarned of this sequela and assured that the reaction is a natural response that will resolve in a few days.

Calcium hydroxide

Calcium hydroxide is an antimicrobial agent that has been highly promoted for its ability to stimulate osseous, cemen-tum, and dentin repair (pulp caps, apexogenesis, and apexification). The use of calcium hydroxide as a sealer has not been shown to be as effective as the zinc oxide–based sealers, and its inflammatory effects on periapical tissues and neurologic structures are greater. Calcium hydroxide sealers are not embraced by endodontists because of the length of time (months) they irritate the periapical tissues.

Epoxy resin

- AH26 (Dentsply) is the most commonly used resin sealer.

Reportedly, the sealer has good handling characteristics, adheres well to dentin, and can be used effectively with heat during obturation. However, this sealer produces formaldehyde as a by-product of its setting reaction, so it has been reported to be toxic for longer periods of time.

- AH26 Plus (Dentsply) does not produce formaldehyde, and though it is irritating to periapical tissue, its inflammatory properties resolve rapidly during the setting process. This sealer is reported to be nontoxic within 24 to 48 hours and is very popular with endodontists.
- Epiphany SE Self-Etch Sealer (Pentron Clinical Technologies) is a dual-curable composite resin sealer (multimeth -acrylate). It is recommended for use in combination with Resilon (Resilon Research) (solid core). The sealer was found to be initially toxic in cell culture, but when compared to AH26 Plus, the initial toxicities were found to be quite similar. Once set, however, Epiphany does remain moderately toxic over a longer period of time than does AH26 Plus.

Glass ionomer

The glass ionomer sealers (Ketac-Endo [3M ESPE]) are pastes made of finely ground aluminosilicate glass and a polycarboxylate copolymer, which should be mixed to the consistency of honey. The sealers are all similarly toxic in the short term. The glass ionomer sealers offer good adhesion to dentin; however, they are moisture sensitive, and require a controlled dry field to set properly.

Sealer placement

- According to studies, a thin coat of sealer may be efficiently deposited into the depths of the canal by inserting a lentulo spiral, running clockwise in a slow-speed handpiece, into the canal with a slight pumping motion.
- An alternative is to place a coated ultrasonic file in the canal, which, when energized, will effectively stream the sealer onto the canal walls.
- A third method is to coat an appropriately sized paper point with sealer and paint the canal walls prior to insertion of a coated master gutta-percha cone.
- The least effective methods are to coat the master gutta-percha cones and/or the final master file with sealer before obturation.

Sealer guidelines

- All obturation sealers are irritants in their freshly mixed states.
- Use a small amount of sealer to minimize the extrusion factor and reduce the potential of irritating the periapical tissue.
- After setting or curing, most sealers are irritants, but over time, they lose their irritant components and become relatively inert. However, patients should be warned that they may experience mild to moderate pain following the treatment. Patients should be assured that postoperative pain is a normal and temporary response, and the discussion should be recorded. If not advised of this, they may (if they do have pain) think something was done incorrectly.
- All sealers are absorbable. Components of sealers can be managed by the immune system unless the material is forced into inaccessible areas such as the sinus or the mandibular canal. If forced into these structures, the sealer must be removed immediately.
- Pastes (alone) are not intended to fill the entire root canal system, and their composition should never include a heavy metal.

OBTURATION MATERIALS

Ideally, the root canal filling should seal all foramina (portals of exit) leading to the periodontium with a stable (nonshrinking) material that adapts and adheres well to the instrumented canal walls, flows into the opened dentinal tubules, and creates a safe 4- to 6-mm solid plug at the prepared apical terminus.

Filling techniques

A wide range of filling material techniques have been shown to provide long-term success (ie, the healing of periradicular lesions following obturation). The most common of these are the following:

- Sealer (cement, paste, or resin) only
- Sealer-coated single cone or a stiff or flexible core material
- Sealer-coated canal and cold compaction of core material
- Sealer-coated canal and warm compaction of core material
- Sealer-coated canal and injection and/or carrier-based system

Sealer only

Studies have shown that paste-only techniques are subject to volume shrinkage during their set. As such, the material pulls away from the walls as it sets, and the resultant loss of interface adhesion leaves gaps and/or channel formations between the dentin wall and the set sealer. This problem makes controlling length and density difficult to impossible, and extrusion becomes a major risk. With the increased risk of extrusion, the toxicity of certain sealers, including paraformaldehyde-containing pastes such as Endomethasone (Septodont), N2 (Indrag Agsa), or SPAD (Dentsply), is a great concern. Though sealers that incorporate calcium hydroxide may be more apt to be absorbed if extruded, the shrinkage factor still exists, and leakage over time is inevitable.

Mineral trioxide aggregate

Mineral trioxide aggregate (MTA) (gray or white) is biocom-patible, and its sealing ability is its greatest asset and the reason for much of its success. MTA is hydrophilic and requires moisture to set, which can make delivery and compaction difficult. A number of carriers are available, and energizing ultrasonic tips have been suggested for condensation.

MTA has been used successfully in myriad ways:

- When used as a pulp capping material, MTA produces a biocompatible seal and maintains or restores the underlying pulp tissue (see lesson 36).
- As a root end filling material used during endodontic surgery, it not only seals the apically prepared root end but also induces osseous and cementum repair over the resected root.
- MTA repairs large perforations in the canal wall and pulp chamber floor. The seal prevents coronal leakage, and its bio-compatibility induces osseous, dentin, and cementum repair and restores the approximating periodontal tissues to health.
- In selected immature root cases (apexification), MTA can be inserted to the WL of a well-instrumented canal, and over time an osseous, dentin, or cementum barrier will form (see lessons 36 to 38).
- Since set MTA is extremely hard to remove, room for post spaces should be prepared in root induction cases at this appointment and the access cavity sealed.
- Upon the patient's return, gutta-percha can be condensed as a backfill against the set MTA (if deemed necessary).

Gutta-percha

- The sizes of standardized gutta-percha cones correspond to the International Organization for Standardization (ISO) sizes (0.02 taper) of endodontic instruments and range from No. 15 to No. 140. Because size tolerances of ± 0.05 mm (a full ISO size) exist for standardized cones, a box of size No. 35 gutta-percha cones actually may contain any number of sizes between No. 30 and No. 40.
- Tapered gutta-percha cones are available in ISO tip sizes and in tapers that range from 0.04 to 0.12.
- Nonstandardized auxiliary gutta-percha cones or accessory cones are not held to ISO size standards and are therefore more tapered than the customary core cones. They are available in sizes from extra-fine to large or A, B, C, and D. Dimensional variations are greater than with standardized cones. A selection of gutta-percha cones is shown in Fig 30-1.

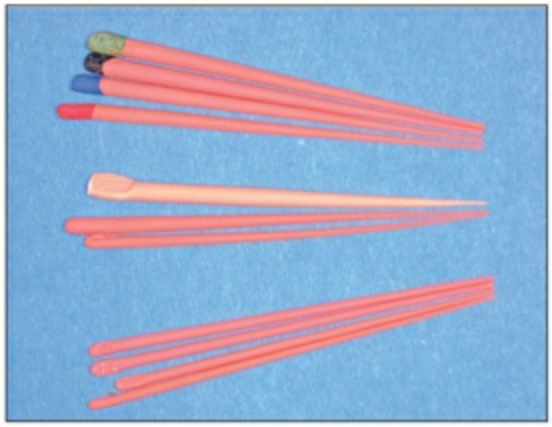


Fig 30-1 Gutta-percha cones tapered and sized according to the ISO standards.

Resilon

Recently, a new root filling material, Resilon (Resilon Research), was introduced. Derived from polymers of polyester, it contains bioactive glass and radiopaque fillers and has the same handling properties as gutta-percha. The Resilon core materials, similar to gutta-percha cones, are available in ISO sizes with 0.02, 0.04, and 0.06 tapers. Additionally, pellets of this material (Epiphany Pellets [Pentron Clinical Technologies]) are available for use with the Obtura II heated delivery system (Obtura Spartan). Resilon is recommended for use in combination with a new dual-curable dental composite resin sealer, Epiphany Root Canal Sealant (Pentron Clinical Technologies). All obturation techniques that are utilized with gutta-percha can be adapted to Resilon.

MASTER CONES

The master cone is the first cone used for obturation. A well-fitted master cone must reach the preestablished WL. It must fit snugly in the apical part of the preparation, and you should experience tug back (resistance) when the cone is withdrawn from the canal. If the cone fits loosely, either select a larger cone or shorten (cut) the end in small increments until it fits snugly at the established length.

If the cone is too wide at its apical diameter or too tapered to reach the apex, select a smaller size or taper. Take a radiograph of the master cone to verify that the cone tip is at the known WL (apical constriction) (Fig 30-2).

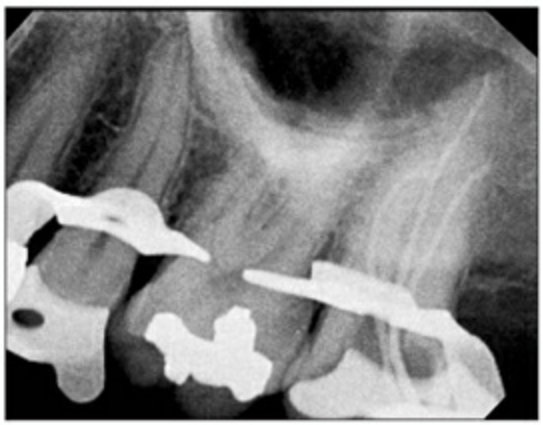


Fig 30-2 Radiograph of a master cone in a maxillary left second molar. Sealer has been added to the cones prior to taking the radiograph.

Selection

The master cone should be customized to fit snugly at WL. Although the following description is for gutta-percha, the same technique also applies for Resilon. There are three options in master cone techniques, and each depends on the size and shape of the gutta-percha and the size and shape of the finished root canal preparation.

- A very helpful tool for this step is a gutta-percha gauge that allows comparison and matching of the master apical file size and cone size. Adjust the master cone in length until it has the same diameter as the master apical file. Pinch the master cone with pliers at the peak of the crown to establish a coronal reference point that will later be used to confirm that the master cone is seated to WL.
- Select a nonstandardized cone size (medium-fine or fine) and trim it back from the tip to visually match the tip of the final file that was used for canal preparation.
- If the root canal preparation was accomplished with more tapered rotary instruments, the taper of the auxiliary cones will better match the shape of the preparation than will standardized 0.02 tapered cones.

Cones in matching sizes and tapers are also available from various manufacturers and may be fit to the position of the last working file used to WL.

Caution

- If a cone is too tapered for the preparation, it will make premature contact with the canal wall coronal to the apical preparation and not reach the WL. Spreaders with large tapers will encounter the same problem and will be unable to reach the apical third of the canal where compaction forces are critical.
- If a cone is not tapered enough, it will be loose and often will look crimped at the tip. To avoid

over- or underfilling, the primary fit (apical tug back) of a master cone should be adjusted to fit both the apical size and taper (resistance form) of the preparation. This fit is critical to a well-sealed apical preparation (Fig 30-3).

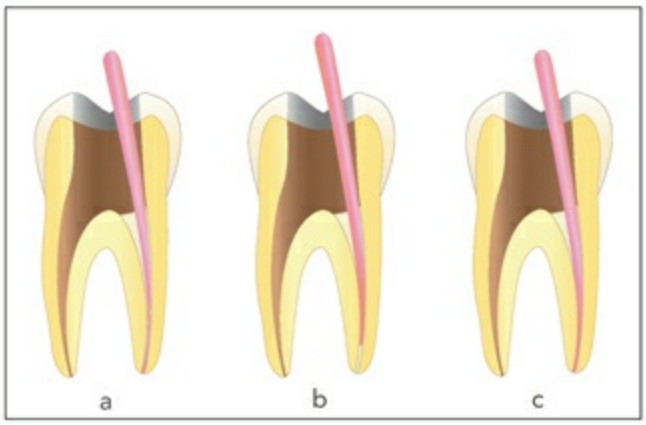


Fig 30-3 Master cone in a mandibular molar. Make sure the master cone is not too loose *(a)* or too thick *(b)*. It should be corrected for a good fit *(c)*.

Adaptation

Adapting the standardized master cone to fit correctly at the apical end of the preparation often demands the tip be cut back to increase the tip diameter. As mentioned, the most precise way to shorten the cone is to insert it into a gutta-percha gauge (Fig 30-4) and cut the cone to the same tip size as the last file that was taken to WL (Fig 30-5). Measure and trim the adapted master cone to WL (0.5 mm short of the electronic and radiographic WL), pinch it with cotton pliers, and insert it into the root canal. The pinch mark should line up with the chosen coronal reference point.

If the cone looks buckled upon its removal, the preparation may be insufficiently tapered, causing tug back to occur in the middle third of the root canal instead of occurring at the most apical level. Make sure the canal is patent (Fig 30-6), and go back through the apical file series.

Repeating a 0.5-mm step-back series and reusing (recapitulation) the master rotary file will result in the desired apical taper and fit (Fig 30-7).

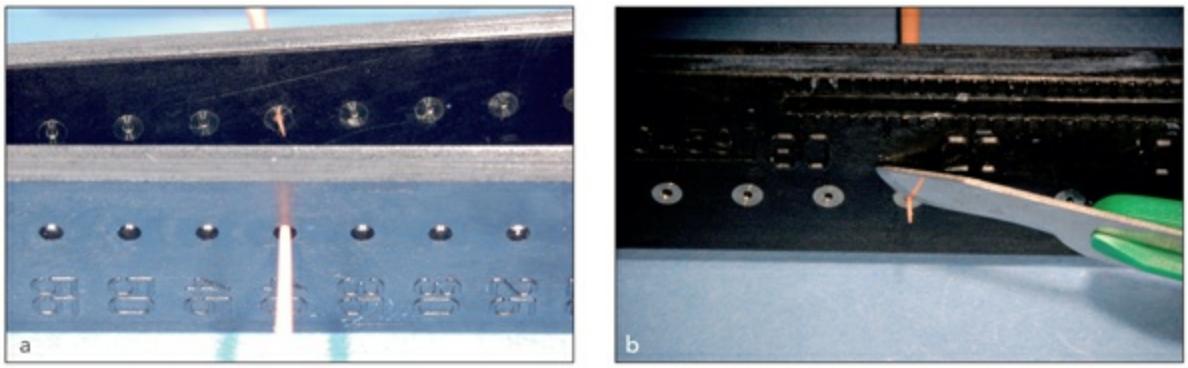


Fig 30-4 *(a)* Gutta-percha cone inserted into a gutta-percha gauge. *(b)* Gutta-percha cone trimmed to size with a sharp instrument (eg, scalpel, sharp excavator).

Fig 30-5 Master cone next to the master file. The tips now have the same size.

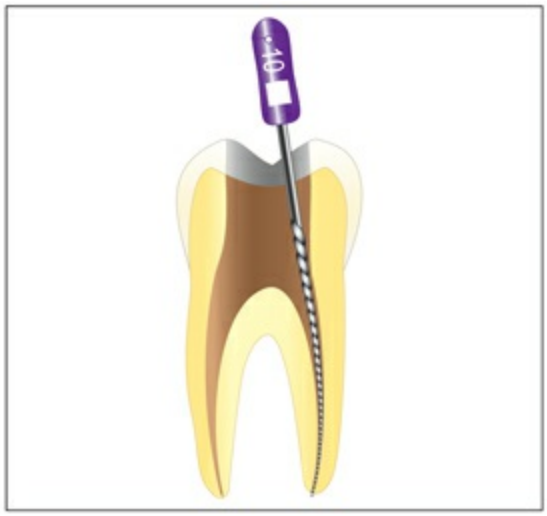


Fig 30-6 Patency is confirmed using an ISO-size No. 10 K-file.

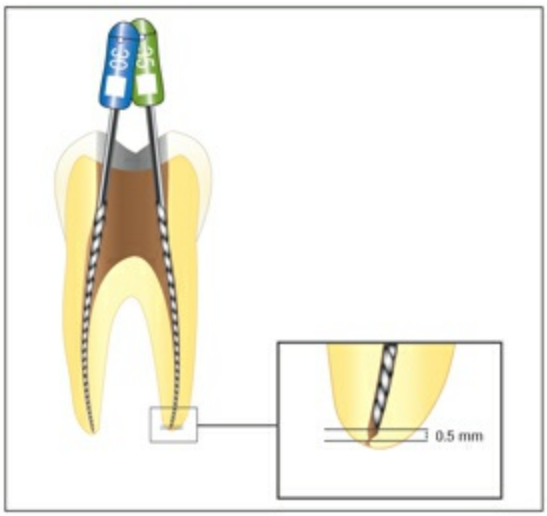


Fig 30-7 Mesial root shows recapitulation to WL with a master apical file. The file in the distal root verifies the 0.5-mm step-back, which provides sufficient taper for obturation.

Material sterility

Studies show that gutta-percha points are not sterile once the manufacturer's packaging box is opened. To ensure that there is no interruption of the aseptic technique, submerge the gutta-percha points or pellets in a 5.25% to 6% sodium hypochlorite solution (full-strength Clorox bleach) for 1 minute. This 1-minute bath is reported to kill all bacteria and spores. Keep in mind that the glass slab used for mixing sealer should also be sterile.

Placement

A gutta-percha or Resilon cone equal in apical tip size, taper, and WL to the last working file should be selected. Some manufacturers offer convenient file–to–gutta-percha size matching that is accurate and decreases the potential of overfilling.

Upon its insertion, the master cone should reach WL with only slight wall resistance. Once the master cone is firmly seated to WL, its removal should be met with a little frictional resistance from the walls of the apical 1 to 2 mm of the root canal. This tug back (see lesson 31) is indicative of a wellfitting cone.

Lateral condensation is still the most commonly taught and used compaction technique. Most endodontists use heated vertical compaction thermoplastic techniques, but the fear of pushing sealer, gutta-percha, and/or Resilon beyond the apical foramen makes many clinicians uncomfortable with heated techniques. However, these heat devices are extremely efficient when the apical terminus has been properly prepared, the master cone has tug back, and the temperature setting and compaction procedure are done in accordance with the manufacturer's guidelines.

LESSON 31

Materials and Methods of Obturation

OBJECTIVE

To understand the use of biologically accepted materials and methods that may be used to protect the periradicular tissues from bacterial recontamination by providing a fluid-tight seal of a cleaned and prepared root canal system.

INTRODUCTION

The research is compelling: Cleaning and shaping of the root canal is the most important factor in the treatment of endodontic pathosis, and the quality of that chemomechanical action is responsible for reversing the infection process and for stimulating healing. However, the long-term success of endodontic treatment relies on a densely compacted and well-adapted root canal filling that will provide a hermetic seal impervious to leakage. It is equally essential to consider that, subsequent to endodontic therapy, no endodontic treatment is complete without providing a leakage-free definitive restoration.

GUTTA-PERCHA FILLING TECHNIQUES

- The root canal to be filled should be assessed before choosing a technique: Is the apical foramen wide open? Is it long, narrow, and curved? Has an apical perforation or zipping taken place? Is the canal blocked apically, or does it end in a delta (multiple canal exits)? Are lateral canals with

associated lesions visible on the radiograph?

- If there is any question regarding the operator's ability to control obturation materials within the canal space, the canal should be obturated and compacted with cold lateral condensation. Liquefied or semisolid compaction (heated) materials may lead to overfilling and should be avoided.
- In some instances, an apical barrier (plug) of mineral trioxide aggregate (MTA) may be placed, and one of the thermoplastic techniques can be used to condense gutta-percha against the MTA at a later appointment (see lesson 25).
- A thermoplastic obturation or controlled injectable technique may allow a more three-dimensional fill.

Single gutta-percha cone with sealer

Single-cone obturation has become increasingly popular with some clinicians since the introduction of nickel-titanium root canal instruments. Preparations have become better centered, and instrument errors have been minimized. As such, it has become easier to match the size and taper of the master cone with that of the last rotary instrument taken to working length (WL).

Though few data are available, single-canal (round) preparations seem to be especially adaptive to matched tapered cones. In studies that compared the obturation outcomes of 0.04 or 0.06 tapered root canals filled by lateral compaction or by using a single-cone technique with matching 0.04 or 0.06 tapered cones, there was no difference in the quality of the root canal fillings.

The goal of a single-cone obturation technique is to adapt a cone of gutta-percha or Resilon (Resilon Research) to the root canal preparation in such a way that the dimensions of the canal preparation and the cone in the last few millimeters of the most apical portion of the prepared canal space are the same. If this goal is met (point seated to WL), you will feel a slight resistance (often referred to as "tug back") when removing the test point from the canal.

The cone is slightly coated with sealer and placed to WL (Fig 31-1). If procedural errors such as apical ledging and canal transportation have altered the apical canal configuration, it will be virtually impossible to place a close-fitting single cone into the apical preparation. In this situation, a single cone should be fitted to WL, and a warm gutta-percha filling technique should be used to increase the flow characteristics of the gutta-percha. The condensation forces (lateral or vertical) will help condense the softened gutta-percha into the apical aberrations, and sealer will fill any remaining space. Because of the shrinkage problem with sealers, you must rely more on the efficiency of your condensation technique to fill the canal space and depend less on the sealer. The safest approach is to keep the sealer layer at a minimum thickness and thus as dimensionally stable as possible.

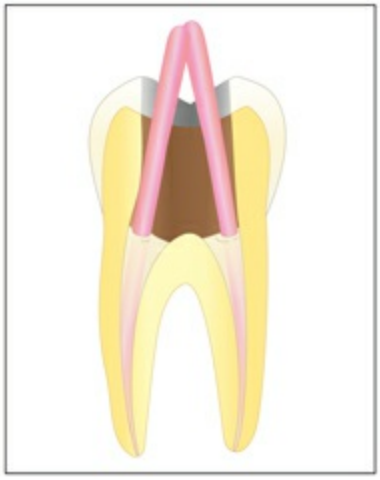


Fig 31-1 Cementing of well-adapted master cones.

Sealer coating and cold compaction of core materials

Cold lateral condensation is the historic standard of root canal filling and a basic technique that can be applied in the majority of situations. Its goal is to fit a master gutta-percha cone to WL and laterally condense (compact) multiple gutta-percha cones until a homogeneous mass of core material is created.

Materials

- Sterile master gutta-percha cone
- Spreaders
- Pluggers

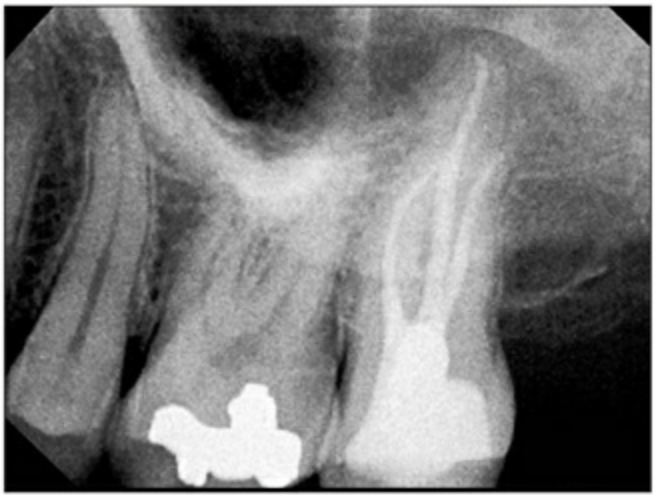


Fig 31-2 Definitive radiograph of the tooth seen in Fig 30-2 confirms that the root canal is filled to the correct length without voids.

Cold lateral condensation: Technique 1

1. Fit a master cone with an apical diameter matching the size of the root canal preparation into the

prepared root canal in such a way that it fits tightly in the most apical part of the canal.

2. Cement this master cone into the sealer-coated root canal, with the purpose of sealing the apical foramen. Add vertically condensed auxiliary gutta-percha points laterally alongside the master cone, densely filling any remaining spaces inside the canal lumen.
3. If done properly, the cones are tightly compacted creating a dense fill (Fig 31-2). Strictly speaking, the forces created by a spreader are both vertical and lateral; a purely vertical or lateral technique does not exist.
4. The bulk of the root canal filling should consist of the solid core material such as gutta-percha, whereas fins, lateral canals, apical deltas, and irregularities should be filled with sealer. Advantages in using gutta-percha include the material's low toxicity, dimensional stability, adaptability, and removability in case a retreatment becomes necessary.
5. Dry the sterilized accessory cones and master cone with sterile gauze, and arrange them in the correct sequence to avoid confusion while obturating more than one root canal.
6. The diameter of each canal varies, and an appropriately sized finger spreader or hand spreader must be chosen. Finger spreaders are an alternative to hand spreaders and have been shown to produce less vertical force during obturation.
7. All compacting instruments should be prefit into the root canal to determine their depth of point penetration and the location of the binding point.

Caution: Excessive intracanal wedging forces during lateral condensation have been identified as possible causes for vertical root fracture; the forces routinely used during lateral condensation are safe, and when properly done should not lead to fractured roots.

Cold lateral condensation: Technique 2

1. The stepwise root filling procedure for the wider, more coronal parts of the root canal includes larger spreader sizes and larger accessory cones.
2. Apply sealer onto the canal walls using a paper point, a lentulo spiral, or alternately, a master cone or hand file (Fig 31-3).
3. Coat the master cone with sealer, and insert it to the predetermined length using a slight pumping motion to allow trapped air and excess sealer to flow in a coronal direction.
4. Slowly position the preselected spreader alongside the master cone to the marked length and hold with measured apical pressure for approximately 10 seconds.
5. During this procedure, the master cone is pushed laterally and vertically as the clinician feels the compression of the gutta-percha.
6. Rotate the spreader by 180 degrees several times to disengage it from the gutta-percha and facilitate its removal from the canal (Fig 31-4a).
7. Fill the void created by the spreader with lightly sealer-coated accessory gutta-percha cones. Using auxiliary cones equal to or smaller than the spreader prevents voids (Fig 31-4b).
8. Repeat the procedure, inserting several fine cones and moving to larger spreaders and cones until the entire canal is filled (Fig 31-4c).

Caution: Before searing off the protruding cones, take a radio graph to verify the apical condensation of gutta-percha. Once complete and thorough obturation of the apical third is confimed, it is appropriate to sear off the coronal part of the cones that are protruding into and obscuring the pulp chamber during obturation.

- In multirooted teeth, it may be helpful to fill no more than one or two root canals at a time to avoid confusion and obscured vision.
- The use of matching (and not larger) accessory cones, compared to the spreader size, prevents the creation of voids that reduce filling density and provide potential pathways for microleakage.

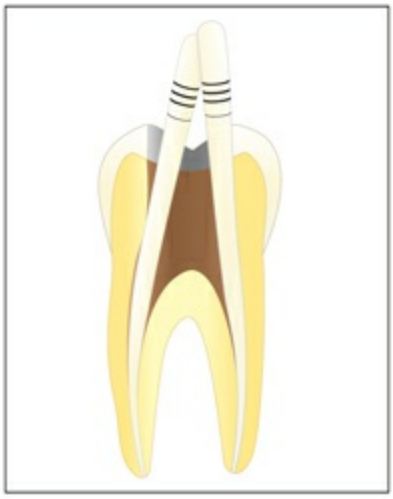


Fig 31-3 Root canal dried with paper points.

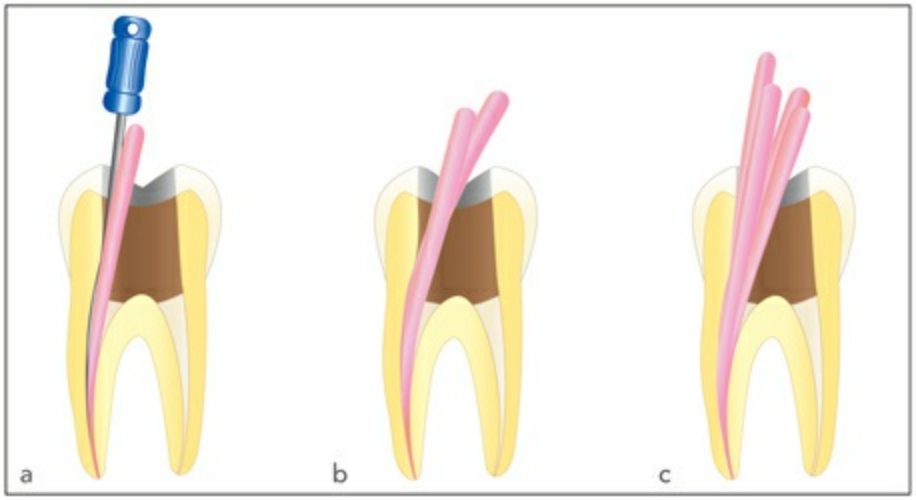


Fig 31-4 Lateral condensation of the mesial root canal of a mandibular molar using a finger spreader. *(a)* Master cone and finger spreader. *(b)* First accessory cone seated. *(c)* Multiple cone–filled root canal.

Sealer coating and warm compaction of core materials

Thermoplastic obturation using heat-softened gutta-percha can fill accessory canals and communications, promoting the movement of softened gutta-percha into lateral canals and isthmuses. This allows for the filling of canals with a higher volume of core material. On the other hand, it can

also result in material extrusion into the periapical area because of the enhanced flow characteristics, especially in cases where the apical foramen has inadvertently been overinstrumented. Clinically, overfilling has been shown to lead to successful healing; however, foreign body reactions and the extrusion of contaminated debris are possible. Confining the root filling to the canal space has predictably shown higher success rates.

Warm vertical condensation

1. Fit a cone slightly short (0.5 mm) of the WL, and verify the fit by testing for tug back. This step produces a cone that is wider in diameter than the prepared apical exit. As such, if the master cone fits well, hydraulic pressure during compaction should not produce an overfill.
2. Cement the cone into the root canal. In the traditional technique for thermoplasticizing gutta-percha, a heat carrier (eg, Touch 'n Heat [SybronEndo] or a flame-heated plugger) is pushed apically into the center of the master cone.
3. Remove the gutta-percha in increments, periodically moving the heated instruments further into the root canal. Use a prefitted cold plugger to condense the mass of gutta-percha in condensation waves until the apical 3 to 5 mm of gutta-percha is compacted.
4. Wipe excess gutta-percha from the utilized pluggers with gauze.
5. Once the apical condensation is confirmed radiographically, repeat the condensation protocol again to add and compact gutta-percha to backfill the coronal portions of the canal.
6. Repeat this procedure until the canal is filled in increments from the apical endpoint to the coronal orifice.
7. Thermoplastic technique can also be used with other core materials (eg, Resilon).

Caution: During condensation with pluggers, avoid excessive force, which could result in root fractures. Proper compaction technique with a cold plugger requires a circumferential vertical motion of the plugger along the wall of the root canal without wedging the plugger.

ADHESIVE OBTURATION SYSTEMS

Adhesive obturation systems that are chemically very similar include Resilon (Fig 31-5), RealSeal (SybronEndo) (Fig 31-6), and Resinate (Obtura Spartan) (Fig 31-7):

- Resilon material is a thermoplastic synthetic polymer-based root canal filling material.
- Based on polymers of polyester, Resilon material contains bioactive glass and radiopaque fillers. It performs like gutta-percha, has the same handling properties, and for retreatment purposes may be softened with heat or dissolved with solvents such as chloroform.
- Similar to gutta-percha, Resilon master cones are available in all International Organization for Standardization (ISO) sizes and accessory cones are available in smaller sizes.
- Resilon and other chemically similar products can be substituted for any gutta-percha technique. The material may bond to a properly prepared canal by using a dual-cure composite resin sealer, such as Epiphany SE Self-Etch Sealer (see Fig 31-5b).

Fig 31-5 *(a)* Resilon. *(b)* Epiphany SE Self-Etch Sealer (Pentron Clinical Technologies).

Fig 31-6 RealSeal.

Fig 31-7 Resinate.

SYSTEMS USING HEATED PLUGGERS

Touch ‘n Heat

This battery-operated unit has been a standard for heating gutta-percha for many years (Fig 31-8). It was developed for the traditional warm vertical condensation technique.

Fig 31-8 Touch ‘n Heat.

System B

System B (SybronEndo) (Fig 31-9) offers variable heating control and condenser tips specifically designed for the continuous wave condensation technique developed by Dr L. Stephen Buchanan. This device is more expensive than the Touch ‘n Heat. The system can be used to obturate canals with gutta-percha or adhesive materials in a single wave of condensation prior to a backfill.

Fig 31-9 System B.

Phase 1: Apical downpack

1. This system employs plugger tips with a tip diameter of 0.5 mm that are heated with the System B unit.
2. Tapered gutta-percha cones optimize the hydraulic forces used during compaction of softened gutta-percha with pluggers of a similar taper (Fig 31-10).
3. After fitting the master cone, try a hand plugger and a System B plugger in the root canal. The goal is to find pluggers that reach to within 5 to 7 mm of the apical canal constriction (Fig 31-11).
4. Mark (with a rubber stopper) the depth of plugger binding, as this is where the instrument touches the canal wall.
5. Set the heat to 200°C. While activating the heat switch, drive the System B plugger into the cemented master cone (Fig 31-12), softening it and pushing a “wave” of softened material in an apical and lateral direction.

   Caution: Heat control is extremely important, and manufacturer guidelines should be strictly adhered to as heat is rapidly conducted into the periodontal ligament if the heat is activated for too

long.

6. Release the switch after 2 seconds while the plugger continues to move apically with measured pressure.

   Caution: When a plugger is bound against the root wall, strong compaction forces could lead to a vertical root fracture(s).

7. The plugger should stop at the premeasured depth (binding) point.
8. After cooling (10 seconds), briefly activate the switch one more time to release the plugger.
9. Withdraw the plugger, and remove excess gutta-percha from the tip.
10. The apical portion of the canal is now filled; compact it with the chosen hand plugger to assure density (see Fig 31-12).

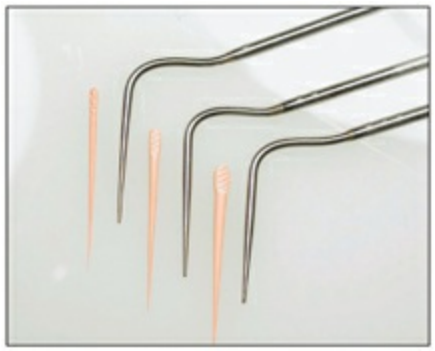


Fig 31-10 System B pluggers and corresponding tapered accessory cones that can be sized apically to become the master cone.

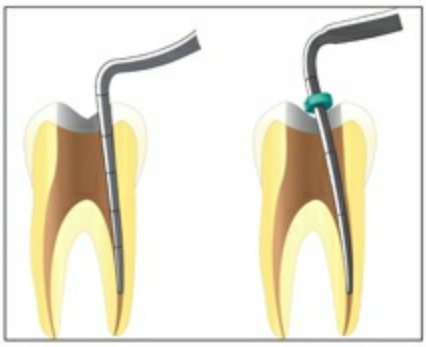


Fig 31-11 Hand plugger *(left)* and System B plugger *(right)* fitted into a root canal. Both instruments reach into the apical third of the canal.

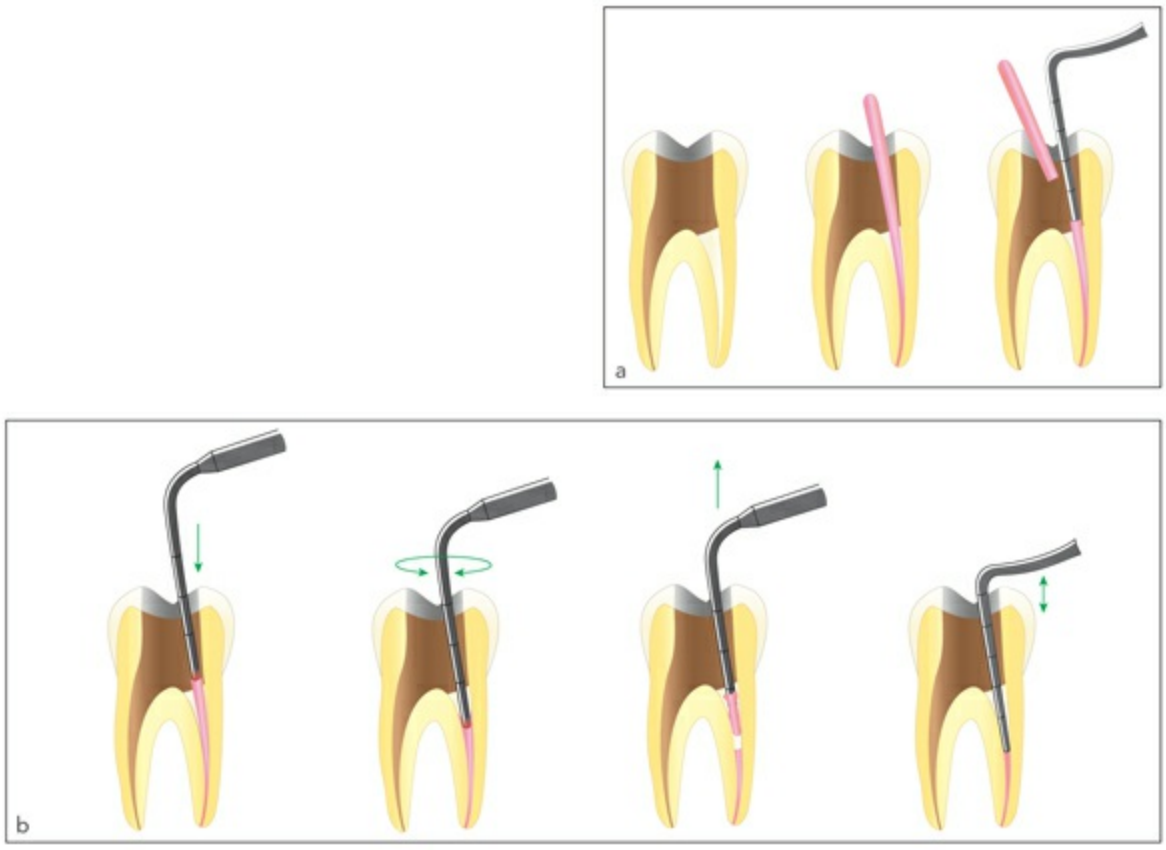


Fig 31-12 *(a)* Cementation of the master cone and removal of excess gutta-percha with a hot System B plugger. *(b)* Downpack of gutta-percha using heated pluggers and manual vertical compaction with a hand plugger.

Phase 2: Coronal backfill

1. Reduce the heat of the System B unit to 100°C, and tightly pack the gutta-percha cones into the canal space with a warm vertical compaction technique, until a cold plugger can only be inserted 2 to 3 mm.
2. Cut off the excess part of the cones with the warm plugger, and condense the material into the orifices with a hand plugger.
3. Eliminate or minimize voids and reduce the reliance on sealer acting as filler by careful compaction until the tip of the plugger advances only about 2 mm into the root canal.
4. On a radiograph, the final root canal filling should appear uniformly dense from the apical foramen to the orifice opening (Fig 31-13).
5. All true gutta-percha brands and the Resilon-Epiphany (Pentron Clinical Technologies) material are suitable for warm compaction.

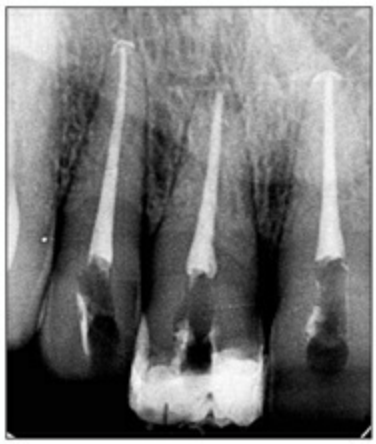


Fig 31-13 Radiograph of a completed thermoplastic root canal filling in three maxillary incisors.

SYSTEMS FOR INJECTION OF CORE MATERIAL

There are several systems and devices that inject warm gutta-percha or an alternate core material into the canal with a cannula. These include the Obtura II system (Obtura Spartan), Calamus Flow Unit (Dentsply), Elements Obturation Unit (SybronEndo), UltraFil 3D (Coltène Whaledent), GuttaFlow (Coltène Whaledent), and RoekoSeal (Roeko Dental Products), among others.

Obtura II

This device (Fig 31-14) is mainly used to backfill canal space after downpacking using a heated instrument and plugger. It can deliver increments of warmed material. Gutta-percha is injected into the canal space, followed by condensation with a plugger until the canal has been obturated.

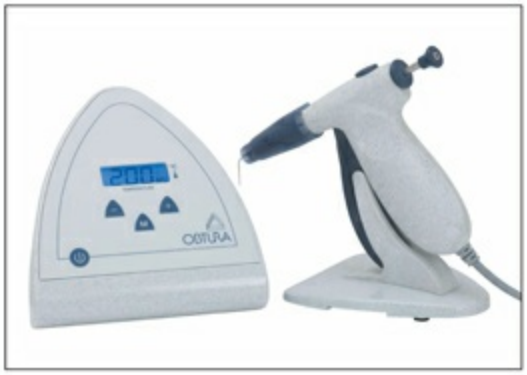


Fig 31-14 Obtura II.

Backfill technique

This technique uses a handheld gun with an attached heat shield (Fig 31-15). The system includes delivery needles in 20- (No. 90), 23- (No. 60), and 25-gauge (No. 50) sizing, which allow delivery of heat-softened gutta-percha or other thermoplastic core materials into the root canal. The temperature maximum is 200°C, but usually root canals are filled at a setting of 160°C to 180°C for an adequate flow:

1. Place gutta-percha pellets into a slot on top of the gun, and push them into a heating chamber.
2. Thinly coat the canal walls with sealer.
3. Carry the needle to the predetermined depth (marked using a rubber stop), and inject gutta-percha into the root canal. *Caution:* The needle wants to back out of the canal as the pressure builds, but the needle should remain against the apical gutta-percha for a few seconds for the materials to fuse and to prevent voids between increments.
4. To achieve a dense filling, withdraw the needle with the back-pressure of the added material.
5. Inject 3-mm increments of gutta-percha, and compact with a hand plugger.
6. Repeat the process in increments until the orifice level is reached.

Caution: An "injection only" technique is not recommended because of the danger of overfill; if the operator chooses this option, the apical fill of 3- to 4-mm should always be verified by radiograph for placement and density before proceeding with the rest of the fill:

- When using injectable techniques as stand-alone filling methods, voids can be created due to air entrapment, and overfilling is always a danger.
- The smallest size 25-gauge needle of the Obtura II sometimes is too thick to reach the apical third in narrow, 0.04 tapered root canals.

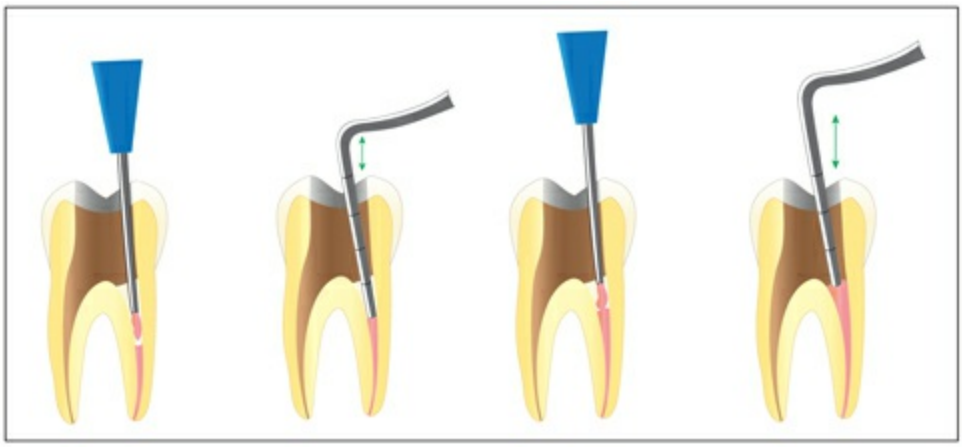


Fig 31-15 Backfilling of the coronal two-thirds of the root canal using an injection technique.

OTHER MARKETED HEATING DEVICES

Thermique Thermal Condenser

The Thermique thermal condenser (Parkell) has spreader-like heating tips (Fig 31-16). The unit can be used for warm lateral or warm vertical obturation techniques. It comes with small, medium, and large tips.

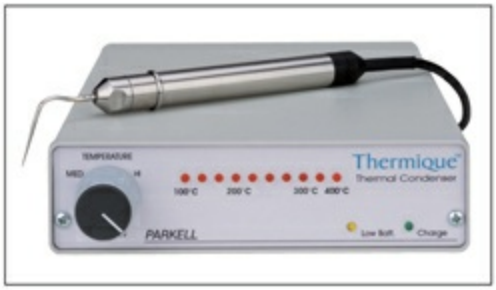


Fig 31-16 Thermique thermal condenser.

DownPak

The principle behind the DownPak (Endo Ingenuity) is to aid in warm vertical endodontic obturation (Fig 31-17). It incorporates heat plus adjustable vibration to distribute warmed Resilon or gutta-percha into the canal. The DownPak is an example of a device that uses a combination of vibration and heat for root canal filling.

Fig 31-17 Downpack.

Calamus Flow

The Calamus Flow (Dentsply) features a powered delivery handpiece that is designed for ease of use and convenience (Fig 31-18). This unit uses gutta-percha that is packed in disposable, single-use cartridges. Microprocessor-controlled temperature and flow controls provide automated control of the gutta-percha flow:

- Gutta-percha is delivered from a self-contained cartridge (0.25 g) that has an attached delivery needle.
- Needle sizes are 20- and 23-gauge.
- This system does not require cleaning after each use.

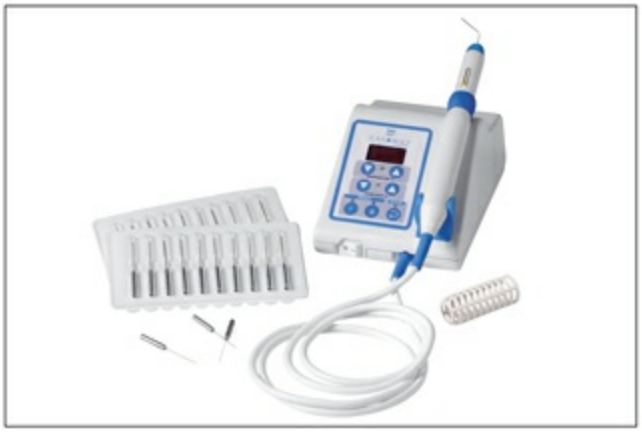


Fig 31-18 Calamus Flow.

Elements Obturation Unit

The Elements Obturation Unit contains a System B device and a gutta-percha extruder in an electrically driven hand-piece (Fig 31-19):

- The Elements Obturation unit is designed to work with the System B obturation method.
- It delivers gutta-percha or adhesive material from capsules with delivery needles attached. Heating and delivery are automated.

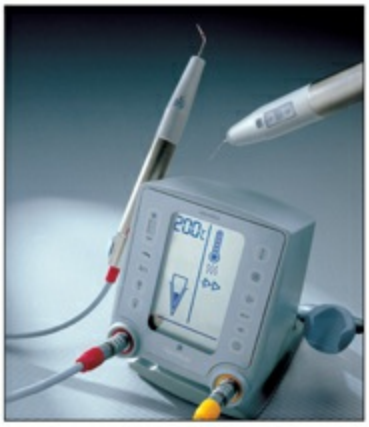


Fig 31-19 Elements Unit.

UltraFil 3D System and SuccessFil

This injection system can deliver three types of gutta-percha with different flow and hardness characteristics (Fig 31-20). UltraFil consists of an injection syringe and disposable gutta-percha cartridges with attached needles that can be preheated in a portable heating unit:

- The gutta-percha heats to 90°C within 3 minutes.
- The gutta-percha can be injected directly into the root canal or delivered to a carrier (SuccessFil [Coltène-Whaledent]) for core obturation.
- The system can be used to completely fill the canal (via carrier or injection) or to backfill (the more

common use). Since the gutta-percha is heated to a lower temperature with this system, the shrinkage may be less. Cannulas are disposable after use, and the needles can be precurved for enhanced access and visibility.

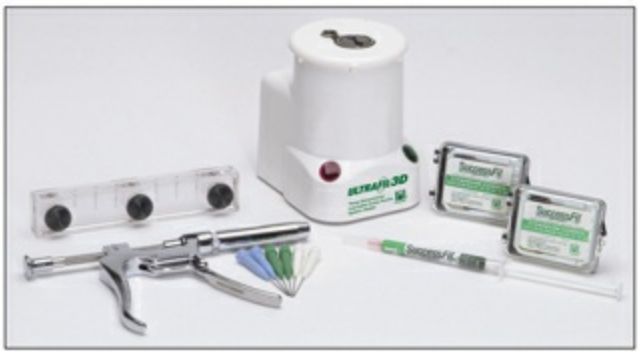


Fig 31-20 UltraFil 3D and SuccessFil.

GuttaFlow and RoekoSeal

GuttaFlow is a cold filling system for the obturation of root canals that combines gutta-percha and sealer in one product (Fig 31-21):

- GuttaFlow employs a cold injectable technique consisting of capsules of gutta-percha in powder form, with a particle size of less than 30 μm, and sealer.
- Its material properties consist of insolubility, no shrinkage, and good biocompatibility.
- The gutta-percha–sealer mixture does not shrink, but it does slightly expand. RoekoSeal and GuttaFlow are also used in combination with lateral condensation or single-cone techniques.
- Delivery is through a "disposable" capsule system.
- A dispensing tip and an applicator inject the paste into the root canal.
- According to the company, GuttaFlow is the first nonheated free-flow gutta-percha that does not shrink. The material's flow properties allow even distribution in the root canal and can be removed if retreatment is necessary.
- GuttaFlow is silicone based (polydimethysiloxane) and consists additionally of gutta-percha, zinc oxide, zirconium dioxide, paraffin-based oil, silicone oil, hexachloroplatinic acid, and silicic acid.
- The technical characteristics of GuttaFlow are similar to those of RoekoSeal, which is also silicone based.
- Dimensional stability, flow, film thickness, biocompatibility, and solubility are very similar for both materials.
- Differences are primarily in the GuttaFlow curing time and in the addition of gutta-percha and zinc oxide.
- GuttaFlow and RoekoSeal are not readily absorbable.

Fig 31-21 GuttaFlow.

HotShot Cordless

The HotShot Cordless (Discus Dental) is similar to the Obtura II except that it is cordless (Fig 31-22):

- The temperature range is variable and it can be used with gutta-percha or adhesive materials for backfilling.
- Anyone who is satisfied with an Obtura II would find this device appealing.

Fig 31-22 HotShot Cordless.

Recommendations

- Heated gutta-percha shrinks when it cools to body temperature and should be compacted while cooling to avoid gaps between canal wall and core material.
- The Obtura II and other injectable systems are frequently used in a hybrid approach. Examples include:
  - System B obturation of the apical third of a canal and backfilling with an injectable technique in the coronal two-thirds
  - Lateral condensation in the apical third of a canal and backfilling with an injectable technique
  - Combination of vertical condensation and an injectable technique

CARRIER-BASED OBTURATION SYSTEMS

Carrier-based systems are made up of a stiff thin carrier (metal or plastic) that is coated with gutta-percha.

Filling root canals

1. The tip of the carrier consists of gutta-percha only.
2. Heat the carrier with gutta-percha in a heating device so that the gutta-percha becomes soft.
3. Push the coated carrier apically into a root canal thinly coated with sealer. This should be done within 10 seconds to avoid cooling and hardening of the gutta-percha.
4. Mark the carrier with grooves to ensure that the carrier reaches the correct length.
5. The root canal also needs to have a sufficient taper equal to or larger than a 0.04 taper.
6. The two most popular carrier based systems are ThermaFil (Dentsply) and SimpliFill (Discus Dental), although Dentsply also offers GT Carriers and ProTaper Carriers.

Caution: Carrier-based systems create an apically directed piston effect during application to the canal. While these systems create a dense filling, care must be taken:

- Do not to use large amounts of sealer.
- Insert the carrier slowly.
- Verify WL to avoid overfilling.

ThermaFil, GT Carriers, ProTaper Carriers

Thermafil (Fig 31-23a) has also been recommended as an adjunctive backfilling technique in conjunction with a cemented master cone:

1. Gutta-percha is delivered on a sized carrier constructed of resin.
2. Each carrier is matched to an appropriately sized rotary file system.
3. Insertion of the warmed gutta-percha creates good hydraulic sealing pressure within the canal.
4. The device is heated by a special oven (Fig 31-23b) and when delivered to the canal, the carrier remains as part of the obturation.
5. The Thermafil carrier is cut at orifice level, remains inside the root canal, and requires removal if retreatment becomes necessary.

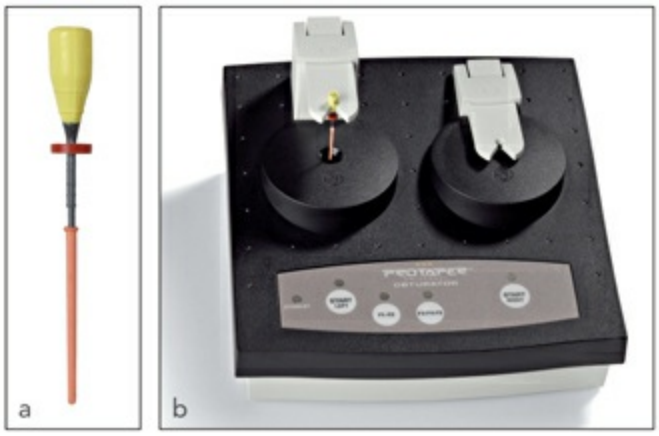


Fig 31-23 *(a)* ThermaFil carrier. *(b)* ProTaper carrier oven.

SimpliFill

SimpliFill is a paste-paste, dual-component root canal sealer delivered in a dual barrel syringe (Fig 31-24). The sealer is an epoxy-based resin. The carrier in this technique is removed, leaving an apical plug, and the canal can be backfilled by several techniques. Resilon or gutta-percha materials are available:

- SimpliFill uses a 5-mm plug of gutta-percha that can be cut back to fit the size of the root canal. The carrier is removed after application of the apical gutta-percha plug in the SimpliFill System.

Fig 31-24 *(a)* SimpliFill kit. *(b)* Carrier obturators of the SimpilFill system.

Recommendations

- To prevent destruction of the apical constriction (if present), it is important not to enlarge the apical foramen during preparation.
- To avoid overextension of root filling material into the peri-apex, it is recommended that you accurately determine WL (see lesson 19).
- Slow insertion of carrier-based warm filling techniques can decrease the rate of overextension but may also lead to voids.

• If inserted too fast, thermoplastic gutta-percha will be wiped off the carrier, and excess will be extruded into the periodontal ligament.

WHICH ROOT FILLING TECHNIQUE IS BEST?

Existing research directs clinicians toward preparation and disinfection of the root canal as the single most important factor in the treatment of endodontic pathosis, and no particular technique can claim superior healing success. Decisions on which system to employ may be based on various factors:

• Clinician skill and comfort in using a certain technique

• Efficiency and past successes

• Simplicity of procedures involved

• Costs incurred

• Clinician desire to stay on the "cutting edge"

CONCLUSION

• When selecting a filling technique, it is important to consider adjacent anatomic structures and the patency (level) of the root canal. There are considerable differences in the viscosity of obturation materials between cold and warm filling techniques, and you must be confident in your approach.

• Maintaining apical patency is advocated by many clinicians, but if the passage of instruments to patency length is not restricted to small instruments (No. 10 or No. 15) you will destroy (widen or transport) the apical constriction.

• Because thermoplastic gutta-percha filling techniques are so effective in filling unusual canal aberrations, they have become the technique of choice for endodontists. These methods emphasize heating the gutta-percha to increase its flow characteristics, but when that flow is not controlled, large amounts of filling material may be extruded into the periapical tissues. This potential for overfilling can be particularly dangerous when the mandibular nerve, the maxillary sinus, or the opened apical foramen is at risk. When dealing with these areas, you must avoid overfilling.

To prevent extrusion into these potentially dangerous areas, insert a small MTA plug to WL (the last 2 to 4 mm of the canal) to serve as a physical (apical) barrier and prevent gutta-percha extrusion (see lesson 25).

Final caution

Prior to treatment, closely inspect and evaluate the tooth and internal anatomy of the roots as well as their root-tip relationship with maxillary and mandibular structures:

• Does this tooth have an open apex? Do the roots extend into the maxillary sinus or approximate the mandibular canal? Is the degree of canal curvature greater then 30 degrees? These questions can

identify teeth where routine endodontic techniques may not meet the demands of a case and referral is in order.

- Are the materials biocompatible? Certain sealers are neuro-toxic (see lesson 30). Sealers that contain paraformalde-hyde or other mutagenic or carcinogenic substances must be avoided.
- Though a little sealer extrusion may be well tolerated and absorbed by the periapical tissues over time, its toxicity will be aggressive if compacted into the sinus or the mandibular canal (eg, sinusitis, paresthesia).
- The WL should be confirmed electronically and maintained throughout instrumentation. The apical constriction (ce-mentodentinal junction) may involve multiple constrictions, be apically narrowing over several millimeters, or not exist.
- Tactile readings are not dependable. A negotiating file may bind anywhere along the canal length and be misinterpreted as the constriction.
- The object of instrumentation is to provide a glide path and a prepared apical constriction for the insertion and compaction of gutta-percha. Poor length control leads to over-instrumentation and overfilling.

LESSON 32

Posttreatment Pain After Obturation

OBJECTIVE

To understand the factors that contribute to patient discomfort subsequent to obturation of the root canal system (posttreatment pain) and to determine management strategies and therapies to resolve these complications.

INTRODUCTION

The incidence of acute pain and/or swelling subsequent to the completion of endodontic treatment is extremely low. To identify the cause of significant postendodontic pain, serious attention must be given to the patient's description of the pain. When swelling accompanies the pain, antibiotics are generally appropriate if there is no drainage. Severe posttreatment pain is stressful both for the patient, who can be overcome by the pain, and for the clinician, who must diagnose and treat the source of the problem. To prevent a break in the patient-clinician relationship, a loss of trust, and possibly a future liability, all postoperative obturation pain should be addressed with the utmost concern.

CLINICAL EVALUATION

- The complaint of persistent, unremitting, or continuing thermal pain should alert the clinician to the possibility of a missed canal, an underprepared or underfilled canal, referred pain from an

adjacent tooth, or a nonodontogenic cause (eg, sinus infection).

- A complaint of biting or chewing pain or of pressure or altered sensation (paresthesia) in the treated area should precipitate careful reassessment of an incidental injury to the periapical tissues (eg, overinstrumentation, overfilling).
- Radiographs taken at two or three varied angles may reveal the presence of a nonspecific apical abscess or a crown or root fracture.

MANAGEMENT OF POSTTREATMENT PAIN

Exacerbations following obturation are intrinsically hampered by the presence of the obturation materials. Treatment options are restricted to the following:

- Pharmacotherapeutic intervention for relief of minor and severe pain. Nonsteroidal anti-inflammatory drugs (NSAIDs) are usually sufficient for mild to moderate pain. For severe pain, opioid analgesics may be taken alternately with NSAIDs. In this latter scenario, the opioid should not be combined with an NSAID in order not to exceed the daily recommended dosage. Acetaminophen prescribed with an opioid(s) is the combination of choice.
- Intracanal retreatment to negotiate the total canal system, locate unfound canals, or vent the periapical tissues.
- Surgical exposure of the periradicular area to vent the pressure within the bone (trephination), to curette the periapex, and/or to resect, prepare, and fill the apical root segment.

Nonsurgical treatment options

For adequate preparation and obturation

- If a tooth was diagnosed initially with a pulpitis and treated in one appointment, and evaluation of the pain points to an acute inflammatory response that will be self-limiting, analgesics and time (2 days to 2 weeks) should be sufficient.
- If a tooth was diagnosed initially as necrotic and evaluation of the pain points to an acute inflammatory or infectious process that will be self-limiting, analgesics and antibiotics (5 to 7 days) should be prescribed (Fig 32-1).

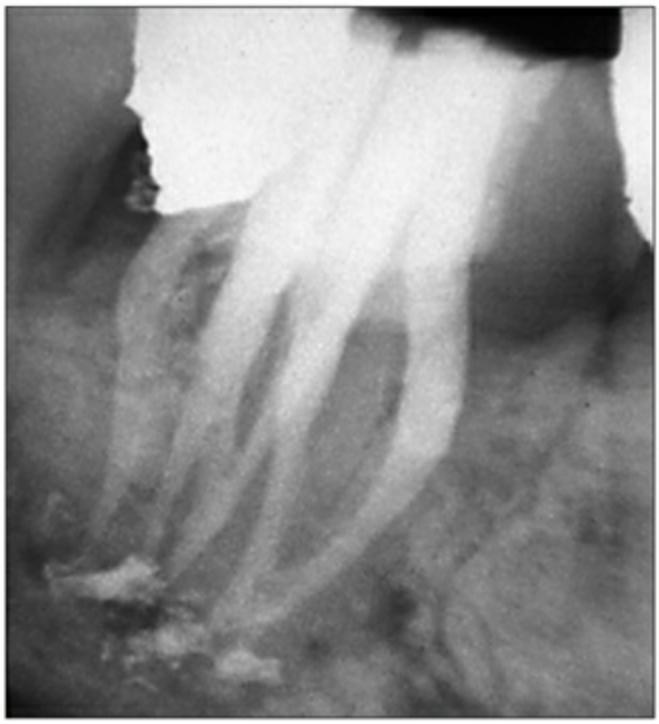


Fig 32-1 Zinc oxide–eugenol sealer overfill of a mandibular molar. The excellent three-dimensional seal and obturation to the root termini will encourage the healing process. Any postoperative pain with such a well-obturated fill is most often self limiting. (Image courtesy of Dr John C. Munce, Santa Barbara, CA.)

For inadequate preparation or obturation

- If the evaluation points to an acute inflammatory or infectious process resulting from an inadequate filing and/or filling procedure(s), residual bacteria in the root canal space may not have been eliminated. As such, stagnant apical canal fluids from a compromised apical seal may be providing a nutritive source for organisms not only to persist but also to proliferate. The best treatment option is to repeat the entire root canal process—reaccess the canal, remove the existing gutta-percha, reestablish an accurate working length (WL), reinstrument the canal to the new WL, place a calcium hydroxide canal dressing, temporarily seal the access opening, and prescribe appropriate analgesics and antibiotics (5 to 7 days). Once the patient is free of symptoms, complete the instrumentation, and reobturate the canal.

Surgical treatment options

For an unidentifiable cause

If a patient presents in pain on an emergency basis and the unidentifiable underlying cause is associated with mucope-riosteal swelling around the suspected tooth, the use of analgesics or antibiotics alone will be inadequate to relieve the pain. It is best managed with a surgical incision to establish drainage and a prescription for an appropriate supporting antibiotic regimen (5 to 7 days) (Fig 32-2). Once the patient is free of symptoms, the cause of the swelling can be more acurately determined. Then, the offending tooth can be rein-strumented and reobturated, or the root tip can be

surgically exposed, resected, and sealed.

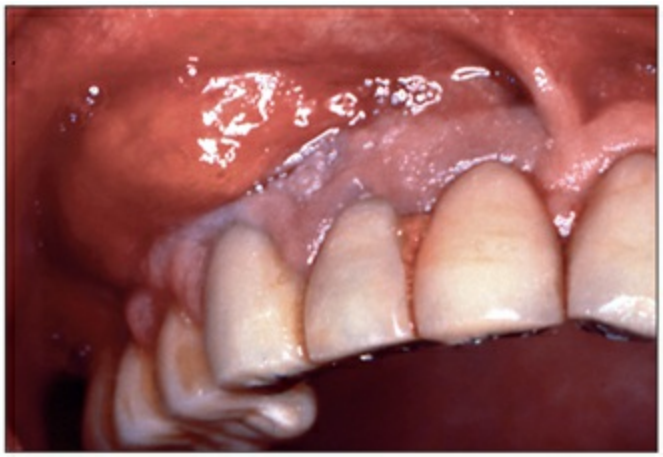


Fig 32-2 Postobturation intraoral swelling 2 days following root canal therapy on a maxillary lateral incisor. Immediate care must include incision and drainage of the acute abscess. In addition, the quality of the conventional root canal therapy must be evaluated to determine the need for retreatment or apical surgery.

For a procedural mishap

If the pain is caused by a perforation, an apical transportation of the canal position, and/or a major degree of overinstru-mentation and overfill of gutta-percha and/or sealer, the best treatment option is corrective apical surgery—curette the periapex and resect, prepare, and fill the apical root segment—supported by an appropriate antibiotic regimen (5 to 7 days).

When large overfills are in close proximity to the neu-rovascular anatomy of the mandible (or, worse yet, within the mandibular nerve canal), the chemical toxicity of the extruded material or the compression and crushing forces of the foreign material during compaction can cause partial or total nerve damage. Paraformaldehyde pastes are a classic example of neurotoxic substances that can cause irreversible nerve damage when expressed periapically. Overfill outcomes that result in anesthesia (total numbness), dysesthesia (burning pain), or hyperesthesia (abnormal sensitivity to stimuli) should be immediately referred for evaluation and intervention by a skilled surgeon in an attempt to reverse or ameliorate the symptoms by removing the overfill. Time is of the essence, and permanent damage can occur in as little as 48 hours (Fig 32-3).

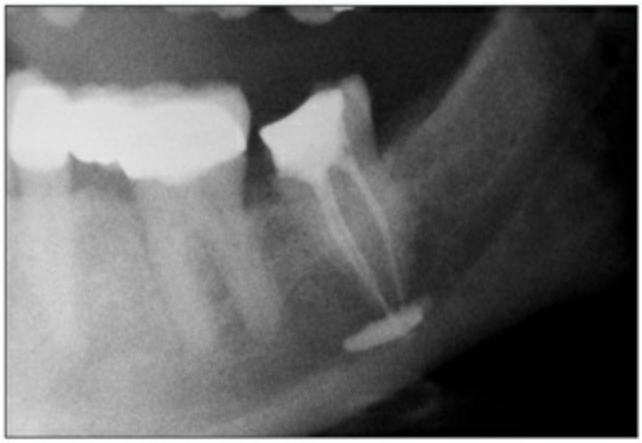


Fig 32-3 Significant sealer overfill into the inferior alveolar canal. The dentist took a "watch and wait" approach to the overfill. Several weeks later, the patient's symptoms of pain and neurologic "burning" worsened and required tooth extraction. Removal of the tooth and overfill had no effect on the permanent injury which occurred in the first 48 hours.

LESSON 33

Responding to Posttreatment Disease

OBJECTIVE

To offer nonsurgical treatment guidelines in response to the signs and symptoms of non-healing endodontically treated teeth.

INTRODUCTION

Depending on the etiology for the posttreatment disease, retreatment cases are not as predictable as are primary endodontic treatment cases. This is particularly true when the initial diagnosis of a case was necrosis. During retreatment procedures, therefore, you must attempt to identify the original etiology of the initial endodontic treatment (eg, pain, swelling, failing pulp cap, trauma) and design an effective antimicrobial treatment strategy to eliminate the cause of the failure.

When confronted with a nonhealing root canal treatment, it is of greatest importance that you make the patient aware of the poorer prognosis and offer a treatment plan that includes the following possibilities: conservative retreatment of the case; apical surgery and root end repair (filling); extraction as well as root end repair and replantation; extraction and an implant; or extraction only. This lesson focuses on the least invasive conventional methods used to re-treat an unsuccessful case.

DIAGNOSIS AND TREATMENT OPTIONS

Determining the cause (etiology) of failure is paramount, and makes clear the decision to treat or not to treat.

Faulty restoration

Defective restorations and associated coronal leakage are responsible for the greatest number of root canal failures. Studies indicate that a poor restoration will cause an endodontically treated tooth with a quality fill to fail from 50% to 70% of the time, and when both the root canal treatment and the restoration are poorly done, the case will fail from 70% to 90% of the time. In such cases, the removal of the restoration and a quality retreatment should be highly successful.

Poor chemomechanical instrumentation

Numerous investigators have shown that bacteria in a contaminated root canal cannot be eliminated from an infected tooth. However, it is also reported that an infected tooth responds favorably if only trace amounts of bacteria are left in the canal after instrumentation. It is assumed that the bacteria are entombed and die from a lack of nutrients. Thus, a failing root canal treatment could be attributed to the ineffectiveness of the cleaning and shaping procedures used during primary instrumentation. In such cases, the mechanical removal of bacteria and debris and the effectiveness of the irrigation solutions at clearing the walls of the smear layer, opening the tubules, and disinfecting the canal of residual bacteria is critically important. A quality retreatment should be highly successful for these patients.

Canal obstructions

At times, an endodontically treated tooth presents with complex canal anatomy (eg, severe curves, mineralization), and a preoperative radiograph shows that the canal was treated and filled well short of an acceptable working length (WL). As such, it is logical to conclude that the prior instrumentation procedure(s) never reached patency length (PL) or WL, and consequently, the apical segment of the root(s) was neither cleaned nor shaped, leaving the residual tissue (diseased or otherwise) to degenerate into an apical pathosis. A quality retreatment and successful outcome depend on the clinician's skill and experience.

Missed canals

It is a given that all roots have canals and that all canals contain pulp tissue. However, roots often develop more than one canal, and this fact should be kept in mind during diagnosis and treatment. Though many of the additional canals will join within a root, Table 33-1 represents the average likelihood of encountering additional canals. In such cases, a quality re-treatment and successful outcome depend on the clinician's skill and experience in locating and navigating complex anatomy.

Table 33-1	Additional canal possibilities in maxillary and mandibular teeth	
Teeth	**Canals (no.)**	**Likelihood (%)**
Maxillary		
Incisors	2	rare
Canines	2	rare
First premolars	3	6
Second premolars	2	28 to 45
First molars	4	72 to 90
Second molars	4	21 to 40
Mandibular		
Incisors	2	41
Canines	2	18
First premolars	2	20
Second premolars	2	20
First molars	4	45
Second molars	4	20 to 40

Failure of the prior endodontic treatment

A failure of this type may not be related to the pulpal therapy but to external problems (eg, an undetected crown or root fracture or systemic factors). In these cases, a quality retreatment and successful outcome depend on the clinician's skill and experience in diagnosing the clinical evidence and addressing the tooth-related structural and attachment issues. The best solution may be to refer the patient to an endodontist or a physician.

TREATMENT STRATEGY

The treatment strategy for a retreatment of a failed endodontic case might be as follows:

1. Clearly explain and discuss the benefits, case difficulty, prognosis, and alternative treatment options (see lesson 10) with the patient. If the patient accepts the treatment recommendations, she or he should sign an informed consent, and it must be included with the patient's records.
2. Obtain a working level of anesthesia, and access and clear the pulp chamber of an anterior or posterior tooth: Use sodium hypochlorite to curette and flush the pulp chamber clean of all restorative material and debris.
3. Using high magnification (preferably with a microscope set within a range of 4.50×to 24×), examine and probe the floor of the pulp chamber (with a No. 16 endodontic explorer) for additional anatomy or for a perforation. If perforated, bleeding will follow the probing.

Problem 1: Perforation in an anterior tooth

A perforation in an anterior tooth is most likely to occur in the labial wall, particularly if the tooth has been accessed through a crown.

- If the perforation is below the gingival crest, it may be repaired from the inside with mineral trioxide aggregate (MTA).
- If the perforation is between the gingival and osseous crests, it may be repaired internally or externally with Geristore (Den-Mat), but the esthetics will be in jeopardy (see lesson 24).

Problem 2: Perforation in a posterior tooth

A perforation in the pulp chamber of a posterior tooth is most likely to occur during primary treatment in the floor of the pulp chamber. If the pulp chamber floor is perforated, the literature points to the great success of repairing these perforations with MTA cement (ProRoot-MTA [Dentsply]) (see lessons 24 and 25). Another region that is often perforated, generally in an maxillary molar, is the area of the floor where the mesiobuccal canals are located. As such, the perforation occurs through the mesiobuccal wall and into the periodontal membrane. As with the anterior tooth, the repair and its sequela (periodontal pocket) depend on the level of the perforation and subsequent repair efforts.

With either perforation (anterior or posterior), the following repair technique is recommended:

1. Expand the perforation (best done with an ultrasonic tip) to isolate the borders of the perforation, and flush the depth and width of the opening clean of debris with sodium hypochlorite.
2. Place a piece of CollaCote or CollaTape (both from Integra Lifesciences) at the floor of the opening as a barrier to prevent excess MTA from being packed into the damaged area below the perforation (see lesson 24).
3. Mix the MTA (white or gray) to a workable texture. Carry it to the surface of the tape, and spread it evenly (2 to 3 mm) across the tape and beyond the borders of the perforation span internally.
4. At this point, cover the MTA mix with a cotton pellet moistened with saline. This moisture prevents the cotton fibers from being incorporated into the mix.

5. Use a thick mix of IRM (Dentsply) or glass ionomer to seal the access opening. Inform the patient of the findings, and if she or he agrees to continue endodontic treatment, propose that another appointment be made in 2 to 3 weeks. See lessons 24 and 25 for in-depth discussions of MTA repairs.

Problem 3: Metal post

The presence of a metal post or silver points in the coronal segment of the canal orifices may have hindered the initial examination of the floor of the pulp chamber, in which case the floor must be addressed first.

If the post is large and easily accessed, it may be easily removed from the orifice with a hemostat or orthodontic pliers and a firm but gentle twist. Unfortunately, this situation is not usual. Typically, you must break down the cement bonding the post in place and make room alongside the post to create space for its removal:

1. This process should be done with an ultrasonic unit and specially designed energized tips (see lesson 23). Burs are extremely dangerous and may perforate the floor or cut off the coronal segment of the post, making its removal even more difficult.
2. Move the tip apically along the walls of the post, and as it creates space through vibratory energy, the forces of cavitation should loosen the post enough to free it from the orifice, enabling you to grasp and remove it.
3. Throughout this process, it is extremely important that you work under magnification, flush the area to clean and cool the post, and aspirate the area clear of debris.
4. If you encounter gutta-percha as you progress apically along the post wall, inject a drop or two of chloroform into the newly created space.
5. Continue apically, following the steps suggested above and in lesson 23 to help free the post.

Problem 4: Following post removal

Having now removed the post (or reclaimed the canal space), the orifice(s) can be located and navigated to both PL and WL with a No. 15 or No. 20 stainless steel file (stronger and more rigid) and an electronic apex locator (EAL). Though the EALs are known to be up to 98% accurate, their accuracy decreases if prior treatment has destroyed the true constriction and altered the apex. Therefore, it is recommended that the EAL result be reconfirmed with a radiograph.

If the failing canal has been filled with gutta-percha, inject a few drops of chloroform to help advance the file and remove the gutta-percha. Clinical research has shown that it is virtually impossible to remove the debris created while attempting to remove the filling material without pushing some of it through the foramen and into the periapical tissues. Because this material is contaminated, it is essential to accompany file advancement with high-volume irrigation (6% sodium hypochlorite) and aspirate. Since some material will be extruded, it is best to confirm WL, maintain PL, and clean and shape the tooth as thoroughly as possible.

No retreatment case should be treated in a single appointment: The time involved is lengthy. The stress factor in removing the obstruction is high. The cleanliness factor is questionable, and the extrusion factor is not only inflammatory and absolute but may incite a flare up.

Problem 5: Fractured file

It is very possible that a case is being retreated because there is a fractured file in the canal. Consequently, the canal has been underfilled and/or leakage has occurred, and the case is now failing. The fractured instrument requires removal. All of the actions discussed for the removal of a post hold true for the removal of a broken instrument (see lesson 23). Success in removing a broken file is directly related to the size of the file and the level of the break.

If the failing case has been filled and gutta-percha surrounds the broken piece, your first attempt should be to bypass the broken piece with a series of small files. At times, you can advance one of these small Nos. 6, 8, or 10 files, aided by a few drops of chloroform injected into the canal, past the fractured instrument. If there is no obstruction beyond the broken file, the small file, now unrestricted, can reach both WL and PL. By slowly increasing the size of the instrument to WL, you can remove the fractured piece along with the gutta-percha fragments and dentin debris by irrigation.

If one or more files can bypass the broken instrument to WL, they may be simultaneously twisted, wrapping themselves around the broken tip. When the files are removed, the broken tip is often dislodged (see lesson 23).

Assorted sizes of ultrasonically activated tips can also be used to loosen sealer and remove the fractured segments. Skill, concentration, magnification, and unobstructed visibility are required to prevent these ultrasonic tips from perforating the canal.

Concluding steps

1. Once the canal is cleared of obstacles, proceed with the normal cleaning and shaping process to WL, and maintain PL throughout.
2. Dry the canal(s) with paper points to WL.
3. Mix a combination of calcium hydroxide and 2% chlorhex-idine (CHX) to a paste consistency, and apply it to the canal walls with a lentulo spiral.
4. Seal the access opening with IRM or Cavit (3M ESPE), and schedule the patient for a follow-up appointment (2 to 4 weeks).

Follow-up appointment

Asymptomatic patient

1. Use the last three files used to WL for the canal preparation to reclean the canal space.
2. Remove all residual calcium hydroxide and 2% CHX.

3. Confirm patency.
4. Rinse the tooth with copious amounts of sodium hypo chlorite.
5. Rinse the tooth with CHX following the removal of the sodium hypochlorite.
6. Test WL with paper points. If they are dry and clean, the treatment may be completed at this appointment.
7. Fit a master gutta-percha cone to the prepared WL.
8. Compact the master cone, preferably with heat (the System B [SybronEndo]) and assorted pluggers.
9. The patient should be seen for a follow-up clinical and radiographic evaluation at 1 month and at 6 months.

Symptomatic patient

If the patient is symptomatic, repeat the filling of calcium hydroxide and 2% CHX paste, and discuss the possibility of a surgical intervention or referral with the patient (see lessons 24, 27, and 34).

LESSON 34

Challenges and Mishaps in Obturation

OBJECTIVE

To understand the properties and characteristics of contemporary obturation materials to prevent untoward outcomes.

OBTURATION MATERIALS

It has long been recommended that the objective of any endodontic technique should be to apply a biocompatible three-dimensional canal filling that obturates the prepared canal space from the pulp chamber *just to* its apical termination. Currently, there is a convincing body of literature that describes the reaction of host tissue to many endodontic obturation materials. The American Association of Endodontists has stipulated that a biologically acceptable semisolid or solid obturating material should be used in conjunction with root canal sealers to provide a fluid-tight seal of the root canal system.

Characteristics of an ideal obturation material

- Easy to manipulate
- Conformable, dimensionally stable, and nonporous
- Nonirritating to periradicular tissues

• Retreatable
• Radiopaque
• Inhibits bacterial growth
• Does not stain tooth structure

Characteristics of endodontic sealers

The following conclusions regarding endodontic sealers have stood the test of time for the last 50 years:

• All obturation sealers are irritants in their freshly mixed states.
• After setting or curing, some sealers lose their irritant components and become relatively inert.
• All sealers are absorbable over time by the body.
• Paste-only formulations intended to fill the entire root canal system are absorbed more rapidly than are solid core obturations with sealer.
• A minimum amount of sealer should be exposed to periapical tissue.

In endodontic therapy, sealers and cements are primarily used to fill irregularities at the interface between the solid core root canal filling material and the walls of the canal system, ideally rendering the system impervious to bacteria. Early investigations into the absorbability of root canal sealers in animal models showed that very hard and compact sealers with low solubility become encapsulated by fibrous connective tissue. Less dense and more soluble sealers are dispersed and absorbed more rapidly.

Large quantities of excess filling materials in the periapical tissues cause necrosis of bone followed by bone resorption and then absorption of the filling materials. Most root canal sealers produce an initial acute inflammatory reaction in the connective tissues. This is followed by the production of a chronic foreign body reaction followed by slow absorption via the body's immune system.

CHALLENGES

Working length control

One of the major challenges in root canal treatment is the determination of the apical end point of the working length (WL). It is a cardinal principle in modern endodontics that instrumentation beyond the apical foramen should be avoided because it is so often associated with a reduced success rate and exposes the patient to the potential for injury.

Most clinicians generally prefer to end the biomechanical instrumentation at the apical constriction (narrowest point in the canal at approximately the cementodentinal junction), where the contact between root canal filling material and the apical tissues is minimal. In addition, many clinicians practice apical patency with small files to maintain communication with the apical tissues and to

prevent canal blockage and ledging coronal to the determined end point.

Despite the limited three-dimensional information provided by conventional radiography, it remains the commonly used standard for WL determination. However, the acceptance of apex locators has widely increased in the last two decades now that the devices are well into their fourth generation. Additionally, many clinicians use paper points to help determine the juncture of the canal confines based on where the serum of periapical tissue moistens the point.

Filling techniques

It has also been shown that great differences in flowability exist between gutta-percha brands when used in a thermo-compaction or heat transfer technique (Fig 34-1). Clinical case reports involving overfill with heat-softened gutta-percha are increasing in the literature. The current practice of maintaining apical patency and the popularity of thermoplastic gutta-percha filling techniques have increased the likelihood that overfills will occur.

Gross overextension of obturation materials usually indicates faulty technique. However, as long as the overextension is not in contact with vital structures, such as the inferior alveolar nerve or sinuses, and the apical terminus is well filled in three dimensions, permanent harm is potentially small, and an overfill of material will usually be well tolerated.

There are a number of contributions to the literature that assess techniques for apical control of obturation materials. Tronstad used monkeys to assess the apical plug of dentin chips. His work showed that a plug of clean dentin fillings could provide an apical matrix that was well tolerated by the tissues and an apical barrier that allowed the canals to be well sealed yet protected against impingement of filling materials on the periodontal tissues. In a second comprehensive study conducted in cats that compared apical plugs of dentin versus calcium hydroxide, investigators found that the plugs of dentin and plugs of calcium hydroxide worked equally well at preventing overfill in cases where the apical foramen had been intentionally overinstrumented.

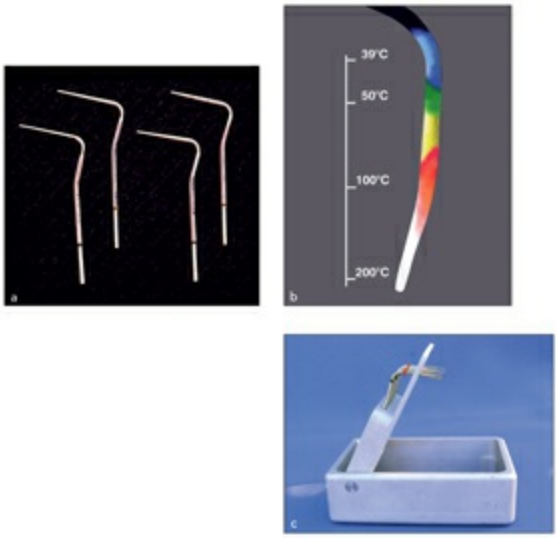


Fig 34-1 *(a)* System B heat plugger tips (SybronEndo) deliver heat to the tip of the plugger at 200°C, which is capable of liquefying gutta-percha during condensation. *(b)* Range of heating in an energized System B plugger. (Image courtesy of Dental Education Laboratories.) *(c)* System B pluggers in an organized, sterilizable tip stand.

PREVENTION

There are a number of remedies to provide a safe and prudent approach to the obturation of teeth. The following are recommended to avoid obturation mishaps.

- Radiographically image and clearly identify the roots and surrounding jaw structures to understand the anatomy in three dimensions and the risks of overfill.
- Use obturation materials that are well tolerated by the body after therapy, rather than unsafe formulations such as paraformaldehyde pastes that should not be used in the good and safe practice of endodontics.
- Practice careful and judicious shaping strategies that use multiple confirmations of WL (ie, electronic apex locators, radiographs, tactile confirmation, and paper points) to take serious precaution against overinstrumentation.
- Use "resistance form" in controlling overfills. This resistance form can be imparted during canal preparation by producing funnel-form, tapered preparations and by selecting gutta-percha cones to match those canal shapes that will resist the obturation forces promoting extrusion.
- When using thermoplastic techniques, respect the flow characteristics of the materials and the heat energy used.
- Be extremely cautious about using paste-fillers and syringes for applying endodontic sealers when in close proximity to neural structures and control is compromised.
- In cases of extreme proximity to the neurovascular anatomy, carefully create a clean dentin plug or material barrier such as MTA at the patent apical terminus, where the risk of extrusion is considerable.

With the use of rotation during instrumentation and with heated obturation devices becoming increasingly available to all practitioners in the last decade, the introduction of endodontic filling

materials into periapical tissues is quite common. This is of major concern when the teeth being treated are in close proximity to anatomically important structures such as the maxillary sinus or inferior alveolar canal (Fig 34-2).

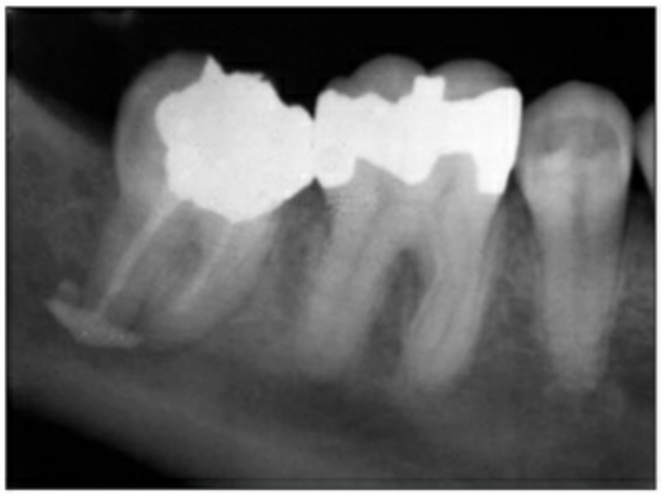


Fig 34-2 Postoperative periapical film demonstrating an overfill into the inferior alveolar canal. Because of the large amount of sealer (zinc oxide–eugenol) used, the patient suffered permanent anesthesia from both its chemical toxicity and the mechanical compression of its mass on the neurovascular anatomy.

POSTTREATMENT DISEASE AND EVALUATION OF HEALING

The period of postoperative observation has been advocated to be from 6 months to 4 years by various investigators. Teeth that receive endodontic therapy for irreversibly inflamed vital pulps without periradicular infections have higher rates of healing than do teeth with necrotic pulps and periradicular infections. A majority of healing studies recommend an observation period of no less than 1 year, and most suggest at least 2 years, with a recognition that root canals that are initially infected take longer to heal.

There is less agreement as to what constitutes healing when a majority of the literature is considered. Nonetheless, certain key characteristics are universally accepted in all considerations of successful healing:

- An absence of pain and swelling
- No evidence of ongoing tissue destruction
- The repair of any sinus tracts
- A functional tooth
- Radiographic evidence of repair or lessening of the rarefaction between 6 and 24 months

The causes for posttreatment disease after endodontic therapy have been classified by many authorities. Regardless of how these outcomes are classified, they invariably are attributed to one or more of the following reasons (Fig 34-3):

- Poor access cavity design and execution
- An iatrogenic mishap or procedural error

- Untreated canals or systems
- Poorly cleaned or obturated canals
- Instrumentation errors such as ledging, perforation, transportation from center, and separated instruments
- Overextension of obturation materials
- Coronal leakage
- Extraradicular infections or cysts
- Root fracture

Disease or health of the periapical region after root canal therapy is mainly assessed by combining clinical and radiographic findings. However, it is important to remember that lesions are frequently discovered on periapical radiographs without apparent clinical signs or symptoms. In consequence, if follow-up radiographs display the same rarefaction indicative of posttreatment disease, then the case has not had a satisfactory outcome, even if during examination the patient reports that symptoms are absent. The lack of pain or discomfort should not be used to postpone treatment or to circumvent retreatment therapy. A periapical rarefaction should be regarded as a sign of inflammation of the periodontium due to infection inside the root canal space and/or the surrounding dentin in the vast majority of cases.

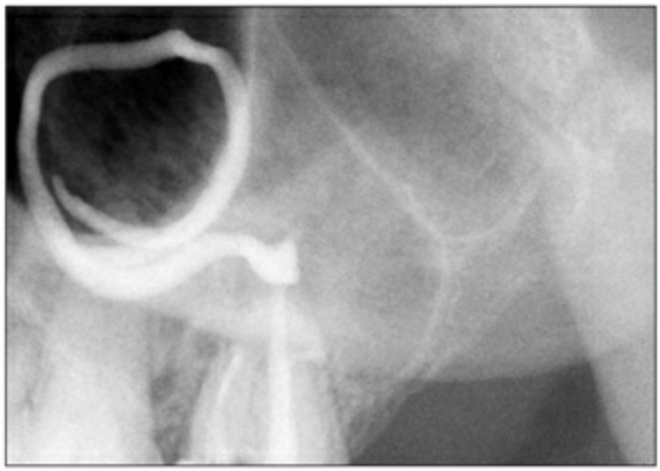


Fig 34-3 Maxillary second molar with apical pathosis in close proximity to the maxillary sinus. An extreme overfill into the sinus resulted from the combination of an overinstrumented apex and an automated thermoplastic technique.

PART SIX

Emergency and Adjunctive Endodontic Procedures

LESSON 35

Endodontic Emergencies and Their Treatment

OBJECTIVE

To understand the presenting features of symptomatic endodontic disease and determine management strategies and therapies to achieve control of pain and/or infection.

INTRODUCTION

The endodontic emergency is a pulpal and/or periapical disease condition that manifests itself through pain, swelling, or both. At the emergency visit, the clinician must first render an accurate diagnosis and then achieve control of pain and/or infection in an expedient manner.

DIAGNOSIS

The patient who complains of "toothache" is likely suffering the effects of pain from pulpal and/or periapical inflammation. However, patients with referred pain, more complex facial pain, sinus pain, temporomandibular joint pain, or nonodontogenic pain in the head and neck may present with toothache-like symptoms. The clinician should first obtain accurate information regarding the patient's medical and dental history. To arrive at a diagnosis and to identify the source of the pain, the dentist must gather the following data:

• A history of dental therapy associated with the area of complaint

- Information regarding the current dental problem
- The appropriate extra- and intraoral examinations
- The requisite dental testing, including pulp tests and radiographs as required

Chief complaint

1. *Where is the pain?* Ask the patient to indicate the location of the chief complaint by pointing to it with one finger. The pain associated with pulpitis is often referred to adjacent structures and poorly localized.
2. *When did the pain develop?* The patient should relate when the symptoms were initially perceived. He or she may be aware of a history of recent dental procedures or past episodes of discomfort and pain.
3. *What are the characteristics of the pain?* Is the pain spontaneous or provoked? If symptoms can be stimulated, are they immediate or delayed? How long do symptoms last when they occur? Are they described as "momentary" or "lingering"? Pulpal and periapical pathoses produce sensations that are described as aching, pulsing, throbbing, and dull.
4. *How intense is the pain?* The pain can be classified as *severe* if it interrupts or significantly alters the patient's daily routine. Pain which interferes with sleeping, work, or leisure activities is *significant*. If potent analgesics are required, the pain is considered *severe*. Intensity is a hallmark of irreversible pulpal disease.
5. *What are the affecting factors?* Which factors provoke, intensify, or alleviate symptoms? The following stimuli are generally associated with odontogenic symptoms when they provoke pain: heat, cold, sweet, percussion, and biting.

Diagnostic tests

Diagnostic tests enable the practitioner to:

- Reproduce the symptoms. Diagnostic tests may include hot and cold thermal testing, tooth percussion, tissue palpation, transillumination and magnification, and anesthetic tests to localize pain. It is imperative to accurately recreate with the thermal tests the conditions that stimulate the pain. If the patient's chief complaint involves pain to biting or chewing, having the patient chew on a cotton roll or flexible suction straw will help you identify a single tooth more quickly than will simple percussion. Using the Tooth Slooth (Professional Results) for cuspal and dentinal fractures will help you readily identify cracks hidden under restorations.
- Provide an assessment of normal responses for comparison with abnormal responses, which may be indicative of pathosis. Several adjacent, opposing, and contralateral teeth should be tested prior to the tooth in question to establish the patient's normal range of response.
- Radiographically observe the pulp's reaction to specific etiologic factors such as caries, fracture, trauma, and deep restorations.

After working through this sequence of questions and the applicable tests, the clinician should be able to identify the offending tooth and diagnose its pulpal and periapical condition.

Common emergency conditions

Emergency pulpal conditions are:

- Irreversible pulpitis
- Necrosis

Emergency periradicular conditions are:

- Acute apical periodontitis
- Acute periradicular abscess

Irreversible pulpitis

In irreversible pulpitis, the pulp is so inflamed that healing is unlikely, and ultimately, pulpal necrosis and infection will re-sult. The symptomatic irreversibly inflamed pulp is usually very sensitive to thermal changes, and the pain lingers as a dull, throbbing, poorly localized ache after the stimulus has been removed. The pain can be referred to a distant site including other teeth. The more severe the pain and the longer it has been symptomatic, the more likely it is that the pulp has been irreversibly damaged. A clear indication of an irreversibly inflamed pulp is a history of spontaneous pain that keeps the patient awake at night.

Irreversible pulpitis with acute apical periodontitis

When the inflammatory process of irreversible pulpitis progresses to the attachment apparatus, the tooth becomes sensitive to touch, bite, and percussion. The symptoms of irreversible pulpitis remain; however, the proprioceptive fibers in the periradicular tissues ensure that the pain becomes localized to the tooth associated with the inflamed pulp. There may be no radiographic evidence of apical pathosis, or the periodontal ligament may be widened.

Pulpal necrosis with acute periradicular abscess

An untreated irreversibly inflamed pulp ultimately results in pulpal necrosis. The root canal system now has a bacterial infection. Pulpal necrosis is asymptomatic; however, it can lead to inflammation and infection in the periradicular tissues. This is often seen as an asymptomatic, chronic apical periodontitis, with the only clinical sign being a periapical lesion on the radiograph. On occasion, however, it is symptomatic, exhibiting pulpal necrosis with acute periradicular abscess. Severe pain is localized to the tooth with the necrotic pulp. The tooth is tender to touch, bite, and percussion, and the pulp fails to respond to thermal testing. If pulpal necrosis occurs rapidly following pulpal inflammation, there may be no radiographic evidence of periapical pathosis. However, if the acute abscess develops from a persistent chronic apical periodontitis, there will be a preexisting periradicular radiographic lesion. Intraoral and/or extraoral swelling may develop, and the patient

may become febrile.

EMERGENCY MANAGEMENT

Deciding to treat or to refer the patient

The dentist must determine what expertise is required to make a difficult diagnosis or render a complicated treatment. The patient's ability to withstand the procedure, emotionally, physically, and medically, and the availability of time for a complex case may be considerations in referring the emergency patient to an endodontist.

It might be necessary to wait a while for vague or referred symptoms to localize. This conservative approach is occasionally necessary when pulpal pathosis is confined to the root canal space. It may be necessary for the inflammation to involve the attachment apparatus before the culprit tooth can be identified.

Treatment planning for predictable comfort

The removal of inflamed or infected pulp is the goal of the emergency encounter. The level of anesthesia required for a patient's comfort during endodontic procedures is far greater than that which is needed for most restorative procedures. Infiltration for maxillary teeth and blocks for mandibular teeth remain the first anesthesia techniques used in preparation for emergency treatment. Often, however, these techniques alone do not provide the comfort necessary for the emergency endodontic procedure. Supplemental techniques, including the periodontal ligament injection and the intraosseous injection, are excellent adjuncts when the standard procedures have not produced adequate anesthesia (see lesson 14).

Irreversible pulpitis

Irreversible pulpitis can be predictably managed by complete pulp removal and cleaning and shaping of the root canal system with copious sodium hypochlorite irrigation. Some clinicians have advocated the removal—in multirooted teeth—of the pulp from the widest canal, followed by the placement of a medicament against the remaining pulp stumps in an attempt to reduce pain.

Note: Because it is impossible to detect clinically the apical extent of the inflamed pulp and hence provide predictable pain relief, it is important to remove all pulp from all canals at the emergency visit. Complete pulp removal is particularly important in cases of irreversible pulpitis with acute apical periodontitis.

Inflamed vital pulp tissue should not be lacerated with small endodontic files and left in the canals. This will likely result in an increase in discomfort as the pulp is now inflamed, shredded, and packed in the canals. A popular idea that medicaments sealed in canals help control or prevent additional

pain is not true. A dry cotton pellet is as effective in relieving pain as a pellet moistened with camphorated para chlorophenol, cresatin, eugenol, or saline. Complete caries removal and an effective coronal seal are mandatory to prevent recontamination of the root canal system between appointments. The use of calcium hydroxide as an interappointment medication (see lesson 28) is also recommended. Occlusion may be relieved, although this is usually unnecessary if pulp removal has been thorough (Fig 35-1).

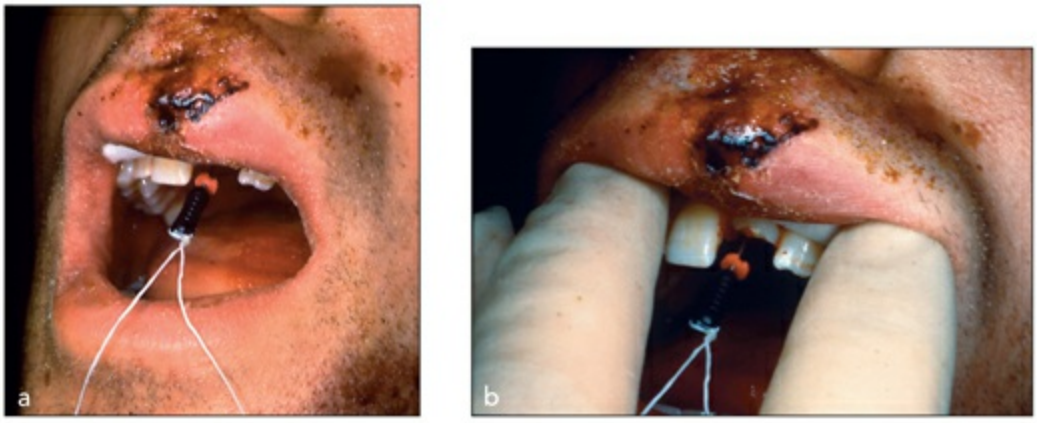


Fig 35-1 (*a)* Traumatic fracture through the pulp space of a mature maxillary incisor. The patient experienced extreme pain with temperature changes. At the emergency visit, rubber dam application was ruled out because of the facial injuries. *(b)* The patient's airway was protected and files were ligated with dental floss during the extirpation procedures.

Pulpal necrosis with acute periradicular abscess

Patients with pain attributed to acute periradicular abscess may have no swelling, or they may have localized intraoral swelling or diffuse facial swelling. In all cases, the aim of emergency treatment is to eliminate the cause of the infection by cleaning and shaping the root canal system, and to incise and drain the swelling if present (Fig 35-2).

Following complete cleaning and shaping, the canals are dried and filled with a nonsetting calcium hydroxide intra-canal medicament. It is good technique to mix a thick calcium hydroxide paste using a product such as Pulpdent Paste (Pulpdent) or calcium hydroxide powder. The paste can be carried into the canal with an amalgam carrier and condensed to place with pluggers or spun down the canal with lentulo spirals (see lesson 26).

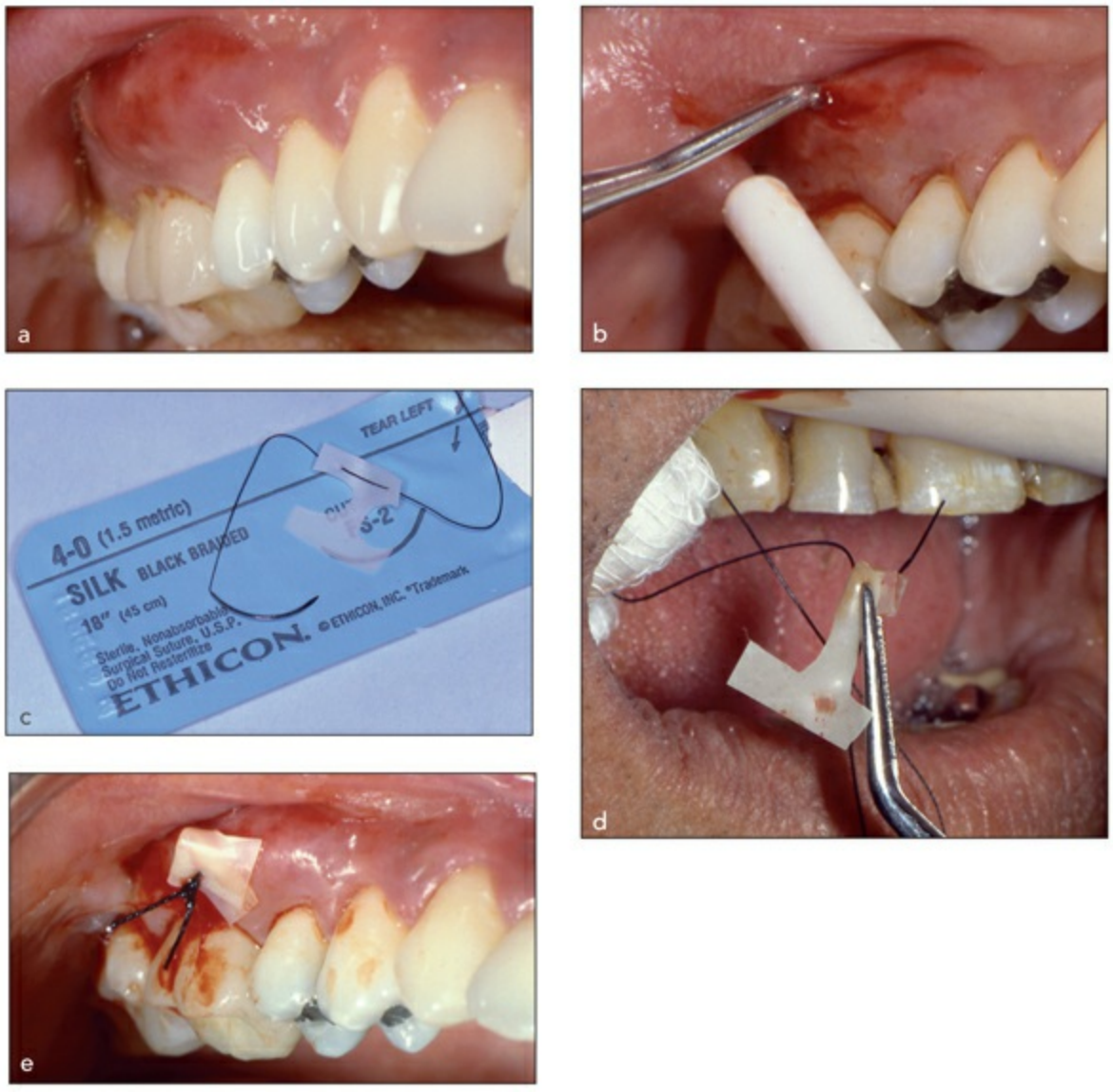


Fig 35-2 *(a)* Acute periradicular swelling associated with a maxillary right first molar. *(b)* A deep incision to the base of the alveolar bone increased access to the swelling, and a surgical curette was used to dissect tissue and facilitate drainage. *(c)* Rubber dam drain in a "T" shape was placed into the soft tissue to minimize premature closure of the incision. *(d)* The rubber dam drain was sutured in place to encourage continued drain-age for 24 to 48 hours. *(e)* The drain in position.

Swelling

For rapid and predictable elimination of an infection with swelling, treatment should include complete cleaning and shaping of the canal(s), calcium hydroxide intracanal medicament, coronal seal, and incision and drainage of the swelling (Fig 35-3). Time constraints may make this treatment goal difficult to achieve in retreatment cases, and referral to an endodontist may be warranted.

Drainage accomplishes two goals: *(1)* relief of pressure and pain and *(2)* removal of a potent irritant (Fig 35-4). Copious drainage achieved through the tooth followed by cleaning and shaping may negate the need for a mucosal incision.

If there is minimal drainage from the canal or if a fluctuant swelling remains following instrumentation, the soft tissue swelling should be incised and drained through a mucosal incision

penetrating to bone. These patients seldom have elevated temperature or other systemic signs, and the use of systemic antibiotics is not necessary if drainage is achieved.

This is not the case with diffuse swellings. These lesions are often rapidly progressive and have dissected into deeper tissue spaces. These patients occasionally have an elevated temperature and feel unwell. The removal of the irritant, by complete cleaning and shaping of the root canal, is paramount. The swelling may be incised, but this can prove difficult (Fig 35-5).

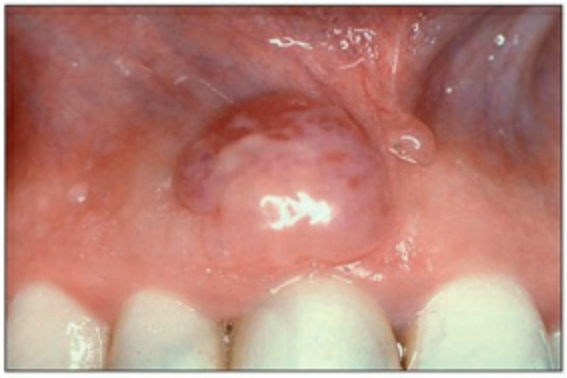


Fig 35-3 Intraoral swelling that is ready to be incised and drained.

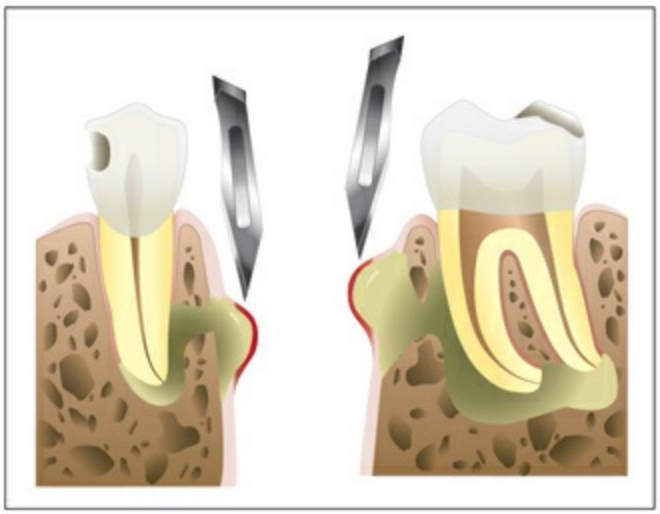


Fig 35-4 The pathway of drainage from the periapical bone through the soft tissue.

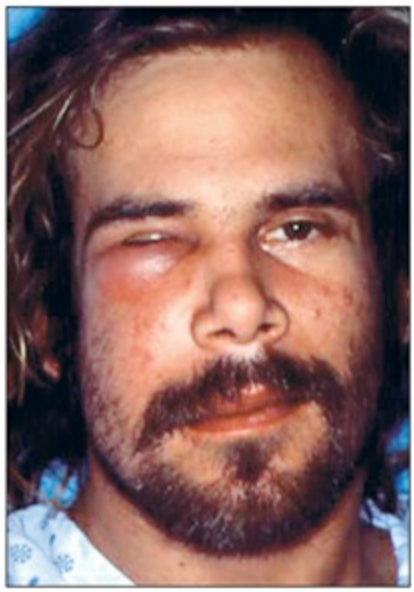


Fig 35-5 Infraorbital space infection caused by a maxillary canine. This infection spread deep within the facial structures because of the length of the canine root and shallow muscle attachments of the vestibule.

Open or closed?

While the majority of endodontists prefer to close most or all teeth between appointments, a number of specialists leave some painful teeth open until symptoms have abated. If clinicians have the time and willingness to thoroughly clean and shape all canals of an acutely painful tooth, predictable results can be obtained when teeth are closed between visits. In acute abscess cases where there is uncontrolled and excessive drainage, the tooth may be left open to drain for 24 hours, with the patient subsequently returning for closure. This situation presents very rarely. All cases of irreversible pulpitis and the vast majority of pulpal necrosis cases should be closed.

Analgesics

Nonsteroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen and naproxen are effective for managing postemer-gency inflammation. Narcotic analgesics may be prescribed for severe pain. They are most effective when taken with NSAIDs, and the patient should be informed and convinced of the importance of taking these medications with food.

Follow-up calls the evening of the emergency are an excellent way to build rapport and show concern for the patient's well-being.

Use of antibiotics

Systemic antibiotics are indicated for diffuse, rapidly spreading infections or in cases of localized swelling in which drainage is not achieved. The preferred and first choice of antibiotic is penicillin,

1,000 mg to start and then 500 mg four times daily. An alternative for penicillin-allergic patients is clindamycin, 300 mg four times daily. Diffuse swellings decrease slowly over a period of perhaps 3 to 4 days. On occasion, a presenting acute periradicular abscess can be very serious or even life-threatening. These situations may require hospitalization and aggressive therapy with the cooperation of an oral surgeon.

LESSON 36

Vital Pulp Capping

OBJECTIVE

To induce the formation of a mineralized barrier at the exposure site of a healthy pulp in a mature adult tooth.

INTRODUCTION

A pulp's response to exposure is predicated on the extent and depth of bacterial contamination at the time of the exposure and the health status of the pulp prior to the exposure.

It is a well-known fact that the pulps of restored or injured teeth may undergo chronic inflammatory changes, perhaps even degeneration, without the patient experiencing symptoms. It has also been reported that this phenomenon of inflammation and degeneration without symptoms may occur when a patient demonstrates radiographic evidence of a positive response (dentin bridge) to a pulp cap. For this reason, it is imperative for the patient to understand that a lack of symptoms following a pulp cap does not guarantee a favorable long-term outcome nor does it mean that no additional treatment will be required to save the tooth (Fig 36-1).

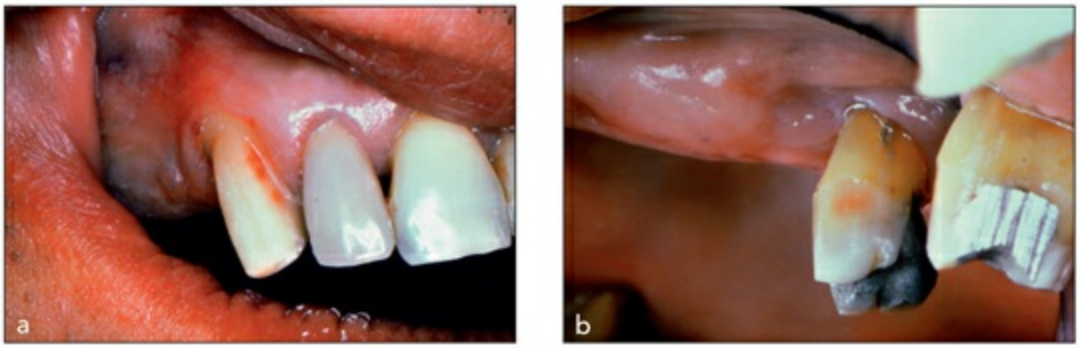


Fig 36-1 *(a and b)* Two examples of pulpal "blush" after preparation demonstrates bleeding into the dentinal tubules. This response to heat and vibration during preparation creates a quandary for the clinician. Is it a true pulp exposure? Will the pulp heal? Does it require immediate endodontic intervention? Most clinicians interpret this to mean the pulp has been irreversibly damaged and requires endodontic therapy.

INDICATIONS

Coronal mineralization-inducing (calcification) procedures should be reserved for vital nonabutment teeth with shallow exposures, and apical closure techniques should be reserved for immature teeth, as in apexogenesis and apexification. When the tooth to be pulp capped is critical to the success of a major prosthodontic reconstruction, serious consideration should be given to the more proven success rates of modern endodontic therapy (92% to 98%) over significantly lower success rates for pulp capping.

MATERIALS

- Anesthetic
- Consepsis (chlorhexidine [CHX] gluconate) (Ultradent Products)
- Calcium hydroxide (Roth Products)
- Dycal (Dentsply)
- Mineral trioxide aggregate (MTA) (ProRoot-MTA [Dentsply])

TECHNIQUE

Step 1: Evaluation and preparation

1. Address all medical concerns.
2. Assure the vitality of the tooth via electic and thermal pulp tests.
3. Take radiographs of the tooth to ascertain apical maturity.
4. Attain a profound working level of anesthesia.

5. Apply well-adapted rubber dam.
6. If the exposure is inadvertent or results from extensive caries, proceed to step 2.
7. If the exposure is the result of an injury, proceed to step 3.

Step 2: Accessing the pulp

1. To prevent cross contamination in a tooth with an anticipated exposure, you must isolate it from the oral cavity with rubber dam.
2. Remove all soft spongy caries, restorative material, and peripherally involved dentin with a high-speed tungsten or diamond bur.
3. Gently and carefully remove the remaining leathery dentin over the roof of the pulp chamber with a sterile, slowly rotating stainless steel round bur (No. 4 or 6) and an accompanying soft water spray.

Note: Since enamel and dentin contain small amounts of water and erbium laser beams are absorbed in water, there has been an increased interest in the use of erbium lasers in operative dentistry. As for their use in endodontics, research has found that erbium lasers caused less bleeding and impregnated fewer dental chips at laser-exposed sites during pulp capping than did dental burs. However, the high cost and the fact that a laser beam is straight (cannot get around a curve) may preclude their use in root canal therapy.

Step 3: Following pulp exposure

1. The exposure should be carefully enlarged, and a thin layer of the superficially inflamed, contaminated, and/or infected tissue should be removed via a sterile, slowly rotating stainless steel round bur (No. 4), accompanied by gentle irrigation with sterile saline.
2. Gently flush all debris from the area with saline rinses. Never blow-dry an exposure site. At no time should forced air, water, or vacuum pressure be directed to or on the exposure site. A number of studies have shown that heat and air (dehydration), along with the intrusion of necrotic and infected debris during the excavation process, will further insult the pulp tissue and reduce its chance of survival.
3. A small amount of bleeding, which confirms the presence of living tissue, should be noticed and expected. Though it is impossible to detect the level of bacterial penetration, the clinical condition of the pulp tissue dictates the ultimate target depth of the intended calcium hydroxide or MTA treatment:
   - A pulp cap is indicated for a vital mature tooth when the clinical appearance of the pulp tissue appears healthy and a minimal amount of bleeding is encountered and controllable (Fig 36-2).
   - A pulpotomy is the first option for a vital tooth with a mature apex when there is heavy persistent bleeding that is difficult to control. This requires removing all of the tissue within the pulp chamber. If the clinical appearance of the tissue at the orifice appears healthy and a minimal

amount of bleeding is met at this level, institute the normal pulp cap steps at this site.

- A pulpectomy (root canal) is indicated when the pulp tissue at or in the orifice shows no sign of vitality (ie, bleeding is absent, tissue lacks body and constancy, and/or there is evidence of fluid and/or a putrescent odor). Any one of these signs points to partial or full-blown necrosis and the need for extirpation and concomitant endodontic therapy.

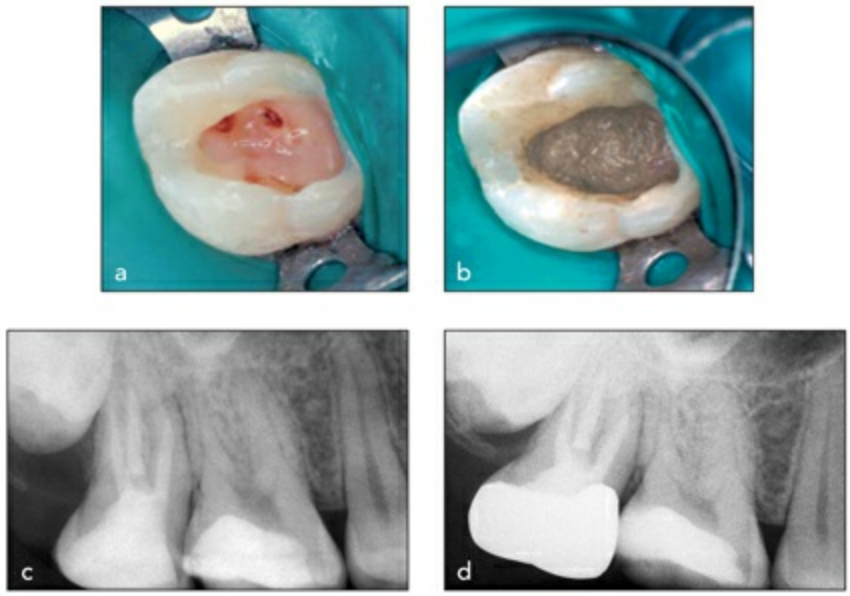


Fig 36-2 *(a)* Vital exposure of a young maxillary molar. *(b)* After bleeding was controlled and the dentin disinfected with CHX, a gray MTA pulp cap was applied. *(c)* Postoperative radiograph showing an etched and bonded restoration at a subsequent visit. The second visit was to verify the set of the MTA, to place an excellent coronal seal, and to verify an absence of symptoms. *(d)* One-year follow-up radiograph demonstrates secondary dentin over the pulp. The pulp remains vital and asympto-matic. Note the reduced size of the pulp chamber.

Step 4: Hemorrhage control and disinfection

1. Continuously but gently flush the exposure site with sterile saline or anesthetic solution until bleeding substantially subsides or stops. (Sodium hypochlorite is a tissue solvent and controversy exists regarding its use on exposed vital tissue.)
2. Absorb excess saline or anesthetic solution from the site with dry cotton pellets without pressuring the exposure.
3. Apply a few drops (or dab a saturated cotton pellet) of Consepsis (2% CHX gluconate) over the exposure site for 1 minute. This agent functions as both a coagulant (if bleeding has continued) and a disinfectant.
4. Flush the Consepsis from the site with normal saline and/or anesthetic solution.
5. Absorb the saline or anesthetic solution from the site (cotton pellets), and gently rinse the exposure a second time with CHX.
6. In addition to reducing the number and patency of the residual bacteria, this process also removes remnant blood clots, which are a perfect medium for bacterial growth.

Step 5: Selecting the appropriate pulp capping agent

- A paste mix of calcium hydroxide powder and sterile anesthetic solution is fine, if it is easy to place without injuring (pressuring) the pulp tissue.
- Dycal is a calcium hydroxide cement that is easy to place, sets quickly, and has a long and well-known clinical history of success in building a desirable mineralized bridge in direct contact with the overlying cement base.
- A paste mix of MTA and sterile anesthetic solution or ProRoot-MTA is biocompatible, hydrophilic (functions best in the presence of moisture, including blood), and easy to apply and has been widely and extensively documented as an inductive pulp capping material. Studies by Torabinejad and Holland revealed that the material induces cementogenesis and bone deposition, similar to the effects of calcium hydroxide. Their studies also indicated that the healing of a dental pulp exposure following a pulp cap does not necessarily depend on the medicinal value of the pulp capping material but may be more related to its ability to prevent bacterial leakage (seal). Numerous studies by Torabinejad and others suggest that the ability to prevent leakage is a major strength of MTA. *Note:* MTA and ProRoot-MTA have an extended set time (4 hours).

- The "total etch" technique advocates using a normal (2- to 3-step) dentin-bonding (composite) technique over the exposure as if the exposure did not exist. Those claiming success with the total etch technique base their success on clinical responses. However, reliable science shows that the absence of signs and/or symptoms cannot be considered the sole biologic basis for success. In a study by Pameijer and Stanley, the authors concluded, "until a modification, or another technique or material is scientifically proven as successful as calcium hydroxide the use of the 'total etch' technique and certain bonding agents in vital pulp capping is contraindicated."

Step 6: Temporary coverage

- The pulp capping agent—whether Dycal (once set), semidry MTA paste (surface moisture should be absorbed with cotton pellets), or ProRoot-MTA—should be covered gently with a thin layer of light-cured glass ionomer.
- Depending on the esthetic and functioning needs of the tooth, the balance of the prepped cavity may be restored with a bonded composite resin, amalgam, or temporary crown.

Step 7: Postoperative care

The doctor or a member of the office staff should contact the patient on the day following treatment to ensure the patient is responding well, to offer advice, and/or to prescribe an appropriate analgesic if deemed necessary.

Situation 1: Favorable response

The patient and the tooth are responding favorably. At 3 months, the condition of the provisional restoration should be inspected and repaired if needed, the tooth pulp tested and radiographed, and all findings recorded. If all is well, the patient should return for a follow-up appointment in 3 more months.

At 6 months, the condition of the provisional restoration should be inspected and repaired if needed, the tooth pulp tested and radiographed, and the findings recorded. If all is well, the patient should return for a follow-up appointment in 6 more months. There should be some radiographic evidence of a developing mineralized bridge at this time.

At 1 year, there should be radiographic evidence of a mineralized bridge at the pulp cap site. If the tooth is responding favorably to pulp and percussion tests and there is no evidence of apical periodontitis, the patient should be informed that conditions favor definitive restoration of the tooth. As previously mentioned to the patient during the consultation, however, the long-term prognosis cannot be assured, and periodic radiographic evaluations should continue.

Situation 2: Mineralization problem

The patient and the tooth are responding favorably, but there is a mineralization (calcification) problem. The patient is asymptomatic and responds favorably to pulp and percussion tests. The tissue is forming a mineralized bridge at the pulp cap site (6 to 12 months), but extensive secondary mineralization is progressing along the walls of the canal.

If this metamorphosis is allowed to continue, the entire canal space could be obliterated. This obstruction would limit any future canal instrumentation and leave apical surgery as the patient's only endodontic treatment option were an apical lesion to form. Mineralization intrusion should be carefully monitored, and when it becomes a critical issue, interceptive endodontics should be considered.

Situation 3: Unfavorable response

The patient and the tooth are not responding favorably. The tooth becomes symptomatic, pulp tests are unfavorable, and/or an apical lesion is apparent on radiographs. It is obvious that the pulp cap is failing. Success in repeating the pulp cap and or performing a partial pulpotomy is doubtful.

To avoid future problems and the loss of a patient's confidence, the ideal solution for a failing tooth with a mature apex is to initiate and complete root canal therapy (92% to 98% success) at this visit (see lesson 27). The patient (at the original consultation) should have been made aware of this possibility and the additional fee(s) for the extended therapy.

Situation 4: Patient relocation

The patient and the tooth are responding favorably, but the patient relocates soon after the pulp cap treatment and before a bridge forms or a permanent restoration can be placed. In this case, the patient should be made aware of the importance of follow-up evaluations.

To avoid being challenged with abandonment, recommend that the patient or guardian contact the state or local dental society where he or she will be residing to get a general dental referral and

assure the patient or guardian that the patient's records will be forwarded, upon request, to the new dentist without obligation. These recommendations should be in writing and should be signed by both parties.

LESSON 37

Apexogenesis and Pulpotomy

OBJECTIVE

To preserve the health of the radicular pulp in an immature vital tooth for the purpose of inducing continued root development.

INTRODUCTION

If a pulp exposure occurs in an immature tooth—be it from extensive caries, mechanical intrusion, or trauma—every effort should be made to keep the pulp tissue vital and healthy. As such, it is imperative that the guardian, and perhaps the patient, be aware of the reasons, risks, rewards, and fees for apexogenesis (ie, the procedure required to protect the exposed tissue and to induce root end formation). The presentation of the treatment plan is extremely important; if the purpose of this approach is not clearly understood, the number of visits and the ongoing costs involved to produce the desired result could be construed as a means of prolonging treatment.

MATERIALS

- Anesthetic
- Consepsis (chlorhexidine [CHX] gluconate) (Ultradent Products)
- Calcium hydroxide (Roth Products)

- Dycal (Dentsply)
- Mineral trioxide aggregate (MTA) (ProRoot-MTA [Dentsply])
- Peridex (Zila Pharmaceuticals)
- Composite resin

TECHNIQUE

Step 1: Evaluation and preparation

1. Address all medical concerns.
2. Assure the vitality of the tooth via electronic and thermal pulp tests.
3. Take radiographs of the tooth to ascertain apical immaturity.
4. Attain a profound working level of anesthesia.
5. Apply well-adapted (nonleaking) rubber dam.

Step 2: Accessing the pulp

The pulp cap or pulpotomy procedures advocated for an immature vital tooth are the same as they are for mature vital teeth. Treatment depends only on the level of the pulp chamber where pulp tissue is found to be healthiest:

- Regardless of the level at which the clinical appearance of the exposed pulp tissue appears healthy, a pulp cap is indicated if there is a minimal amount of bleeding (controllable) (return to lesson 36; steps 2 through 7) (Fig 37-1).
- If there is heavy persistent bleeding that is difficult to control at the exposure site, a pulpotomy is indicated. That is, remove all of the tissue in the pulp chamber, and if the tissue appears healthy at the orifice, institute the normal pulp cap steps at this site (return to lesson 36; steps 2 through 7) (Fig 37-2).
- If there is no evidence of vital tissue in the chamber or orifice (no bleeding) and there is evidence of fluid (pus) or a putrescent odor, it is highly probable that you are dealing with a partial or total necrosis, in which case you should initiate an apexification procedure (see lesson 38).

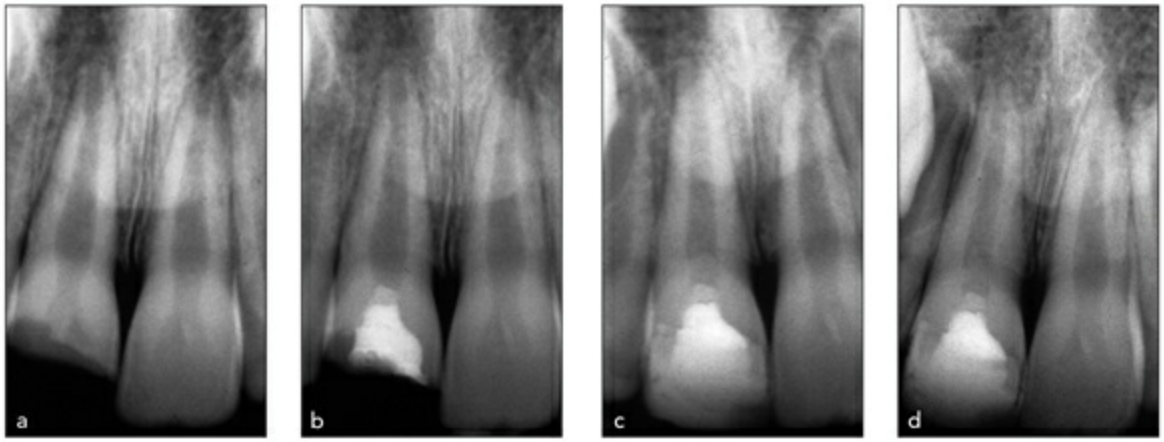


Fig 37-1 *(a)* Traumatic fracture into the tooth pulp of a 9-year-old child, 1 day after injury. *(b)* Coronal exposure was opened and debrided with round burs, and a small chamber pulpotomy with MTA was placed down to healthy bleeding tissue. *(c)* The tooth at 6 months was asymptomatic and normal in function. A bonded incisal edge was used for the coronal seal and esthetics. *(d)* After 1 year, the pulp remains asymptomatic and vital. There is good evidence of continuing root development and closure. (Images courtesy of Dr Kenneth Tittle, Pleasant Hill, CA.)

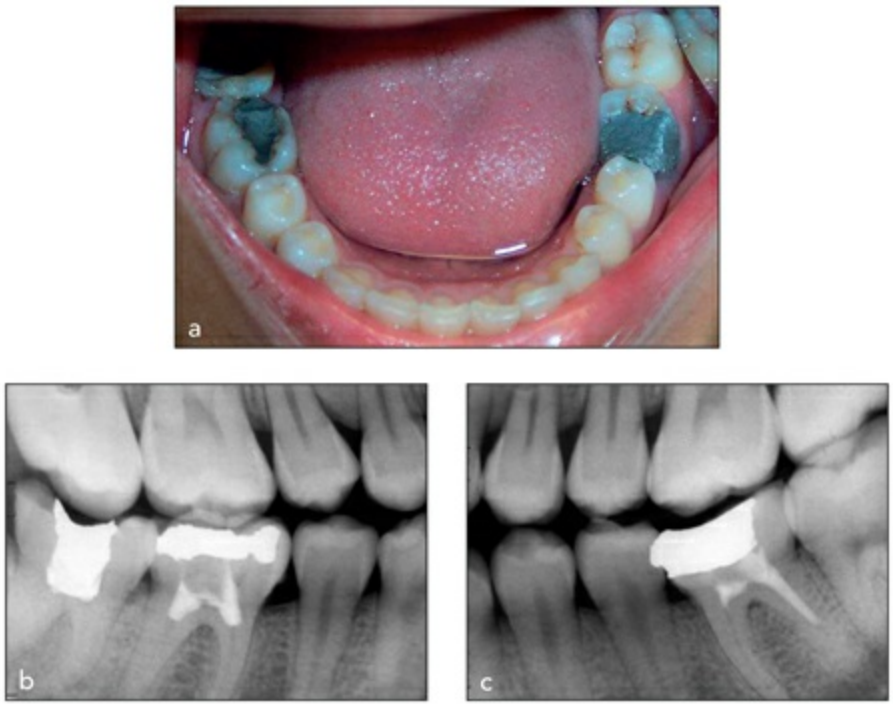


Fig 37-2 *(a)* Clinical situation of a young teenager with extensive caries under restorations in the mandibular left and right first molars and right second molar. *(b)* The mandibular right first and second molars received MTA pulpotomies to allow the remaining pulpal tissues to continue root development. *(c)* The mandibular left first molar received pulpotomy therapy with MTA at two different levels within the roots after a determination of where healthy bleeding was present. (Images courtesy of Dr Kenneth Tittle, Pleasant Hill, CA.) becomes critical. If this is not the case, interceptive endodontic therapy and apexification procedures may have to be instituted before the canal obliterates itself.

Step 3: Postoperative care

- Contact the patient on the day following treatment to ensure that he or she is responding well, to offer advice, and/or to prescribe an analgesic if deemed necessary.
- Apexogenesis cases require multiple examination appointments over a period of 1 to 4 years. The patient should be alerted to this possibility at the original consultation appointment.

Situation 1: Unfavorable

If at any time during the postoperative appointment period the patient develops symptoms and/or radiographs reveal a pathosis, question the vitality of the pulp, reaccess it, and evaluate the tissue. It is likely you will find evidence of necrosis (fluid or odor), in which case you should proceed to lesson 38.

Situation 2: Favorable

If at a 3-month follow-up appointment the patient is asymptomatic and there is no radiographic evidence of infection (pathosis), record all findings and schedule the patient for a follow-up visit. It is doubtful a change in the apical development will be noticed at this time.

If at the 6-month appointment the patient is asymptomatic and there is no radiographic evidence of infection (pathosis), record all findings, compare the results with those from the 3-month appointment, and schedule the patient for a follow-up visit 6 months later. It is possible a change in the apical development will be noticed at this time.

If at the 1-year appointment the patient is asymptomatic, apical development should not only be evident radiographi-cally but also should be expected.

If at this 1-year postoperative appointment the patient is asymptomatic and the radiographs do not show signs of pathosis but there is no evidence of apical development, then the vitality of the pulp is in doubt. Reaccess and evaluate the pulp; if there is evidence of living tissue, repeat the pulp cap steps at the orifice and schedule the patient for further evaluation. If the pulp cap is reaccessed and there is evidence of fluid (pus) or odor, then the pulp has not survived and you should proceed to lesson 38.

Situation 3: Potentially unfavorable

Apexogenesis is really a pulp cap with a deeper targeted tissue. As such, it is meant to induce mineralization. However, secondary mineralization can progress apically along the walls of the canal before the apical portion mineralizes. Chances are that the apex will form before the mineralization intrusion

Step 4: Definitive restoration

If the patient is asymptomatic, there is radiographic evidence of a mineralized bridge at the

pulpotomy site, and the apex has completed its formation, then a definitive restoration for the tooth is justified. As with a pulp cap, the patient should be informed that the conditions favor restoring the tooth definitively but that the long-term prognosis cannot be assured.

REVASCULARIZATION

A new treatment option that is described as *revascularization* of the pulp space has recently been introduced into clinical practice. Many of the biologic principles involved in these revascularization techniques have arisen from the trauma literature.

The principles and procedures involved in the revascularization process mandate disinfection of the immature root canal system with conventional irrigation and the use of a triple antibiotic paste to allow for maximum disinfection of the root canal space, formation of a blood clot matrix into which regenerated cells can grow, and high-quality sealing of the coronal access. In the majority of published cases, narrowing of the wide apical opening is evident as is the continued maturation and thickening of the dentin walls in necrotic immature permanent teeth.

As described in this lesson, the treatment of the immature nonvital tooth with apical pathosis presents several treatment challenges. The mechanical cleaning and shaping of a tooth with an incompletely formed root is difficult, if not impossible. The thin, fragile lateral dentinal walls can fracture during mechanical filing, and the large volume of necrotic debris contained in a wide root canal is difficult to disinfect.

The development of normal, sterile granulation tissue within the root canal is thought to aid in revascularization and stimulation of cementoblasts or of the undifferentiated mes-enchymal cells at the periapex, leading to the deposition of mineralized tissue at the apex and on the lateral dentinal walls. So far, only isolated case reports and small case series have been reported in the literature. The revascularization technique generally follows these guidelines:

1. After rubber dam isolation and access to the root canal system, copiously irrigate the canal space with 2.5% to 6.0% sodium hypochlorite solution, with minimal or no filing to prevent further weakening of root canal walls. Carefully measure the canal length so as not to irrigate beyond the open canal.
2. Mix a combination of ciprofloxacin, metronidazole, and minocycline pastes to a firm consistency with a water-soluble carrier such as propylene glycol, and with pluggers, place it to the desired depth within the root canal. Determine the depth of placement of the antibiotic paste by the quality of the remaining tissues found within the canal (either close to the apical blood supply or higher coronally against vital tissue).
3. Schedule the patient for a follow-up visit (2 to 4 weeks) to assess the resolution of the infectious process in the periradicular tissues.
4. If the infection is resolved, then at the second appointment use a No. 30 K-file or larger to gently irritate the tissue apically to create some bleeding into the canal. Leave the tooth to bleed for at least 15 minutes so that the blood can clot.
5. Carefully place MTA over the blood clot, followed by the placement of a wet cotton pellet and Cavit (3M ESPE) or IRM (Dentsply).

6. Two weeks later, if the patient returns asymptomatic, replace the provisional restoration with a bonded resin restoration.
7. At the 6-month recall, the patient should be asymptomatic. Take a radiograph to confirm resolution of the radiolucency.

The canal space, formerly occupied by the blood clot, should be stable or narrowing.

8. The intraoral radiograph will act as a baseline record to compare with follow-up radiographs to be taken at 6-month intervals. Both clinical and radiographic evaluations should be done at each follow-up visit.

Regeneration of tissues rather than replacement with artificial substitutes is an emerging and exciting field in the health sciences. The revascularization of infected, nonvital immature teeth to stimulate regeneration of apical tissues and induce apexogenesis has been documented and is emerging as a new treatment modality for such teeth.

Mechanisms of revascularization

- One hypothesis explaining the mechanism of revascularization is that a few vital pulp cells might remain at the apical end of the root canal. These cells might proliferate into the newly formed matrix and differentiate into odontoblasts under the organizing influence of cells of the Hertwig epithelial root sheath, causing apexogenesis and—on lateral aspects of dentinal walls of the root canal—reinforcing and strengthening the root.
- A second possible mechanism attributes root development to multipotent pulpal stem cells from the apical papilla or periodontal ligament. Similarly, instrumentation beyond the confines of the root canal to induce bleeding might transplant mesenchymal stem cells, which have extensive proliferating capacity, from the bone into the canal lumen.
- A third possible mechanism could be that the blood clot itself, being a rich source of growth factors, plays an important role in regeneration.

LESSON 38

Apexification

OBJECTIVE

To induce the formation of a mineralized or osteoid apex in a nonvital immature root.

INTRODUCTION

If a pulp loses its blood supply before the normal root terminus has formed, it is virtually impossible to successfully meet the demands of a quality root canal treatment (ie, sealing the apical foramen). To comply with the endodontic criteria for success, you must be able to induce a partial or complete cementum-dentin-osteoid mineralization of the canal walls until an apical closure (complete or partial) is assured. This requires eliminating inflammation at the apical-periodontal communication by removing all existing bacteria from within the root canal (ie, cleaning, shaping, and disinfecting to the immature terminus) and placing an inductive material or bone inducer at the contact point of the incompletely formed root tip and the approximating periradicular bone.

MATERIALS

- Anesthetic
- 6% sodium hypochlorite
- Peridex (Zila Pharmaceuticals)

- Ethylenediaminetetraacetic acid (EDTA) pastes or gels (RC Prep [Premier Dental], Glyde File Prep [Dentsply])
- Calcium hydroxide (Roth Products)
- Mineral trioxide aggregate (MTA) (ProRoot-MTA [Dentsply]) (Fig 38-1)
- Composite resin
- Electronic apex locator

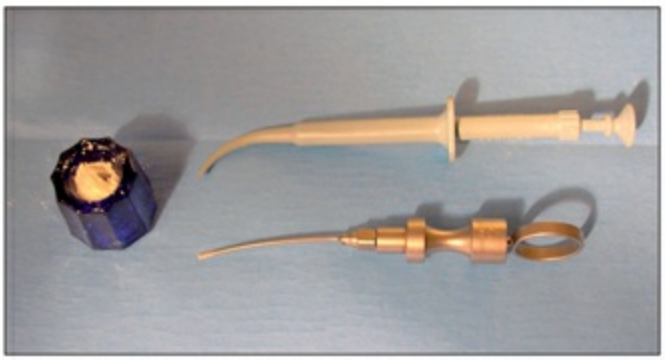


Fig 38-1 MTA and placement syringes for apexification.

TECHNIQUE

Step 1: Evaluation and preparation

1. Address all medical concerns.
2. Assure the loss of vitality via electric and thermal pulp tests.
3. Take radiographs of the tooth to ascertain apical maturity.
4. Attain a profound working level of anesthesia.
5. Apply well-adapted (nonleaking) rubber dam.

Step 2: Accessing the canal terminus

1. Access the pulp chamber and remove all soft spongy caries, restorative material, and peripherally involved dentin.
2. Since the cementodentin junction is wide open, negotiate an endodontic file to a recognizable point (the radiographic root terminus [RT]).
3. The canal of an immature tooth is generally large and wide enough to accommodate a No. 30 through No. 40 (.02) K-file, a No. 30 tipped (0.04, 0.06) ProFile (Dentsply), or even a No. 40 tipped (0.08, 0.10) GT file to the root terminus length (RTL).
4. The RTL may be determined on a radiograph (measured visually from a quality parallel film) or on an enlarged digital image, and/or read via an electronic measuring device such as the Root ZX II (Morita USA) or Elements Diagnostic Unit (SybronEndo).

Step 3: Instrumentation

1. Since the initial techniques to measure RTL may be off by 1 to 2 mm, it is best to confirm the RTL with a radiograph or digital image before the cleaning and shaping process ensues.
2. Set working length (WL) 1 mm shy of the confirmed RTL.
3. Serially instrument the canal in accordance with the operator's preferred filing system.
4. During the instrumentation process, alternately and intermittently irrigate the canal with 6% sodium hypochlorite and EDTA (to remove smear). Set the injection needle (for sodium hypochlorite and EDTA) at least 3 to 4 mm shy of RTL, and make every effort to prevent binding the needle and/or forcing either solution beyond WL.

Step 4: Obturating materials

Option 1: Calcium hydroxide

1. Using a paste mix of calcium hydroxide powder with sterile saline or anesthetic solution or a commercially available calcium hydroxide product such as Calasept (JS Dental Manufacturing), Pulpdent (Pulpdent), or Hypo-Cal (Ellman International), carry or inject it into the canal, and condense it to WL. Schilder pluggers (Dentsply), Nos. 6 through 12, are well suited for this compaction process.
2. Take a radiograph to confirm the quality and density of the obturation. The calcium hydroxide mix offers an opacity equal to that of dentin, whereas the other ready mixed materials may offer a wide range of opacity.
3. If voids are apparent, remove the material, and repeat the placement and compaction process.
4. To appraise apical development, evaluate the patient clinically and radiographically every 3 months over a period of 2 to 4 years.

Option 2: MTA

Studies by Torabinejad and Holland revealed that MTA induces cementogenesis and bone deposition similar to, but more consistently than, that induced by calcium hydroxide.

1. Carry or inject a semidry paste mix of MTA powder and anesthetic solution (ProRoot-MTA) into the depth of the canal.
2. Use Schilder pluggers (Nos. 6 through 12) and/or large coarse paper points to compact the material. At times, because of moisture buildup, it is useful to periodically place small amounts of dry MTA powder into the canal as you compact.
3. Since the MTA would be difficult to remove at a later appointment (because of its hard set), take a radiograph of the compaction progress to assure that the last 5 mm of the root are (being) densely packed.
4. Since the MTA will remain and harden in the canal once it is placed, create a post space while it is

convenient:

- The downside of MTA is that surgery and a concomitant apical root end fill is the only option if the induction process is unsuccessful.

5. Take a final radiograph to confirm the quality and density of the obturation. The MTA should appear solid and lack voids (Fig 38-2).

The sign of a successful apexification has always been the development of a hard tissue barrier (dentin-bridge) across the open apex and the absence of inflammation beneath it. Pitt Ford et al reported superior success with MTA when compared to calcium hydroxide after 30 and 60 days. This speaks well to MTA's ability to induce apical osteogenesis at the apical terminus of the immature root end.

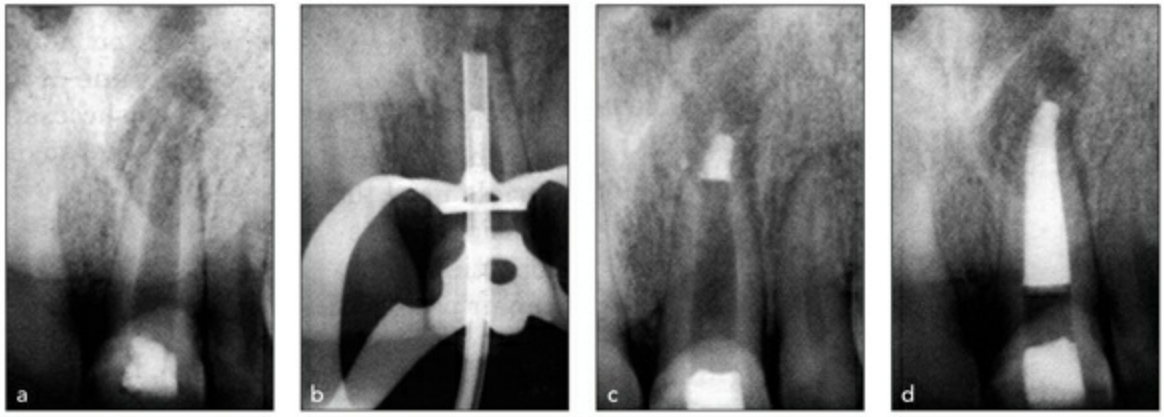


Fig 38-2 *(a)* An "immediate" apexification procedure on an infected immature central incisor. *(b)* MTA is carried to the apex after cleaning and disinfection of the root canal space. *(c)* After radiographic verification that the MTA is well placed, dense, and intact, the tooth is temporized with a moist cotton pellet behind the MTA. Backfill of the canal can proceed at the next visit. *(d)* Once the set of the MTA is verified at the next appointment, careful backfilling with injectable gutta-percha completes the immediate apexi-fication procedure. (Images courtesy of Dr Ralan Wong, San Francisco, CA.)

Step 5: Provisional restoration

Option 1: Calcium hydroxide fills

1. Place a small nonmedicated cotton pledget over the calcium hydroxide at the orifice.
2. Compact a thick base of IRM (Dentsply) or light-cured glass ionomer over the cotton.
3. Based on the esthetic needs, double seal the balance of the chamber with a bonded resin composite or amalgam.
4. To appraise apical development, evaluate the patient clinically and radiographically every 3 months over a period of 2 to 4 years.

Option 2: MTA fills

Approach 1

1. The balance of the canal may be temporarily closed, similar to that suggested for calcium hydroxide cases. In this situation, final canal obturation (gutta-percha) to the level of the MTA would take place at a future appointment.
2. To appraise apical repair, evaluate the patient clinically and radiographically every 3 months over a period of 2 to 4 years.

Approach 2

1. The balance of the canal space may be obturated immediately with thermoplasticized gutta-percha. With minimal to no resistance from unset MTA, the Obtura II (Obtura Spartan) injection technique and minimal vertical condensation are recommended for this approach.
2. To appraise apical health, evaluate the patient clinically and radiographically every 3 months over a period of 2 to 4 years.

Step 6: Postoperative care

Option 1: Calcium hydroxide at 3 months

Favorable

- If there are no symptoms or periapical pathosis and the root end appears to be forming, there is no need to reassess or to change the calcium hydroxide canal filling material. Radio-graphic examinations at 3-month intervals should be continued to monitor root end closure.
- If there are no symptoms or periapical pathosis but the root end shows no signs of forming at the 3-month evaluation, the existing calcium hydroxide should be removed and the calcium hydroxide canal filling procedure repeated (steps 1 through 4).

Unfavorable

- If the tooth has become symptomatic or a periapical pathosis is apparent, remove the calcium hydroxide and repeat the cleaning, shaping, and calcium hydroxide filling process.
- Radiographic examinations at 3-month intervals should be continued until the root end has completed its development.

Option 2: MTA at 3 months

Favorable

If there are no symptoms or periapical pathosis, continue the 3-month radiographic evaluation appointments until the root end has completed its repair.

Unfavorable

If symptoms appear or periapical pathosis is evident and the root end is not healing, you may inform the patient that endodontic surgery may be the only viable option.

Step 7: Final canal obturation of favorable responses

Option 1: Calcium hydroxide procedure

1. Once the apex has completed its formation, instrument the canal to the newly established (tooth or bone deposit) WL, which is best set 1 mm shy of radiographic length. Reopen the dentinal tubules, and remove the set calcium hydroxide from the walls of the canal(s). EDTA must accompany the filing procedure.
2. A gutta-percha obturation completes the therapy.

Option 2: MTA procedure

If not filled at the time the MTA was placed, enlarge the canal to the MTA coronal level and fill with compacted gutta-percha.

Step 8: Definitive restoration and/or the completed healing process

Once the apex has completed its formation, a definitive restoration (preferably a crown) may be placed at any convenient appointment thereafter.

LESSON 39

Pulpal Treatment in Primary Teeth

OBJECTIVE

To maintain the health of the primary teeth until the permanent teeth erupt in their place.

INTRODUCTION

There are two distinct pulp treatments that are traditionally used to save primary teeth:

- *Pulpotomy:* In primary teeth, this process involves amputation of the affected coronal pulp tissue and preservation of the vitality and function of the remaining radicular pulp.
- *Pulpectomy:* This process involves the total extirpation of the pulp tissue when the infection has spread beyond the crown.

MATERIALS

Because of its ease of use and clinical success, the most popular pharmacotherapeutic agent has been formocresol. Its systemic distribution and potential for toxicity, aller-genicity, carcinogenecity, and mutagenicy have caused some criticism. However, formocresol continues to be used in practicing pediatric dental offices, and its use continues to be taught in the majority of pediatric dentistry departments in dental schools.

Glutaraldehyde, calcium hydroxide, collagen, and ferric sulfate have also been studied and advocated by researchers. None of these agents has proven superior to formocresol, nor have the agents gained wide support.

Nonpharmacologic and hemostatic techniques, including electrosurgery and laser therapy, are being advocated, and they are being taught in some dental schools.

PULPOTOMY

Contraindications

Pulpotomy is contraindicated under the following conditions:

- Nonrestorable tooth
- History of spontaneous toothache
- Evidence of periapical or furcation pathosis
- Presence of a sinus tract
- Inability to control hemorrhage after coronal pulpal amputation
- Pulp with a serous or purulent drainage and/or without hemorrhage
- Internal or external resorption

Accessing the pulp chamber

1. Attain a working level of anesthesia.
2. Isolate the tooth with rubber dam.
3. Remove all caries and all pulp chamber tissue filaments with a slowly rotated sterile round bur (Nos. 4, 6, and 8).
4. Wash and dry the chamber (cotton pellets).
5. Hemorrhage at the canal orifices is normal and indicative of healthy radicular tissue. You can easily control this bleeding by compressing slightly moistened sterile cotton pellets against the exposed pulp canal stumps.

Technique 1: Use of formocresol

1. Once hemorrhage is controlled, place a cotton pellet saturated with diluted formocresol in contact with the pulp stumps.
2. Leave the formocresol solution in contact with the pulp stumps for 5 minutes, and then remove. The tissue should appear brown and be free of hemorrhage.
3. Place a thin mixture of zinc oxide–eugenol over the pulp stumps.
4. Restore the tooth with a stainless steel crown.

Note: If bleeding is uncontrollable, or there is no bleeding but there is an odor, the pulpotomy procedure should be aborted, and the clinician should resort to a total pulpectomy, root canal therapy, or extraction.

Technique 2: Laser or electrosurgery

1. Apply the electrosurgery arc or laser beam to the exposed tissue in accordance with manufacturer recommendations.
2. Place a thick mixture of zinc oxide–eugenol over the cauterized pulp stumps.
3. Restore the tooth with a stainless steel crown.

Postoperative care

- The patient should be clinically evaluated 3 months post-treatment.
- Palpation and/or visual recognition of a sinus tract indicates failure.
- Failure is rarely accompanied by pain.
- Since primary teeth do not respond well to electric and thermal testing, radiographs should be taken to detect signs of pathosis.
- If pathologic root resorption and/or a loss of bone in the furcation are apparent, the canals should be extirpated and treated as a pulpectomy, or the tooth should be extracted.

PULPECTOMY AND ROOT CANAL THERAPY

While there has been literature concerned with damage to the developing teeth following this procedure, the research does not substantiate this fear. Reports indicate that success rates on teeth with vital or nonvital pulps range from 75% to a high of 96%. For the patient, it is less expensive to perform root canal therapy on primary teeth than to provide space maintenance.

Contraindications

- Excessive pathologic root resorption involving more than a third of the root
- Excessive pathologic bone loss with loss of the normal periodontal attachment
- Mechanical or carious perforation of the pulp chamber floor

Technique for multivisit treatment

Phase 1

1. Anesthetize the tooth, and isolate with rubber dam.
2. Access the chamber and remove all caries with a sterile, slowly rotated round (No. 4, 6, or 8) bur.
3. As with permanent teeth, develop a straight-line access to each canal with a sterile fissure bur. Because of the shallow depth of the pulp chambers in primary teeth, be careful to avoid perforating

the pulpal floor during the access preparation.

4. Once the canal orifices have been located, negotiate the canals to apical length (AL) with an appropriately sized endodontic file. Length may be preestimated from a preoperative radiograph and confirmed with a radiograph or digital image of the negotiated file in place. Since most primary teeth have some degree of resorption, apex locators are unreliable.
5. In much the same manner as with permanent teeth, use a sequence of endodontic hand files and/or rotary nickel-titanium files to enlarge, shape, and clean the canals.
6. Accompany the instrumentation with intermittent irrigations of 2.5% to 6% sodium hypochlorite.
7. Because the dentin walls in the roots are thin, the use of Gates Glidden drills, Peeso drills, and sonic and ultrasonic endodontic instruments is contraindicated.
8. Since a calcium hydroxide paste will fill the canals during the interappointment phase, an apical taper, though desirable, is unnecessary. The main objective of the chemical and mechanical preparation is thorough debridement.
9. Dry the canals with paper points.
10. Compact a slurry of calcium hydroxide paste into the canals with a rotating lentulo spiral, cotton pellets, and/or large paper points.
11. Close the access opening with a provisional restoration of zinc oxide–eugenol or IRM (Dentsply).
12. Schedule the patient for a follow-up visit 2 to 3 weeks posttreatment for the second phase.

Phase 2

1. The tooth may often be reentered without anesthetizing the patient. Access the chamber and copiously irrigate with sodium hypochlorite.
2. Relocate the canals, and reinstrument and reclean them with the last size of endodontic file utilized in phase 1.
3. Dry the canals with paper points.
4. Fill the canals with a thin, flowable, and packable mix of zinc oxide–eugenol via a rotating lentulo spiral.
5. Condense the filling material with a blunt-end plugger or a cotton pellet. Since the apices of primary teeth are generally resorbed to some degree, take care to avoid extruding the zinc oxide–eugenol paste into the periapical tissues.
6. Take a radiograph to check the adequacy of the root canal filling.
7. If the canals appear to be adequately filled, place a fast-setting temporary cement, such as IRM, in the pulp chamber. 9. Restore the tooth with a stainless steel crown.

Postoperative care

- The patient should be clinically evaluated posttreatment at 3-, 6-, and 12-month intervals. Radiographic examination should accompany the clinical evaluations until exfoliation of the tooth occurs.

- Palpation and/or visual recognition of a sinus tract indicate failure.
- Failure is rarely accompanied by pain.
- Bone loss and tooth loosening are the usual signs of failure. These conditions do not warrant retreatment.
- Depending on the length of time before natural exfoliation, a failing pulpectomized tooth is a candidate for extraction and space maintenance.

CONCLUSION

- The presentation of a treatment plan must clearly indicate the reasons for attempting any pulp treatment on a primary tooth.
- The patient's parent or guardian must understand the reasons for the treatment, recognize that the treatment may fail, and know what other options are available.
- Parental consent must be given, preferably in writing.

LESSON 40

Treating the Avulsed Tooth

OBJECTIVE

To replant an avulsed tooth into its natural alveolus and maximize healing outcomes.

INTRODUCTION

Even before the advent of extreme sports on television and in local competition, both young and old are involved in activities that often place the dentition at risk for injury. Though most organized sports require a player to wear a mouthpiece, it is rare that someone who is biking, skiing, jogging, or even driving a car would consider wearing one. As a result, the mouth is often subjected to violent forces that can exfoliate a tooth. If the tooth can be replaced within 60 minutes from the time of the avulsion, the success rate can be as high as 90%. This lesson describes the different treatment techniques used to meet the various challenges of replantation.

REPLACEMENT WITHIN 60 MINUTES

Phase 1: At the scene of the accident

The treatment at the scene of the accident will positively or negatively affect the outcome. As such, the doctor who sees this patient must learn those facts before offering the patient, parent, or guardian

a prognosis.

Positive outcome

A parent, guardian, or responsible friend was present at the time of the accident and found the tooth intact. The parent, guardian, or friend then:

1. Had the victim rinse with plain water and used pressure (eg, finger, toweling) against any obvious intraoral and extraoral bleeding sites.
2. Grasped the tooth by the crown and without touching the root surface gently rinsed the tooth free of debris with water.
3. Inserted the tooth into the socket, into the mouth between the cheek and the posterior teeth, or into a cup of water.
4. Took the victim and the tooth to the family dentist, where the doctor was able to treat and replant the tooth in the socket within an hour of the accident.

   Prognosis: There is a 90% chance of revascularization of the attachment.

Negative outcome

The victim was alone. A layperson found and vigorously cleaned the tooth, and in so doing, scraped the periodontal tissue tags off the root. The person then:

1. Attempted to replant the tooth and damaged the socket walls, inserted the tooth between the labial plate and the gingival tissue, or let it air-dry and/or wrapped it in difficult-to-remove facial or toilet tissue.
2. The parent or guardian was eventually contacted, but crucial time passed before the patient was taken to the dentist.

   Prognosis: This tooth has little to no chance of reattachment and survival.

Phase 2: Arrival at the dental office

Treating a minor accompanied by a friend

After determining the child's name and phone number, every effort must be made to reach the parent and/or guardian. Until then, only the following emergency first aid procedures can and should be administered:

1. Check vitals (ie, pulse rate, blood pressure, breathing). If any are considered to be abnormal, you must call 911.
2. If the patient is bleeding, determine the source and initiate control methods (eg, pressure, ice).
3. Clear the patient's face, mouth, and airway of any tooth particles, debris, or coagulated blood.
4. Make the patient comfortable, and continue to observe her or him until the parent and/or guardian are contacted and arrive at the office.

5. Examine the tooth under magnification to determine if it warrants replantation (ie, no root fracture, has sufficient root length, is restorable).
6. If the tooth is deemed salvageable, immediately submerge it in Hank's Balanced Salt Solution (HBSS) (Krackeler Scientific) or Save-A-Tooth (Phoenix-Lazerus) until a legally responsible person arrives (Fig 40-1).
7. Record all of the above procedures and responses in the patient's chart.

Fig 40-1 Save-A-Tooth or HBBS is a key factor in maintaining a viable periodontal ligament subsequent to an avulsion injury.

Treating a minor accompanied by a parent and/or guardian

Before the actual replantation procedure is initiated, the following details (for litigation purposes) must be recorded:

1. Initiate the emergency steps listed previously, and record the results.
2. Assess and record any obvious or related indications of bodily injury and the patient's physical condition at the time of arrival at the office.
3. Recommend that the parent and/or guardian take the patient to the family physician following this emergency visit. If the physician visit has already occurred, record the physician's name, address, phone number, and the date and time the patient was examined.
4. Record a detailed explanation of the accident including the treatment provided at the scene, the names of any persons who treated the patient at the scene, and the names, addresses, and phone numbers of the patient's parent and/or guardian.
5. Take, review, and evaluate a past and present medical history.

Phase 3: Patient evaluation and treatment

1. Flush the injured site clean with saline.
2. Examine the clinical appearance and condition of the soft (facial and mucosal) and hard (alveoli and bone) tissue approximating the injured site, and describe and record any and all damage.
3. Take radiographs of the injured site. Never make an endodontic evaluation and diagnosis from a single view. Always evaluate at least two radiographs taken from two different angles and

directions.

4. If a satisfactory view of the avulsion site can be achieved and the mouth can be opened wide enough, the tooth is a good candidate for replantation.
5. If the injury prevents the patient from opening his or her mouth wide enough to take a periapical image, critical damage beyond the loss of a tooth should be suspected. In such cases, it is advisable to take a panoramic radiograph and/or refer the patient for a computed tomography (CT) scan.
6. If one is unable to get a decent image of the injury site, the tooth should be stored in the HBSS or Save-A-Tooth, and the patient should be referred to an oral surgeon (or the emergency room) to investigate serious bone or joint damage.

Phase 4: Presenting the treatment plan

1. Explain the final emergency treatment plan (or referral) to the parent and/or guardian, including immediate treatment procedures and/or procedures that will be necessary at a later date, the options available, and whether a restoration will be needed in the future.
2. Offer a realistic prognosis based on the condition of the tooth, the treatment at the scene, and the avulsion time frame.
3. Record all patient, parent and/or guardian, and doctor comments (particularly about treatment time frames and fees), and obtain an informed consent in writing, signed by all parties.

Phase 5: Tooth management

For a tooth replanted at the accident site

1. Confirm and record the clinical position of the tooth with the patient and parent and/or guardian. Since this may be your first contact with this patient, preexisting conditions such as protrusion, spacing, length, and other esthetic aberrations may be unknown.
2. Once the position is approved or corrected (the records must indicate approval), splint the tooth if mobile, and clear the occlusion of any premature contact.

For an empty alveolus

1. Flush the empty alveolus free of blood with a gentle saline rinse. If a clot has already formed, the central zone of the socket may require a gentle curettage with Lucas curettes (Nos. 82 and 83).
2. To avoid detaching the periodontal tags, the curette should not contact the alveolar walls.
3. The need to anesthetize the injured area should be determined by the patient's demeanor during the socket preparation.
4. If the injury or the pressure used to control bleeding has caused the labial alveolar wall to collapse, widen the opening by inserting a mirror handle to the depth of the socket and gently pressing the shaft of the instrument against the inner wall of the labial plate.

5. If the labial plate is fractured and facially displaced (protruding), gently but firmly reposition it with finger pressure. To keep the wall from collapsing during this process, use the mirror handle (as described) (Fig 40-2).

Phase 6: Replantation technique

If a tooth has been out of the socket less than 60 minutes, the following technique should be used (Fig 40-2):

1. Remove the tooth from the HBSS, and soak it in a doxy-cycline solution (approximately 1 mg per 20 mL saline) for 5 minutes. Studies have reported that this antibiotic bath doubles the rate of a successful revascularization.
2. Hold the tooth by the crown, carry it to the alveolus in a doxycycline-saturated gauze square, and slowly reinsert it into the socket.
3. A slow insertion prevents further injury to the adhering periodontal fibers, allows entrapped air and blood to escape along the walls, and facilitates positioning of the tooth to the full extent of the alveolus.
4. Once the tooth is fully seated, check the occlusion, and if found to be satisfactory, have the assistant hold the tooth firmly in place while the labial surfaces of the replanted tooth and the adjacent teeth are dried and etched. A small bar (rope) of resin or resin and polyethylene fabric (Ribbond [Ribbond]) is then bonded and cured to the enamel surfaces to form a provisional three-tooth labial splint.
5. In children, an adjacent immature tooth may not as yet have erupted, in which case the avulsed tooth must be sutured in place. The suture(s) should cross over the interdental papillae and back twice, biting at least 2 mm of the labial and lingual attached gingiva each time. The grooves between the mammelons can serve as notches and help hold the suture(s) and the tooth in place.
6. Attention is now devoted to repositioning, repairing, and/or suturing (if deemed necessary) the gingival tissues.
7. Take radiographs of the the tooth (two angles) to confirm its position in the depth of the alveolus.
8. If the images are acceptable, call upon the patient and parent and/or guardian to verify and confirm that the clinical position of the tooth is the same as it was before the accident.
9. Record this confirmation and agreement in the patient's chart, and take a photo. (This record may be needed to negate any subsequent questions regarding possible changes in the tooth's position.)
10. Once the position is confirmed, ask the patient to slowly bite down on a three-layer thickness of indelible marking paper. Tell the patient to stop at the first sign of tooth movement.
11. Make appropriate occlusal adjustments to clear the premature contact points.
12. Since the tooth was more than likely contaminated when found, prescribe an antibiotic. Tetracycline is the antibiotic of choice (1000 mg immediately, then 500 mg every 6 to 8 hours for 7 days).
13. A nonsteroidal anti-inflammatory drug is the analgesic of choice (eg, ibuprofen: 600 mg immediately; 400 to 600 mg every 6 hours for 3 to 4 days).

14. Refer the patient to his or her physician to evaluate the need for a tetanus booster.
15. Give the patient and parent and/or guardian both verbal and printed postoperative instructions.
16. Contact the patient in 24 hours for evaluation, and schedule a follow-up appointment (7 to 10 days).

Note: If the patient begins to complain of having a headache, vision impairment, or deep neck pain during treatment, insist that the patient and parent and/or guardian seek medical help as soon as they leave the office. Record the symptoms and the recommendations in the chart, and do not offer an analgesic. In addition, tell the patient and parent and/or guardian to seek immediate medical help (eg, physician or emergency room) if any unusual symptoms arise in the forthcoming week(s). Record this conversation in the chart.

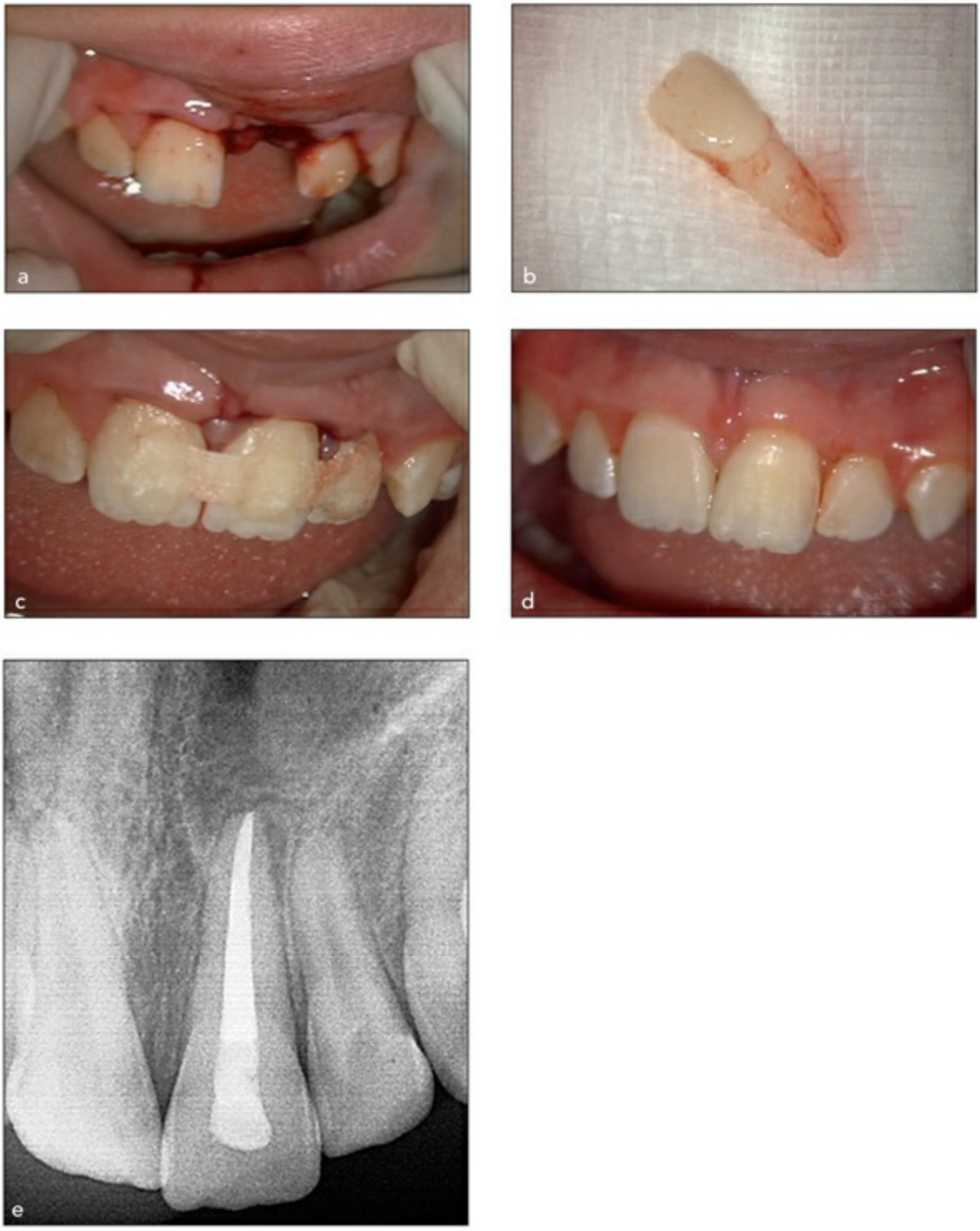


Fig 40-2 *(a)* Avulsion site within 60 minutes of the injury. *(b)* The tooth immediately prior to replantation after rehydration in HBSS. *(c)* The tooth is repositioned and splinted with a resin-impregnated polyethelene fabric bonded to the adjacent teeth. *(d)* After 1 year, the tooth shows normal color and the attachment architecture is healthy. *(e)* Follow-up radiograph shows good periodontal repair and an absence of active resorption or apical pathosis. (Images courtesy of Dr Wyatt Simons, San Clemente, CA.)

Phase 7: 7- to 10-day return visit

1. Evaluate the patient's postoperative experiences.

2. Examine the mucosal tissue for healing, and remove sutures if they were placed.
3. Remove the composite splint (suture). However, if the labial plate was fractured and displaced, retain the splint for a longer period (2 to 4 weeks). Unfortunately, this is not ideal in the case of an immature tooth. As such, the suture(s) may need to be replaced frequently before the tooth tightens.
4. Take radiographs of the injured site (two angles), and compare the images (tooth position) to the radiographs taken after the tooth was replanted and splinted.
5. If the tooth has shifted in any way, make appropriate intraocclusal adjustments.
6. If the tooth appears to be stable to finger pressure, it is best to not resplint and to allow the biting (chewing) forces to stimulate a new periodontal blood supply.
7. Evaluation appointments should be preset every 6 to 8 weeks throughout the first year.

Phase 8: First 6- to 8-week return visit

Positive outcome

- The patient's experiences are excellent.
- The tooth is radiographed (two images), and the images compare well with the prior radiographs (ie, no negative signs or symptoms of pathology or resorption).
- The pulp is tested and found to be vital, a sign of pulpal revascularization.
- Though no further endodontic treatment may be necessary, both mature and immature teeth should be monitored every 6 to 8 weeks throughout the first year and every 6 months for the following 5 years.
- If the situation remains positive, the apex of the immature tooth will continue to form naturally.

Negative outcome

The tooth tests nonvital and shows signs of periradicular pathosis and/or root resorption (Fig 40-3). Endodontic therapy is indicated.

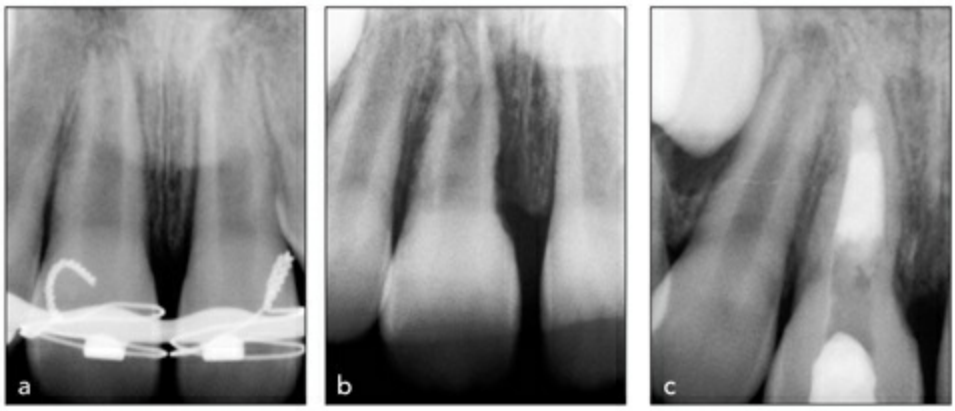


Fig 40-3 *(a)* Immature tooth avulsed and splinted with a rigid arch wire. *(b)* Follow-up radiograph demonstrating external resorption of the root and apical pathosis. *(c)* Apexification procedure with MTA has stabilized both the resorption and apical pathosis. (Images courtesy of Dr Kenneth Tittle, Pleasant Hill, CA.)

Phase 9: Endodontic treatment

For the nonvital mature tooth

1. Access the pulp chamber, extirpate the pulp, instrument the canal to working length (WL), and fill the prepared space with calcium hydroxide mix.
2. Schedule a follow-up evaluation appointment (4 to 6 weeks), and if at that time the radiographic examination shows no evidence of resorption or pathosis, reinstrument the canal, obturate with gutta-percha, and take radiographs.
3. Schedule preset evaluation appointments every 6 to 8 weeks throughout the first year.

For the immature tooth

The patient and/or guardian should be told during the presentation that the apexogenesis and apexification processes are host dependant, and only time and possibly treatment repetition will tell if it the processes will be successful.

Vital pulp

The pulp chamber and canal orifice are accessed and bleeding is met:

1. Remove the chamber tissue, and if bleeding is controllable, cap the exposed pulp tissue at the canal orifice with mineral trioxide aggregate (MTA) or calcium hydroxide (see lesson 37).
2. Examine the patient in 30 days. If the radiographic examination shows no evidence of resorption or pathosis and there are no other symptoms, schedule the patient for a follow-up appointment (6 weeks), at which time you should evaluate the tooth to note the progress of root development.

Nonvital pulp

No bleeding is encountered at the orifice, or no apical development is noted 6 weeks after the pulpotomy:

1. Extirpate the pulp, instrument the canal to WL, and fill the canal with calcium hydroxide or place an apical barrier of MTA to induce apical osteogenesis (see lesson 38) (see Fig 40-3).
2. If MTA was used, you can complete the canal obturation at a subsequent appointment upon verification that the MTA was well placed and has set.
3. If calcium hydroxide was used, schedule a follow-up evaluation appointment (4 to 6 weeks), and if at that time radiographic examination shows no evidence of apical development, repeat the apexification technique until apical formation takes place or a decision is made to place an apical barrier with MTA.

Phase 10: Over the first year

Nonvital mature tooth

Unless during the course of time a radiograph shows signs of resorption or pathosis, the long-term outcome is excellent.

Nonvital immature tooth

Once the apex has developed an apical closure or was closed with MTA to create an apical stop, any calcium hydroxide should be removed and the canal obturated with compacted gutta-percha.

REPLACEMENT AFTER 60 MINUTES

Nonvital tooth

The patient and parent or guardian present to the office 60 minutes or more after avulsion.

1. Immediately place the tooth in HBSS or Save-A-Tooth.
2. Make all records current, as described in phases 3 and 4 of replacement within 60 minutes.
3. To prevent a foreign body reaction to necrotic cells, scrape the root surface clean of all periodontal tissue remnants. The likelihood of these tissue tags surviving after 60 minutes is negligible. As an alternative to manually scraping the root clean, you can soak the tooth in a citric acid solution for 5 to 10 minutes.
4. Immerse the tooth in a fluoride solution for 5 to 10 minutes.
5. Carry the tooth to the replant site in a fluoride-saturated gauze square, and place it into the socket.
6. Confirm (and record) the tooth position with the patient and parent and/or guardian (as previously described), and take a radiograph of the tooth before it is splinted in place with a suture or a bonded splint of cured resin.
7. Give the patient verbal and written home-care instructions, and schedule the patient for a follow-up appointment (7 to 10 days) for reevaluation. Emphasize the importance of good oral hygiene.

Return visit in 7 to 10 days

1. With the splint in place, access the pulp chamber and thoroughly instrument the canal to WL.
2. Calcium hydroxide paste is injected or spun (with a rotating lentulo spiral instrument) into the canal. Condense the paste material to the apical terminus with appropriately sized pluggers. Calcium hydroxide is currently the most effective intraradicular medication to resist the initiation of inflammatory root resorption.
3. Take a radiograph of the tooth to determine the density of the fill. Since most calcium hydroxide mixes are opaque, its presence and density are easily identified.
4. Schedule the patient for follow-up radiographic evaluation (6 to 8 weeks).

Return visit in 6 to 8 weeks

For the mature tooth

1. Take a radiograph of the tooth for evaluation.
2. If no resorption or pathology is apparent, reinstrument the canal to remove the calcium hydroxide, and condense the gutta-percha to WL.
3. If symptoms appear (at any time during the evaluation period), reinstrument the canal to remove the residual calcium hydroxide, and refill the canal with new calcium hydroxide. A new 6- to 9-month evaluation period begins.
4. Once the tooth is asymptomatic and the periapex appears healthy, obturate the canal.
5. Schedule the patient for a follow-up radiographic evaluation every 6 to 8 weeks throughout the first postoperative year.

A successful outcome is not predictable, but there are case reports where successful replant cases occurred when the period prior to replacement was as long as 15 days and other cases where the replanted teeth have been retained for periods of up to 42 years.

For the immature tooth

1. Attempt the apexification process. An MTA closure offers the most effective means to close the apex.
2. Once closed, obturate the canal with gutta-percha.
3. Schedule the patient for follow-up radiographic evaluation every 6 to 8 weeks throughout the first postoperative year.

LESSON 41

Bleaching Techniques for Nonvital and Vital Teeth

OBJECTIVE

To understand etiologic factors associated with staining of dentin and enamel; to diagnose stain types; and to perform appropriate bleaching procedures.

INTRODUCTION

Diagnosis of the etiology of dental stain is necessary to apply the proper technique. Depending on that diagnosis, the clinician can elect to use internal bleaching to remove stain from dentin, external bleaching for enamel stain, or microabrasion for superficial enamel defects. In many instances, combinations of techniques offer the best and most cost effective means of treatment. This lesson addresses the techniques of internal and external bleaching.

INTERNAL DENTIN STAINS

A stained anterior tooth in the esthetic zone is frequently a chief complaint of patients. Routine examination and testing, consisting of radiographs and vitality tests, should accurately diagnose the etiologic factors involved. With internal stains, there is usually a history of trauma or caries (restoration) close to the pulp. One of the following situations will most likely be encountered:

- The stained tooth responds vital to electric pulp testing (elevated reading), and a radiograph discloses accelerated mineralization (calcific metamorphosis) of the pulp canal space.

- The stained tooth responds nonvital to all vitality tests, and a radiograph may disclose periradicular pathology. Endodontic therapy is indicated.
- The stained tooth has been endodontically treated. Success or nonhealing of the endodontic therapy must be evaluated prior to internal bleaching.

Clinical situations

Vital stained teeth

Inflammation of the pulp may result from trauma, caries, or restorations. The typical stain pattern is brownish gray.

Stain resulting from trauma

- The location of the stain is the dentin. Therefore, vital bleaching techniques will not produce acceptable results.
- The operator must decide between endodontic therapy in conjunction with internal bleaching or masking with a porcelain veneer. If the stain is severe, however, a veneer may not be opaque enough to hide the stain, and endodontic therapy will be necessary anyway.

Stain resulting from mineralization

- The stain pattern may result from the deposition or irritation of dentin in the chamber as the mineralization process continues.
- Depending on the density of the mineralization, vital bleaching techniques will not produce acceptable results.
- If endodontic therapy is elected for the mineralized tooth, the operator must use specialized endodontic equipment:
  - Magnification is essential. The minimum magnification is in the range of 4×loupes. The best magnification source is the operating microscope.
  - Small long-shank round burs (M bur [Dentsply] or LN bur [Dentsply]) are designed to allow extension of the access preparation into the coronal third of the root.
  - Specialized ultrasonic tips allow even deeper penetration. Ultrasonic tips, when used with water spray, flush debris and dentin smear from the canal space. Ultrasonic energy can dislodge mineralizations.

Nonvital stained teeth

With necrosis of the pulp, hemosideran (blood) pigments stain the dentin (Fig 41-1):

- This stain is effectively oxidized by peroxide (15% to 40%) as long as the smear layer over tubules is removed to allow penetration of the bleach. Peroxide does not dissolve soft tissue, but it does oxidize iron-based stains.
- During the course of endodontic therapy, particular care must be given to proper use of sodium hypochlorite irrigation. At least 30 minutes of exposure is necessary to dissolve the soft tissue

fragments that contribute to staining.

- Guidelines for proper access preparation must be followed to remove necrotic pulp, particularly in the pulp horn area. After endodontic therapy, internal bleaching can begin immediately.

Note: Removal of the smear layer from the dentin in the coronal chamber is accomplished by acidetching for 30 seconds prior to placing the bleach mixture. Remove the acid by flushing with water or by irrigating with sodium hypochlorite.

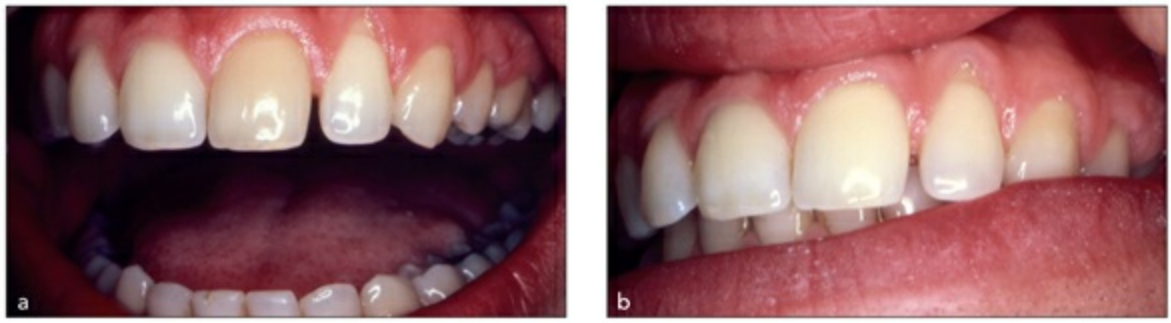


Fig 41-1 *(a)* After trauma, a central incisor exhibits the yellow-orange stain of blood pigments permeating the dentin. *(b)* Intra-coronal bleaching after root canal therapy has the desired result.

Endodontically treated stained teeth

Endodontically treated teeth must be evaluated before bleaching may begin (Fig 41-2). Failing endodontic therapy (due to leakage) may result in painful exacerbation if internal bleaching is started before proper retreatment. If peroxide is chosen as a bleaching agent, by-products may percolate through the apical foramen into the periradicular tissues, resulting in severe inflammation. Therefore, if there is any question about the apical seal provided by the previous endodontic therapy, the case should be retreated prior to bleaching.

The removal of tooth-colored restorative material from the access preparation can be difficult. The goal is to remove the restorative material with minimal removal of dentin. Aids to removal include the use of magnification to see the compositedentin interface, cutting without water coolant, the use of ultrasonic instruments to dislodge the restorative material, acid-etching (composite does not etch), fiber-optic transillumination, and examination of the access preparation between bleach changes (composite does not bleach and will appear darker).

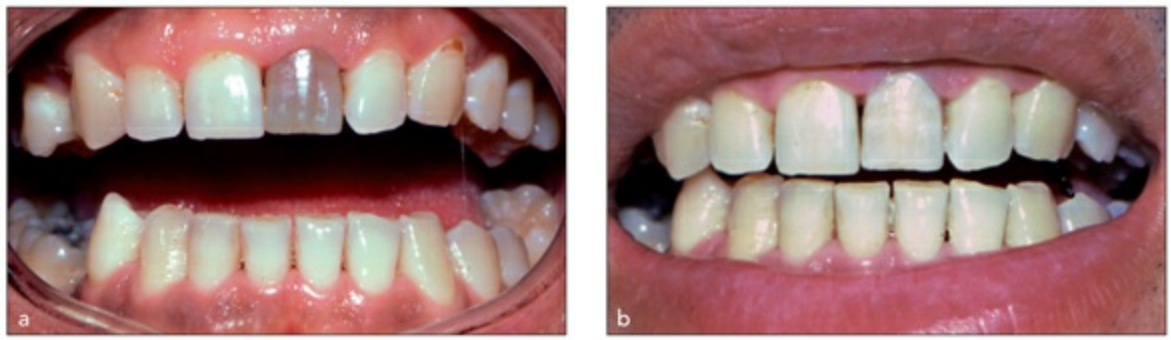


Fig 41-2 *(a)* Darkened appearance of a central incisor with a silver cone and coronal metal restoration. Coronal leakage and silver corrosion have contributed to the gray-brown shade. *(b)* Retreatment with gutta-percha and intracoronal bleaching has produced a excellent results.

NONVITAL BLEACHING

Indications

- Pulpally involved teeth; endodontic therapy necessary
- Failing endodontic therapy; endodontic retreatment necessary
- Failing or improper restoration of endodontically treated teeth
- Pulpal mineralization due to trauma
- Tetracycline stains (Fig 41-3)

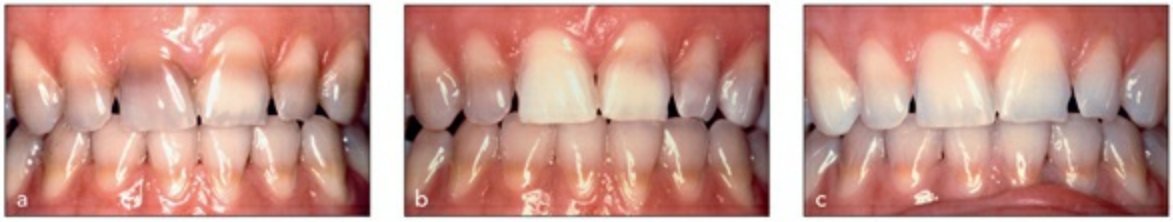


Fig 41-3 *(a)* Severe tetracycline stains. Endodontic treatment allowed direct bleaching of the stained dentin in the maxillary anterior dentition. *(b)* Appearance of the teeth after endodontic treatment. *(c)* Appearance of teeth after intracoronal bleaching.

Preparation

Cervical resorption can result from the irritation of bleach permeating through the cervical dentin tubules (Fig 41-4). Therefore, an orifice seal should be placed to reduce the chances of bleach penetration. The following steps will protect the cervical dentin and open the tubules in the chamber, so the bleach can penetrate into the stained tubules:

1. Remove 3 mm of obturation material apical to the canal orifice.
2. Place a sealing material, such as glass ionomer, to seal the tubules in this area.
3. Acid-etch the coronal chamber for 30 seconds. Rinse with water for 5 seconds and dry.

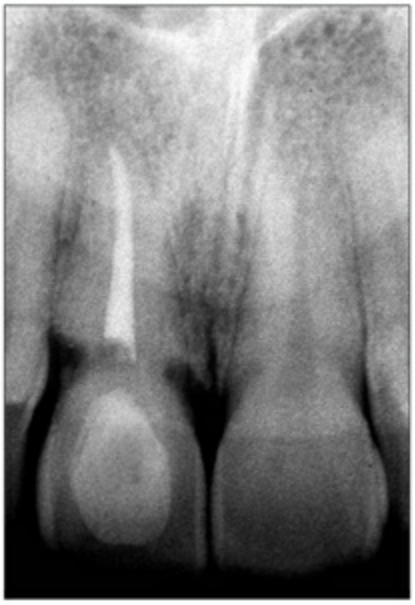


Fig 41-4 Radiograph depicting cervical resorption resulting in the loss of a bleached central incisor. Failure to use a cervical cement barrier allowed concentrated peroxide bleach to injure the attachment and trigger the resorption process.

Materials

- Rubber dam, eye protection
- Sodium perborate (Endoco [Moyco Technologies])
- Hydrogen peroxide 35% (Superoxol [Sultan Healthcare]) or water

Note: 35% hydrogen peroxide is a highly caustic and dangerous chemical bleach. Both doctor and assistants as well as patients must be protected by wearing safety glasses, and operators must watch with care to avoid spills to skin and clothing. Emergency responses to chemical burns are required.

Technique

1. Ask questions to establish the etiology of the stain and revise the root canal therapy if necessary. For example: Is the etiology of the stain due to a poor root canal therapy? Is it due to a failing restoration or to the metal stain from silver point, post, or amalgam corrosion? Could it be caused by inadequate debridement of access preparation?
2. Apply rubber dam, and expose the gutta-percha at the orifice. Correct any access deficiencies.
3. Remove 3 mm of gutta-percha below the canal orifice. The barrier must cover up to the level of the cortical bone to protect against cervical egress of the bleach, which can trigger resorption.
4. Place an orifice barrier, such as glass ionomer, Cavit (3M ESPE), Vitremere (3M) (recommended), or similar. Use a small-needle tube and a C-R syringe (Centrix) to place glass ionomer. Do not smear in chamber.
5. Etch the chamber for 30 seconds, then wash and dry.

6. Mix sodium perborate with peroxide or water (thick mix); the crystals of sodium perborate must be finely milled to create a sufficiently small particle size.
7. Carry the mixture with a clean amalgam carrier, and fill the chamber of the tooth. Blot excess liquid with a cotton ball. With an excavator, remove enough paste (2 to 3 mm) to provide room for the provisional restoration.
8. Place a thick mix of IRM (Dentsply) or zinc phosphate cement directly over the paste. (Do not place a cotton ball in the chamber.)
9. Evaluate the results in 5 to 7 days. Replace the bleach mixture or neutralize the bleach for a permanent restoration. Any residual sodium perborate can be irrigated from the chamber with water or neutralized with sodium hypochlorite irrigation. If a composite restoration was removed initially, look for residual composite. Composite can usually be removed with an explorer after exposure to the peroxide for a week.
10. To neutralize bleach, irrigate the chamber with sodium hypochlorite (2.5%) followed by water or alcohol (removes residual peroxide). Remove the Cavit if this material was used for the orifice barrier; glass ionomer does not have to be removed.
11. Restore with bonding agent and layered composite, using the double light activation method. Select a lighter shade of composite than the shade of the tooth.

Note: If a provisional restoration is placed after bleaching, avoid using IRM (eugenol). Instead, use Cavit until the access cavity is restored with composite (after internal bleaching has been completed).

Problem management

- *Restaining*: This problem is related to orthograde leakage around the access restoration or possibly through cracks (craze lines) in the enamel. Bonded composite with layering can prevent or delay this problem.
- *Underbleaching:* Try power bleach to remove enamel stain or suggest home bleaching. If the cervical area of the tooth does not bleach adequately, remove some of the plug material to expose more dentinal tubules in that area and rebleach.
- *Overbleaching:* Advise the patient to watch the progression of color change during the bleaching procedure. When the color change equals the desirable result, discontinue bleach (contact dentist). A home-bleaching procedure will usually match the shades of all teeth.
- *Dislodging the provisional filling:* The most common problem during the bleaching process is loss of the provisional filling.
- A thick mixture of IRM or zinc phosphate cement will usually hold for 7 days, but the patient should be seen at least weekly.
- *Protecting the pulp cavity:* If the pulp cavity is large (young tooth) or the access preparation is excessive (near perforation), mix the sodium perborate with water instead of 35% hydrogen peroxide. Sodium perborate alone with water will achieve adequate bleaching outcomes, but the process requires longer periods of time. Reluctance to use strong bleaching agents such as 30% hydrogen peroxide is well founded if there is an issue with the patient's compliance to return and

remove the bleaching agents.

Note: Remember that once a tooth is devitalized, the dentinal tubules remain the size they were at the age of devitalization forever. Therefore, barriers must be sound to prevent the tubules from allowing bleach into the attachment at the cervical of the tooth.

Restoration after bleaching

After successful bleaching of the dentin, the single-most important variable in the longevity of the outcome is the quality of the access restoration. Orthograde leakage (between the restoration and the dentin) is the major cause of restaining. Layering of composite is recommended to reduce setting shrinkage. The following steps will maximize the seal of the composite to the dentin and minimize the risk of restaining:

1. Remove any residual sodium perborate by irrigation with sodium hypochlorite, rinse with water, and air-dry and etch the dentin.
2. Place a dentin bonding agent.
3. Select a composite at least one shade lighter than the enamel shade. If future rebleaching is necessary, the lighter shade will facilitate removal.
4. Place the composite in layers (cure composite between layers) (Fig 41-5).

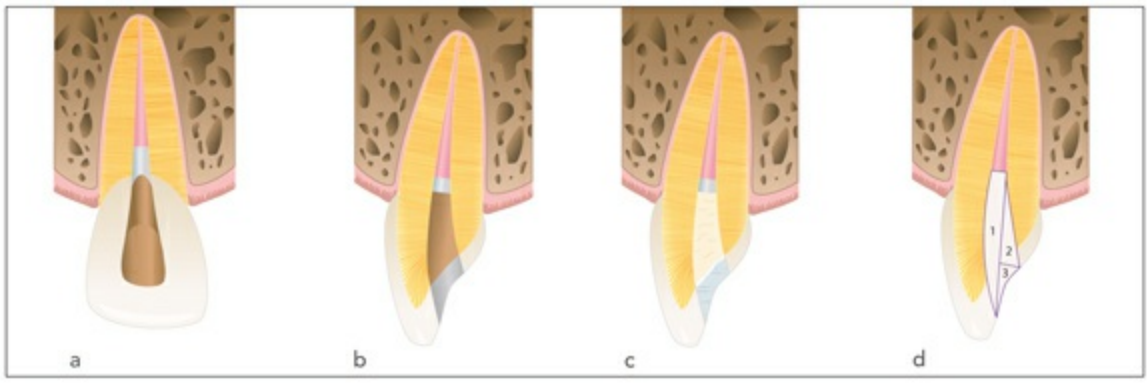


Fig 41-5 (a) Cervical tubules must be sealed to prevent peroxide from perfusing into the periodontal tissues. The barrier rises at the interproximal junction of dentin and cementum. (b) A cervical barrier of glass ionomer cement or similar material seals the dentin tubules. (c) The chamber is filled with the bleaching paste and blotted with cotton. To provide space for the provisional filling material (eg, IRM, zinc phosphate), 2 to 3 mm of paste must be removed. Composite filling material should not be used because peroxide interferes with the setting of composite. (d) To minimize leakage, a dentin bonding agent is placed followed by a layered composite.

Additional considerations

The following factors should be considered during diagnosis:

- The internal bleaching procedure bleaches dentin, not enamel. Enamel stains can be removed using power (chair side) or tray (home) bleaching techniques.

- Craze lines in enamel or large restorations reduce the longevity of the bleaching because of the potential for leakage through the enamel cracks. Craze lines in enamel are easily seen clinically by transillumination.
- Removing composite from the access preparation requires more clinical time, and the fee for this service should be adjusted accordingly.
- The internal bleach procedure is the most predictable of all bleaching techniques.

EXTERNAL ENAMEL STAINS

Removal of external stain and superficial enamel defects greatly enhances the esthetic result of major cases. However, any patient with permanent teeth may be a candidate for these conservative procedures. Physiologic stains result over time. Therefore, even in patients with no other dental needs, vital bleaching is a desirable treatment option. The dentist has the best training for stain diagnosis and the delivery of safe, effective treatment.

Physiologic stain

Etiology

Water-soluble dyes found in food and drinks accumulate in enamel with time. All natural teeth slowly yellow to some degree as these products concentrate in enamel. Since this stain is extrinsic, the bleaching prognosis is good. The rate and amount of stain buildup over time varies among individuals. Variables include diet, oral hygiene, and variations in enamel porosity and quality.

Diagnosis

The physiologic stains must be differentially diagnosed from other stains:

- *Pulpless discoloration.* Nonvital tooth with localized, brownish gray discoloration resulting from trauma or root canal therapy.
- *Flurosis stain.* Vital tooth with multiple brown discolorations and floride greater than 1.5 ppm.
- *Tetracycline stain.* Vital tooth with multiple grayish brown stains and history of drug treatment.
- *Swimmer calculus stain.* Vital tooth with multiple brown stains from spending 6 hours per week in a swimming pool.
- *Chlorhexidine stain.* Vital tooth with multiple brown-blue stains and a history of using a mouthwash with chlorhexidine as an active ingredient.

The diagnosis of physiologic stain can usually be confirmed if the teeth appear to have a yellow to light brown appearance and the patient feels that the teeth were a lighter shade when he or she was younger. The vital bleach procedure removes only stain and does not artificially lighten the original unstained shade of the teeth. Since this stain is within enamel, prophylaxis cannot remove it. The dentist must ensure that the etiology of the stain is extrinsic, that the thickness and quality of the enamel is normal, and that there are no factors, such as bonding, that will interfere with the bleaching

process.

VITAL BLEACHING

1. Take an impression, usually with alginate, and fabricate a stone cast.
2. Place spacer material, termed *reservoir*, on the labial and occasionally on the lingual of the teeth to be bleached.
3. Vacuum a rubber or plastic material over the cast and trim, often in a scalloped design, to cover the teeth but not the gingiva.
4. Instruct the patient to apply the bleach (10% to 20% carbamide peroxide), in the tray and wear from 1 to 8 hours per day according to different schedules of use. In some cases, overnight wear is recommended.
5. The duration of the primary bleaching ranges from 2 to 6 weeks. Intrinsic stains, such as tetracycline, require a much longer time for bleaching.

Power bleaching

The use of lasers for dental bleaching offers even faster results and minimal participation in the bleaching process (ie, not having to wear a bleaching tray). Concentrated hydrogen peroxide gels (20% to 35%) were developed for this technique. These gels allowed more control of the bleaching agent during application, which minimized chemical burning of the gingiva.

In addition to lasers, intense curing lights have been used to promote faster release of the peroxide during power bleaching. The validity of the perception among dentists and patients that power bleaching produces better results requires further research.

Treatment planning

Many over-the-counter (OTC) methods for vital bleaching are available, and professional dentist-delivered systems can appear excessively expensive in comparison. Therefore, dentists must excel in the following areas to compete in the current market:

- Provide expert stain diagnosis to apply the proper techniques.
- Provide a treatment plan that can realistically satisfy the patient's expectations.
- Offer different bleaching options based on diagnosis, patient attitude, and delivery costs.
- Provide detailed instructions to enhance patient compliance, minimize gingival irritation, and reduce thermal sensitivity of the teeth.
- Provide follow-up examinations to determine results and patient satisfaction.
- Offer more complex cosmetic procedures, such as bonding and veneers, to complement bleaching results.

• Develop office policies for marketing cosmetic procedures within the dental practice.

Treatment

After diagnostic procedures indicate that the etiology of the stain is due to extrinsic factors, the clinician should evaluate all bleaching options that will satisfy the patient's expectations and cost considerations.

Light to moderate stain

Without tray construction

Light to moderate stain is generally seen in younger adults (age 15 to 30 years). The prognosis for bleaching is generally favorable, and several techniques produce acceptable results:

• Supreme Crest Whitestrips (Procter & Gamble) is available only through dental offices and is cost competitive with many OTC products:
  - The bleaching agent is hydrogen peroxide (14%) and is prepackaged in flexible plastic strips that are applied directly to the teeth. However, the strips only cover from canine to canine in most cases, and the lingual surfaces of the teeth are not bleached.
  - The application times are for 30 minutes, twice a day.
  - This system is also useful for touch-up bleaching if the patient has lost the custom tray or if it no longer fits the teeth due to restorative changes.

Instruction from the dentist for using this system is necessary to minimize chemical irritation from the concentrated peroxide. Patients may experience significant gingival irritation or thermal sensitivity because of leakage of the peroxide. The frequency of use can be reduced to minimize these side effects, or a custom tray can be fabricated.

• Trèswhite (Ultradent) is delivered as a prefilled, disposable tray:
  - This design provides the ultimate in user convenience if the tray fits properly.
  - The patient is instructed to simply open the tray and insert it into the mouth.
  - This tray delivery system can be used for touch-up bleaching.

With simple tray construction

A customized bleaching tray is advantageous in many situations. All teeth will be bleached on both the labial and lingual surfaces, and with proper patient instructions and tray fabrication, gingival and thermal sensitivity will be reduced. Laboratory procedures are minimized to reduce delivery costs:

1. Take an impression, and pour with die stone, such as Die Keen (Heraeus Kulzer). Remove any bubbles of stone from the trimmed cast prior to tray construction.
2. Reservoir (spacer) material is not necessary for short application times. A 1.0- to 2.0-mm rubber tray material is recommended.
3. After vacuum investment, trim the tray to the level of the gingiva in a scalloped design.

4. Instruct the patient to apply the bleach in the tray, insert it in the mouth, and remove excess bleach from the gingiva. Removal is best accomplished by gently brushing the gingiva with a soft toothbrush, followed by a rinse.

Major advantages of this type of tray are its ease of construction and comfort during wear. Because the rubber is flexible, leakage of the bleach from the tray is significant. Therefore, the bleach must be replenished every 30 to 60 minutes during wear, and the tray is not recommended for overnight use. Furthermore, this type of tray system should be delivered for a moderate cost to the patient.

Power bleaching can be incorporated into this delivery system, but it will increase the cost. For patients with light to moderate stain who are compliant with the tray system instructions, power bleaching is not necessary. Power bleaching accelerates the initial lightening of the teeth but does not necessarily produce a better final result. However, many patients prefer the power bleaching method and are willing to accept its higher cost.

Moderate to heavy stain

Complex tray construction

To remove moderate to heavy stains, the commitment and compliance requirements for the patient are more demanding if the best possible results are to be obtained, and a longer wear regimen is necessary. Therefore, the dentist should fabricate a tray that will minimize leakage of the bleach and provide reservoirs to carry a larger volume of bleach for extended wear time. The laboratory procedures and materials to produce this tray are more expensive and time-consuming for the dentist. Therefore, the delivery fee should be greater for this design:

1. Prepare and trim the stone cast as previously described.
2. Apply reservoir material (LC Block-Out Resin [Ultradent Products]) to the labial and lingual of the teeth to be bleached. The reservoirs should be 1.0-mm thick and extend to within 1.0 mm of the gingiva. The incisal edges of the teeth should not be covered.
3. Cure the resin through light-activation. Any brand of light-activated resin will perform this function; however, LC Block-Out is supplied in syringes, which facilitate its application.
4. Apply separating medium to the cast, and use rubber tray material (2.0-mm thickness) to fabricate the tray. The best tray material for longer wear times is supplied by Great Lakes Orthodontics.
5. Heat the tray material according to the manufacturer's instruction, and vacuum-form or pressure-form it over the prepared stone cast.
6. After cooling, separate the tray material from the cast, and trim the tray in a scalloped design that terminates at the marginal gingiva. Care should be given not to cover the gingiva to avoid chemical irritation from the bleach.

Note: These vital bleaching methods will maximize the results of bleaching for a wide range of stain etiologies. Patient considerations, such as cost factors, can be incorporated within the dentist's recommendations. Power bleaching can be added to any of these tray techniques if desired.

Problem management

Gingival irritation

Gingival irritation occurs from a poor fitting tray or from continual leakage of the bleaching agent onto the gingiva. The patient must follow instructions for removal of the excess bleach after insertion of the tray. Failure to remove residual bleach from the gingiva is the most common cause of this chemical irritation. The dentist should supply the patient with a very soft toothbrush as part of the bleaching kit. The patient is instructed to clean the teeth, load the tray with bleach, insert the tray, gently brush the gingival areas, and rinse with water to remove excess bleach. If the tray is well constructed, rinsing thoroughly with water will not remove bleach from the tray.

Thermal sensitivity

Thermal sensitivity is usually caused by extension of the tray, and subsequent bleach, over cervical areas of teeth. The dentist can predict cervical sensitivity prior to tray bleaching by testing suspect teeth with an air blast on the cervical thirds. If the patient is sensitive to the temperature changes produced by the air, then pulpal irritation to the bleach is likely. The scalloped area of the tray should be trimmed to uncover the sensitive areas of the teeth. Fluoride gels have been recommended to control this sensitivity, but the most effective method is to trim the tray away from any areas of the tray that cover cervically sensitive dentin.

If sensitivity continues, the patient should reduce the wear time of the tray and/or reduce the frequency of bleaching (alternate days). Normally, gingival and thermal sensitivity will reduce with time and will completely resolve after bleaching has been completed.

Although vital bleaching with carbamide peroxide does cause changes in the surface morphology of enamel, they are clinically insignificant. However, different formulations and concentrations of carbamide peroxide bleaching gels have been shown to cause different effects on enamel. Minimal damage to existing composites may occur, but the replacement of these composites is often desirable in order to match the bleached shade of the teeth.

Residual bonding material

Prior to vital bleaching, the dentist should inspect the teeth for the presence of bonding material. Any residual composite must be removed from the enamel prior to bleaching. Otherwise, an uneven shade will result because neither the composite nor the underlying enamel will bleach. A combination of microabrasion, sandpaper discs, and rubber wheels will remove composite.

Additional considerations

Touch-up bleaching

After the teeth are bleached, the lighter shades will last for months. However, the enamel will be exposed to the same staining agents from the diet and will require short bleaching touch-ups to maintain the lighter shade. Patients should be warned not to bleach their teeth immediately after a dental prophylaxis because of potential gingival and thermal sensitivity. The patient should wait at

least a week to bleach the teeth and limit the time of exposure.

A major advantage of the tray bleaching method compared to the power bleaching method is the cost of touch-up bleaching. A patient should be instructed to preserve the tray and to store the bleach in the refrigerator. Refrigerated carbamide peroxide has a long shelf life. An average touch-up regimen requires only 1 to 2 hours of bleaching every 6 months. Short bleaching times of 30 minutes to 2 hours are recommended for touch-up bleaching to minimize gingival irritation.

Note: If the original tray no longer fits the teeth because of restorative or orthodontic changes, a simple rubber tray with no reservoirs should be fabricated to satisfy the needs for touch-up bleaching. Another alternative is to supply the patient with a trayless system such as Crest Supreme Whitestrips or Trèswhite.

Bleaching gel choices

The dentist should discourage patients from using OTC products. Professional bleaching agents are pH controlled, available in a variety of viscosities and flavors, and formulated in a variety of concentrations:

- Most professional bleaching gels are carbamide peroxide, which has a stable shelf life and slowly releases hydrogen peroxide.
- Concentrations are available from 10% to 20% carbamide peroxide that are equivalent to one-third the concentration of hydrogen peroxide. A 15% carbamide peroxide gel would equal a 5% hydrogen peroxide gel.
- Professional gels containing hydrogen peroxide are available. They are reported to have a faster release but a shorter shelf life. Any professionally supplied bleaching gel is adequate and will successfully bleach the teeth of a compliant patient.
- A lower concentration of carbamide peroxide (10%) has been shown to produce the same final bleaching result as more concentrated solutions, but more time is necessary.
- Higher concentrations of bleach may produce more gingival irritation. A well-fitted tray and detailed patient instruction for the removal of residual bleach are recommended when using higher concentrations of bleach. In these cases, a shorter wear time may be necessary to minimize irritation.

LESSON 42

Restoration of Endodontically Treated Teeth

OBJECTIVE

To discuss the rationale and technical philosophy of restoration for anterior and posterior teeth with endodontic treatment, including post space assessment, preparation, and biologic considerations during case selection and crown preparation.

INTRODUCTION

Endodontic therapy is not considered successful unless the treated tooth can be restored to comfortable function. Philosophies of restoration for endodontically treated teeth differ between endodontists and prosthodontists.

Prosthodontists focus on restorations with maximum rigidity and retention. Therefore, post-and-core restorations with full-coverage crowns are often advised for anterior and posterior teeth alike. The goal is to maximize the protection and retention of the restoration.

Endodontists desire to protect the root of the tooth against vertical fracture. All literature indicates that endodontically treated roots with posts fracture more frequently than do those without posts. Therefore, endodontists generally recommend fewer posts in all teeth and fewer full-coverage crowns in anterior teeth.

However, even the best and most meticulous endodontic treatment will fail if the root canal system is contaminated by microorganisms stemming from the oral cavity. Treatment results are always poorer when teeth have not been definitively restored or are restored with inadequate coronal

restorations

A significant factor of endodontic failure is coronal microleakage. It has been understood for many decades that gutta-percha and root canal sealers are not effective barriers to the oral environment. As far back as the early 1960s, coronal leakage was investigated to determine its role in the failure of endodontic therapy. In recent years, endodontic research has focused on the quality and integrity of the interface between the definitive restoration and the dentinal surface sealing the root canal. Numerous studies have confirmed that sealing the coronal aspect of the tooth is paramount in the overall success of root canal therapy.

Adhesive resins should be considered as a secondary seal to prevent intra-orifice microleakage. The placements of these orifice plugs have also been suggested to augment the seal of conventional root canal fillings. Gray and white mineral trioxide aggregate as well as bonded resins and glass ionomer cements have been advocated as coronal plugs to prevent bacterial leakage into the obturated root canal.

Case selection criteria

- Is the crown-to-root ratio adequate? Does the root length allow for placement of a post with adequate retention? At least 4 mm of obturation material must remain in the apical third of the root to maintain the endodontic seal.
- Should endodontic retreatment be performed? If the fracture exposes the endodontic filling material to saliva for more than a week, retreatment must precede post placement. If the clinician has any reservations about the endodontic prognosis or the integrity of the endodontic seal, retreatment is recommended.
- Will the crown-to-root ratio be at least 1 to 1 after treatment? This empirical ratio is generally considered to be the minimum necessary to retain the root.

ANTERIOR TEETH

The forces of occlusion in anterior teeth tend to be oblique and therefore are tangentially distributed along the long axis of the roots. When those same forces of occlusion are directed on an endodontically treated anterior tooth that does not have a post for support, the fracture involves the clinical crown and extends angularly through the coronal third of the root. This oblique fracture in a natural tooth may be treatable. However, if a post is present, the fracture usually occurs along the long axis of the root, which may result in an untreatable situation. For this reason, endodontists are inclined to support posts for posterior teeth but not for anterior teeth unless no natural care exists.

The type of definitive restoration recommended for an anterior tooth after endodontic therapy is determined by the amount of remaining tooth structure. If the only loss of tooth structure results from a conservative access preparation, then a bonded, layered composite restoration is adequate. If the tooth is weakened by a large or misdirected access preparation or proximal caries and previous restoration, then a crown should be considered as the definitive restoration. A post is necessary when

the remaining tooth structure (after crown preparation) will not retain the core. A post should be avoided whenever possible to reduce the probability of root fracture.

If a composite is chosen for the definitive access preparation restoration, the patient should be advised that internal bleaching may be necessary in the future. The need for future bleaching is influenced by:

- The surface area of the restoration. The greater the surface area, the greater the potential for orthograde leakage and staining.
- The quality of the enamel. Cracks and craze lines in enamel allow the penetration of stain. This type of stain can be minimized by tray bleaching techniques.
- Porcelain veneer placement. If the tooth stains over time, the thin porcelain veneer may not block the stain. If the composite in the access preparation can be removed (not covered by the veneer), internal bleaching may restore the original color.

Note: In some situations, an oblique fracture involving the coronal third of the root may be treated. The clinician can perform a periodontal crown-lengthening procedure if the esthetic result will be acceptable, or extrude the root ortho-dontically if the surgical procedure to expose the root would leave an unacceptable and unhealthy gingival height and contour. These procedures should be considered alternatives to implant placement.

POSTERIOR TEETH

Both prosthodontists and endodontists agree that all endodontically treated posterior teeth should be protected against fracture by placing restorations that will protect the cusps against vertical fracture. The forces of occlusion during mastication are directed vertically, along the long axis of the roots in posterior teeth. Therefore, direction of fracture in posterior teeth tends to extend to the endodontically treated roots, and the prognosis becomes hopeless. The consensus of both endodontists and prosthodontists is that full-coverage crowns should be placed on all endodontically treated posterior teeth.

The average person can exert 150 to 200 lb of force on posterior teeth, or about nine times the amount of force that is exerted on anterior teeth during closure. The “high heel” effect results in over 1 million psi of stress applied to posterior restorations. Therefore, cusps of posterior teeth must be protected against vertical fracture. Proper restoration of posterior teeth involves two possible techniques: core placement alone or post and core placement. There are advantages and disadvantages associated with each.

Core placement

Although amalgam has been the traditional core material for over a hundred years, current trends in dentistry are replacing the use of this material with core composite material. Core composite is heavily filled composite. It has the advantage of superior strength, but it has less flow compared with other esthetic composite materials. This material must always be used with a dentin-bonding agent

(Fig 42-1):

- Amalgam is the strongest of the plastic core materials. Amalgam does not bond with tooth structure, but it does provide excellent strength and seal. Amalgam may present esthetic issues (stain and dark color) with certain types of all-porcelain crowns. Amalgam has lost favor with patients and dentists because of the metallic color and a perceived problem of mercury release from the material over time. Since posterior endodontically treated teeth should be covered with a full crown, the amalgam core restoration will not be exposed to oral tissues or fluids. As such, the presence of the amalgam should not pose a concern for the dentist or the patient.
- Core composite bonds to the tooth structure and may be advantageous when restoring endodontically treated teeth with incomplete fractures. According to recent studies, exposed tooth structure resists bonding if any residual sodium hypochlorite (final flush before obturation) or eugenol (sealer) is on its surface. Both agents prevent the set of composite. The clinician performing the endodontic procedures must take this issue into consideration if the core is to be placed immediately after the endodontic procedure. In such cases, the root canal must be final flushed with chlorhexidine (CHX), and a non–eugenol-based sealer should be used for obturation. If the composite core is to be placed at a later date (1 week), both the sodium hypochlorite and the eugenol-based sealer (fully set) will have lost their deleterious effect. Amalgam is not affected by either residual sodium hypochlorite or eugenol.

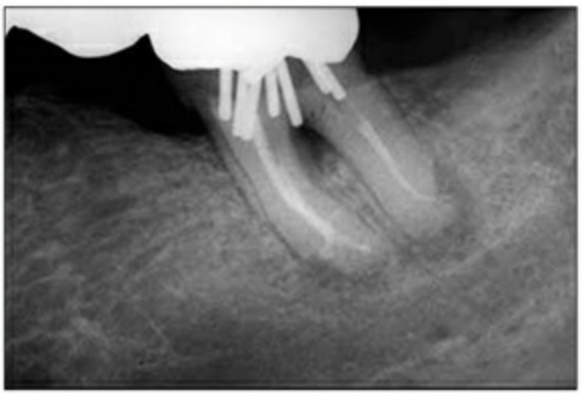


Fig 42-1 Buildup using multiple-pin retention with no regard for the remaining dentin structure. This is an extreme example that shows disregard for modern restorative principles.

POST PHILOSOPHY

The function of a post is to retain a core restoration. The function of a core restoration is to retain a crown. To reduce the potential of vertical root fracture, a post should be placed only when necessary for core retention. The most important factor influencing whether a post will be necessary is the amount of supporting tooth structure remaining after crown preparation. If three supporting walls of dentin remain, a post is not necessary.

All metal posts, regardless of design or type of cement used, transmit forces developed during mastication to the root of the tooth and thus can promote fracture over time if the root is structurally compromised.

Nonmetal posts have been developed that are intended to prevent the fracture problem associated

with metal posts. These posts are bonded in the canal and have some degree of flexibility (similar to the modulus of elasticity of dentin). However, there are reports of debonding and failure with this post system design. The clinician must remember the relationship between the eugenol in some endodontic sealers and its effect on bonding. Further improvement in nonmetal post systems will be necessary before they can totally replace metal post systems.

Post placement criteria

To prepare for the placement of any type of post, obturation material must be removed from the canal. After removal of the obturation material to the proper apical level, the canal can be safely sized to accommodate the post. The apical extension and post placement are regulated by the following factors:

- At least 4 mm of obturation material must remain in the apical third of the canal. Even if the root length is shorter than desired and the post length will be less than ideal, at least 4 mm of obturation material must remain. Research demonstrates that this is the minimum amount of gutta-percha required to maintain the endodontic seal.
- The post preparation must stop short of any curve in the canal. All posts are straight and cannot bypass canal curvatures. Gouging, stripping, or perforation of the root wall will result if the clinician attempts to forcefully bypass a curve with a drill (eg, Gates Glidden and Peeso).
- The post preparation (as such, the post) should be aligned with the long axis of the root.
- Obturation material should be removed from the canal with endodontic instruments set to the appropriate canal depth before drilling is initiated. Removal of obturation material to the proper level for post preparation is termed *pilot post space*. This "empty" canal space provides a path of least resistance for sequentially larger drills and ensures that the sizing drills will stay on course without perforating or gouging the canal.
- Any prefabricated or custom post system can be used after the pilot space has been created.
- The maximum size of a post is approximately a third of the mesiodistal dimension of the root. This dimension and the corresponding post diameter can be estimated from a radiograph.

Preparation of pilot post space

The canal receiving the post should be measured (from preexisting canal preparation information or estimated from a quality radiograph) so that at least 4 mm of obturation material will remain after post preparation. For longer roots, more obturation material should remain in the canal. The following steps will ensure safe removal of gutta-percha and sealer from the canal:

- The pilot space may be prepared with rotary instruments set at a predetermined length. A small amount (conservative) of chloroform or xylene helps to soften the gutta-percha and facilitate instrument penetration. Once the desired depth has been reached, the remaining gutta-percha is apically compacted with appropriately sized Schilder pluggers (Dentsply).
- Several types of electronic heating devices can be used to efficiently heat and compact core-filling

materials (mainly gutta-percha) during or after endodontic obturation. One of the most popular units, the "Touch 'n Heat" (SybronEndo), offers a variety of sizes and shapes of heating tips to vertically condense (final fill) or remove excess gutta-percha when other condensation techniques are employed (eg, lateral condensation). The technique for preparing the pilot space with heat is as follows:

1. Select an appropriately size endodontic plugger, and place a silicone stop at the predetermined safe length.
2. Place the tip of the electronic heat carrier at the orifice of the canal and activate for 3 seconds. Gutta-percha is a poor thermal conductor, and time must be allowed for the heat to warm the material apical to the tip of the heat carrier.
3. Wait 1 to 2 seconds and heat again for 3 seconds. Remove the heat carrier. Gutta-percha should stick to the carrier (usually 2 to 3 mm). Immediately pack with the selected cold plugger. Push any gutta-percha from the wall of the canal. The gutta-percha will exhibit a "spongy" feel while it is warm. As it cools, the material becomes firm.
4. Repeat this sequence, advancing apically in the canal 2 to 3 mm with each cycle. Always pack with the cold plugger after each heat cycle.
5. Do not heat longer than the recommended 3 seconds during any cycle. The temperature of the heat carrier can rise to over 700°C, and excessive heat can damage the periodontal ligament. By applying heat in pulses and allowing time for cooling, the risk to the periodontal ligament is minimized.
6. When the measured depth is obtained, a final cold pack with the plugger will reinforce the endodontic seal in the apical third of the canal.
7. If residual gutta-percha remains on the walls of the canal, a flash heat (1 to 2 seconds) followed by rotating a small Peeso reamer (No. 1 or 2) in a slow-speed handpiece (20,000 rpm) will remove excess material. The warm gutta-percha will adhere to the flutes of the Peeso reamer.
8. The canal can be sized to fit a post.

Note: This technique is not advocated to prepare post space for a carrier-based system (such as ThermaFil [Dentsply]). Special burs from the manufacturer are designed for this system. Preparing the post space by drilling plastic-core obturation material from the canal is not recommended. The burs may be deflected by the solid obturation material and gouge or perforate the root and even break the endodontic seal. In addition, sectioned carrier-cores would be difficult to remove if a retreatment became necessary. As such, this system is not recommended if a post placement is anticipated.

TECHNICAL AND BIOLOGIC CONSIDERATIONS

An important but frequently overlooked aspect of preoperative diagnosis and case selection is the evaluation of postoperative issues associated with the endodontically treated tooth. Successful treatment is determined by more than just the technical considerations involved with nonsurgical endodontic therapy. Issues to be considered preoperatively include restorability, materials, periodontal condition, and strategic value of the tooth.

Restorability

An endodontically treated tooth must be returned to comfortable function to be considered successful (Fig 42-2).

Should all restorative material be routinely removed from a tooth prior to endodontic therapy?

- Rubber dam isolation may become more difficult if total excavation is routinely done prior to starting the endodontic therapy. However, all caries should be removed when there is a question of prognosis. Is the tooth restorable? Is there a fracture? Is the prognosis unknown until the caries are removed? Will a leaking restoration allow contamination of the canal system between appointments? If in doubt, remove any existing restoration before initiating canal penetration.
- While endodontic procedures should never be done while there is active caries in a tooth, endodontic therapy may be pursued and completed prior to the removal of existing restorative material. The decision should be based on the fact that the restorability of the tooth is not a concern.
- At the completion of the endodontic phase of treatment, the clinician can remove the remaining restorative material and place a new core restoration. During this phase the need for a post to retain the core can best be determined. Therefore, the clinician must evaluate the following variables as part of the preoperative diagnosis:
  - Amount of remaining tooth structure
  - Functional demands on the restored tooth
  - Arch position and opposing occlusion
  - Length, width, and curvature of the roots
  - Materials chosen to restore diseased structure

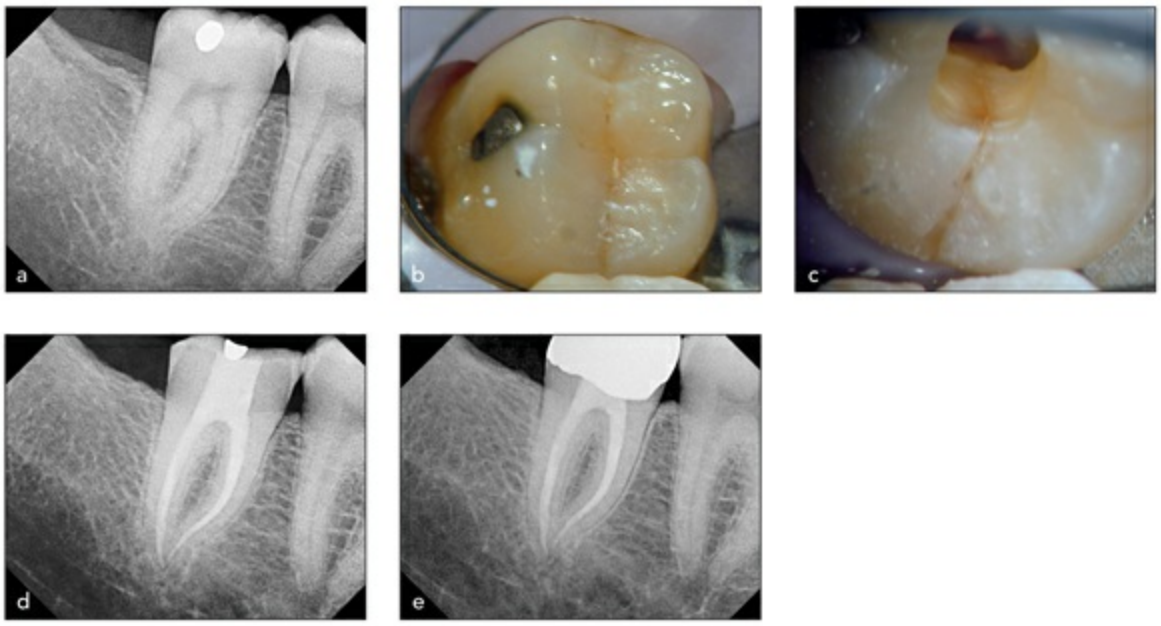


Fig 42-2 *(a)* Mandibular second molar with symptoms of irreversible pulpitis. *(b)* Under a microscope, a deep crack is visible from the mesial to the distal. *(c)* Access opening demonstrates that the crack has encroached on the pulp chamber but has not continued down the root. *(d)* Successful endodontic therapy eliminates all symptoms. *(e)* The tooth was restored with a full-coverage crown with a well-sealed ferrule. (Images courtesy of Dr Ralan Wong, San Francisco, CA.)

Myth of endodontically treated teeth

It is a popular belief that endodontically treated teeth become more brittle due to loss of moisture in the dentin. Yet research shows that moisture loss may only slightly affect the collagen of dentin and that an endodontically treated tooth's susceptibility to fracture is primarily caused by loss of structure due to caries, prior restorations, fractured cusps, and the access cavity—not by the loss of moisture. Therefore, the strongest tooth with the best restorative prognosis is the one that retains maximal structural integrity of dentin and enamel.

Biomimetics

Traditional restorative techniques have incorporated corono-radicular materials that are more diverse in their behavior than is dentin. Since many endodontically treated teeth are restored with numerous material components (eg, gold, stainless steel, ceramic, composite, alloy), the potential for these materials to behave differently than dentin under dynamic function or thermal expansion may affect the resultant modulus of elasticity, tensile strength, and compressive strength of each tooth and its remaining structure.

The emerging materials science of biomimetics focuses on the recovery or mimicking of biomechanical traits of natural tooth. Choosing restorative materials with similar traits to dentin is a developing trend in dentistry and in the rehabilitation of endodontically treated teeth.

Periodontal evaluation

Periodontal assessment must be a routine part of preoperative evaluation. Caries or fracture extending below the crest of the bone may condemn the tooth to extraction unless periodontal crown lengthening can restore proper biologic width and healthy contour of the periodontal attachment apparatus:

- Biologic width is the space between the epithelial attachment apparatus and the crest of the bone. This space is approximately 2.0 mm and allows for the sulcus to maintain normal architecture. The biologic width is sometimes defined as the total measurement of supracrestal fibers, junctional epithelium, and sulcus.
- If a crown margin extends to the crest of the bone and violates the biologic width, there will be inadequate space for a normal sulcus. Gingival inflammation, recession, and progressive periodontal bone loss is inevitable.
- An isolated deep pocket may be a clinical sign of vertical root fracture. The clinician must rule out fracture before endodontic therapy is initiated. There are two methods for visualizing a fracture:
  - *Nonsurgical:* Excavation of caries or restorative material to inspect the area of the periodontal pocket.
  - *Surgical:* An envelope flap can be reflected in the area of the periodontal pocket to inspect the root surface for fracture.

Strategic value

On occasion, teeth that can be retained with endodontic therapy have no value to the existing dentition. An example would be an isolated molar with no antagonist. If the antagonist tooth can be replaced with an implant, then the unopposed tooth becomes an asset. However, if the opposing tooth cannot be replaced, then the tooth to be treated endodontically has no functional value and should be extracted.

Other examples include teeth requiring extensive restoration (ie, posts) that might be used as abutments for removable partial dentures. If the partial denture does not depend on this tooth for function and esthetics, the tooth could be included in the denture.

Occasionally, patients wish to retain teeth that have no strategic value; it is their choice. Treatment is acceptable as long as the patient clearly understands the preoperative explanation (the recommendation to extract). If you adhere to the patient's request, be sure to record all documentation of the discussion to remove the tooth as being nonessential, and obtain a signed informed consent.

An additional example of counseling tooth retention as an alternative to extraction might include a patient on long-term bisphosphonate therapy. Introduced in the mid-1990s, oral bisphosphonates are prescribed as an alternative to hormone replacement therapies for osteoporosis. Bisphosphonates are potent inhibitors of normal and abnormal osteoclastic bone resorption. They may inhibit angiogenesis in bone, which is associated with a reduced immune response and absent or delayed healing, usually after dental extractions or injury to the attachment. Retaining a tooth with endodontic therapy will avoid the possible risk of osteonecrosis of the jaws, which has been reported in patients on long-term bisphosphonate therapy.

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