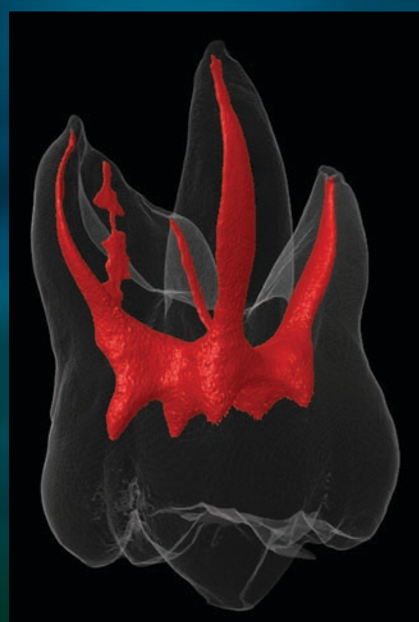
Grossman's

ENDODONTIC PRACTICE



13TH EDITION

EDITORS

B. SURESH CHANDRA • V. GOPIKRISHNA

Wolters Kluwer Health

With DVD-ROM

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Dr. Louis I. Grossman (*Reproduced with permission from AAE Archives, American Association of Endodontists, Chicago, IL*)

Preface to Thirteenth Edition

He who studies Medicine without books sails an uncharted sea,
but he who studies Medicine without patients does not go to sea at all.

—Sir William Osler

It has personally been an intellectual evolution in bringing out this thirteenth edition of the evergreen classic *Grossman's Endodontic Practice*. The process necessitates oneself to be a student in assimilating the sweeping changes that are happening in the specialty of endodontics. It was as much a learning and enriching process as it was enlightening.

The twelfth edition brought out by us in 2010 re-established this textbook as the premier teaching and clinical textbook for students across South Asia. The current edition builds up on this platform by updating and revising concepts, materials, and techniques. The increased awareness and research in biological concepts of treating the pulp tissue has made us revisit the chapter on vital pulp therapy, thereby updating it according to the current clinical guidelines. We have incorporated two new chapters into this edition: Chapter 7, *Endodontic Emergencies*, and Chapter 11, *Regenerative Endodontics*. We have also included *"Clinical Notes"* in each chapter that highlight the pertinent important clinical aspects of the topic being discussed. This book contains over 1100 figures, radiographs, and illustrations, many of which are contributions from clinicians and academicians from across the world. The format and style of presentation has also been changed to make it reader friendly. Accompanying the text is a *"Visual Masterclass" DVD* presenting videos of important clinical procedures.

We have strived to live up to the legacy of Louis I. Grossman by ensuring that this edition of *Grossman's Endodontic Practice* continues to be an evidence-based resource for students and practitioners in the field of endodontics.

B. Suresh Chandra • V. Gopikrishna

Contents

Chapter 6

Diseases of the Periradicular Tissues

Life tells you nothing … it shows you everything.

—Richard Bach

Pulpal disease is only one of the several possible causes of diseases of the periradicular tissues. Because of the inter-relationship between the pulp and the periradicular tissues, pulpal inflammation causes inflammatory changes in the periodontal ligament even before the pulp becomes totally necrotic. Bacteria and their toxins, immunologic agents, tissue debris, and products of tissue necrosis from the pulp reach the periradicular area through the various foramina of the root canals and give rise to inflammatory and immunologic reactions. Neoplastic disorders, periodontal conditions, developmental factors, and trauma can also cause periradicular diseases. The sequelae of periradicular diseases is given in **Box 6.1** while the post-treatment sequelae of periradicular diseases is given in **Box 6.2**.

The diseases of periradicular tissues can be classified on the basis of the etiology, symptoms, and histopathological features. The clinical classification of the diseases of the periradicular tissues is given in **Box 6.3**.

PERIRADICULAR DISEASES

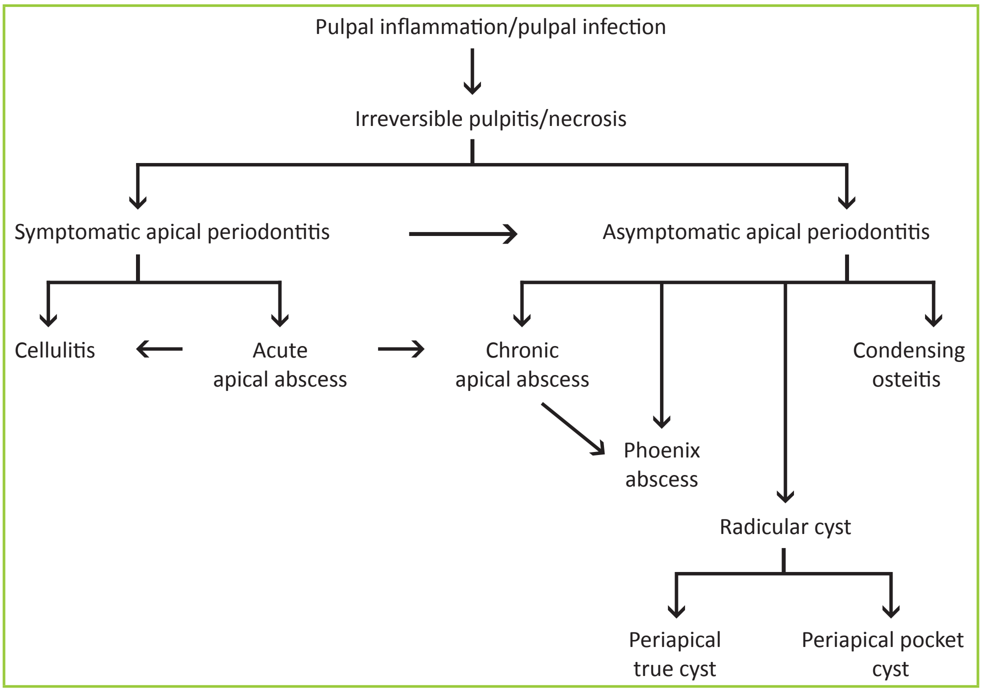
I. SYMPTOMATIC PERIRADICULAR DISEASES

These disorders include symptomatic apical periodontitis, acute alveolar abscess, and acute exacerbation of a chronic lesion (Phoenix abscess).

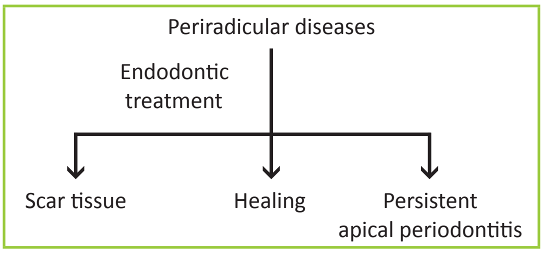
A. Symptomatic Apical Periodontitis (*Previously known as acute apical periodontitis*)

Definition: *Symptomatic apical periodontitis is a painful inflammation of the periodontium as a result of trauma, irritation, or infection through the root canal, regardless of whether the pulp is vital or nonvital, producing clinical symptoms including painful response to biting and percussion.*

Box 6.1 Sequelae of Periradicular Diseases



Box 6.2 Post-Treatment Sequelae of Periradicular Diseases



Box 6.3 Clinical Classification of Diseases of Periradicular Tissues

1. Symptomatic periradicular diseases
   (a) Symptomatic apical periodontitis (*previously known as acute apical periodontitis*)
      (i) Vital tooth
      (ii) Nonvital tooth
   (b) Acute alveolar abscess
   (c) Acute exacerbation of asymptomatic apical periodontitis (phoenix abscess)
2. Asymptomatic periradicular diseases
   (a) Asymptomatic apical periodontitis (*previously known as chronic apical periodontitis*)
   (b) Chronic alveolar abscess
   (c) Radicular cyst
   (d) Condensing osteitis
3. External root resorption
4. Persistent apical periodontitis
5. Diseases of the periradicular tissues of nonendodontic origin

Causes

- Symptomatic apical periodontitis may occur in a *vital tooth* that has experienced occlusal trauma caused by
  – Abnormal occlusal contacts
  – Recently inserted restoration extending beyond the occlusal plane

Chapter 10

Vital Pulp Therapy, Pulpotomy, and Apexification

Never must the physician say the disease is incurable. By that admission he denies God, our Creator; he doubts Nature with her profuseness of hidden powers and mysteries.

—Paracelsus

The unaffected, exposed vital pulp possesses an inherent capacity for healing through cell reorganization and bridge formation when a proper biological seal is provided and maintained against microbial leakage. Throughout the life of a tooth, vital pulp tissue contributes to the production of secondary dentin, peritubular dentin, and reparative dentin in response to biological and pathological stimuli. The pulp tissue with its circulation extending into the tubular dentin keeps the dentin moist, which in turn ensures that the dentin maintains its resilience and toughness (**Fig. 10.1**).

HISTORICAL PERSPECTIVE

The earliest account of vital pulp therapy was in 1756, when Phillip Pfaff packed a small piece of gold over an exposed vital pulp to promote healing. By 1922, in the light of his experiences with similar antiseptic treatments, Rebel summarized his thoughts in the expression, "*the exposed pulp is a doomed organ.*" He concluded that recovery of the vital unaffected pulp when exposed to the oral environment was invariably doomed and that one must consider it as a lost organ. Despite Rebel's much-quoted statements, the realization gradually evolved that the dental pulp did at times possess definite powers of recuperation and repair. Major advances in the practice of vital pulp therapy have been made and the emphasis has shifted from the "doomed organ" concept of an exposed pulp to one of "*predictable repair and recovery.*"

MATERIALS USED FOR VITAL PULP THERAPY

Cohen and Combe have given the requirements of an ideal pulp capping agent (**Fig. 10.2**):

- It should maintain pulp vitality.
- It should stimulate reparative dentin formation.
- It should be either bactericidal or bacteriostatic in nature and should be able to provide bacterial seal.

Box 10.2 Clinical Decision Chart Between Direct and Indirect Pulp Capping

Deep carious lesion

↓

Anesthesia and rubber dam isolation

↓

Removal of caries
A. Infected dentin partially removed with a round bur (# 6 or #8) in a slow-speed handpiece
B. Peripheral carious dentin removed with a spoon-shaped excavator (31 and 33 L)

↙ ↘

No pulpal exposure and no signs of irreversible pulpitis

↓

Remaining infected dentin is covered with $Ca(OH)_2$ and an overlying base of IRM

↓

2nd appointment:

Wait for 3–8 weeks

↓

Patient asymptomatic

↓

Anesthesia and rubber dam isolation

↓

Temporary filling material is removed carefully

↓

Careful further excavation and clinically confirm the change in color and hardness of affected dentin

↓

Hard set $Ca(OH)_2$ is placed followed by an RMGIC base and a bonded composite restoration/amalgam

Pulpal exposure

↓

Direct pulp capping/Cvek's partial pulpotomy/ full pulpotomy

CLINICAL MANAGEMENT OF PULPAL EXPOSURE

The clinician has to decide upon one of the following treatment options when faced with an exposed pulp:

I. Direct pulp capping
II. Pulpotomy
  A. Partial/Cvek pulpotomy
  B. Full pulpotomy
III. Pulpectomy

The following sections would elaborate on the above-mentioned treatment options except pulpectomy, which is discussed in Chapters 12 and 13.

Factors Affecting Prognosis of Pulpal Exposures (Fig. 10.12)

According to Seltzer and Bender, carious pulpal exposure is normally associated with inflammation and subsequent necrosis. Hence, mechanical exposures always have a better prognosis than a carious exposure. The next most important prognostic factor is the sizes of exposure, with larger exposures having lower healing potential than smaller pinpoint exposures.

The time gap between the exposure and the pulp capping procedure is critical, as the longer the time gap, the higher the chances of bacterial microleakage and contamination of the pulp space. Mechanical exposures should be pulp-capped *immediately*. Care should be taken to ensure that the bleeding is controlled before the pulp is capped.

Clinical Note

The following variables make the clinical outcome of a pulpal exposure favorable:

- Pulpal exposure due to traumatic injuries is more favorable than carious pulpal exposure.
- Control of the hemorrhage is achieved in 10 minutes.
- Size of the exposure is less than 1 mm.
- Treatment is done within 48 hours of exposure.

The flowchart depicting the clinical management of pulpal exposure is given in **Box 10.3**.

Figure 10.10 Endodontic spoon excavator. (*Courtesy: Hu-Friedy Mfg. Co., USA.*)

(a)

(b)

Figure 10.11 (a) Dycal—hard-set calcium hydroxide preparation. (*Courtesy: Dentsply Caulk.*) (b) IRM—reinforced zinc oxide–eugenol preparation. (*Courtesy: Dentsply DeTrey.*)

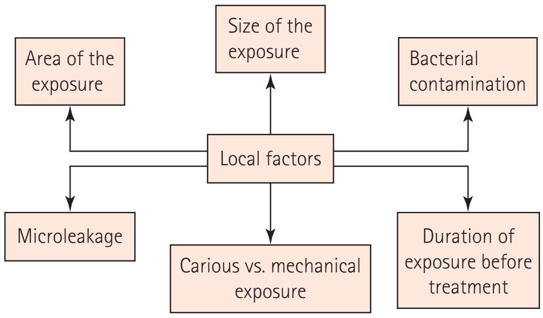


Figure 10.12 Factors affecting prognosis of direct pulp capping.

I. DIRECT PULP CAPPING

Definition: *Direct pulp capping is defined as a procedure in which the exposed vital pulp is covered with a protective dressing or base placed directly over the site of exposure in an attempt to preserve pulpal vitality.*

Indications

- Asymptomatic (no spontaneous pain, normal response to thermal testing, and pulp is vital before the operative procedure)
- Small exposure, less than 0.5 mm in diameter
- Hemorrhage from the exposure site is easily controlled (within 10 minutes)
- The exposure occurred is clean and uncontaminated (rubber dam isolation)
- Atraumatic exposure and little desiccation of the tooth with no evidence of aspiration of blood into the dentin (dentin blushing)

Techniques of Direct Pulp Capping

Two techniques have demonstrated success with direct pulp capping: calcium hydroxide technique and MTA technique. Caries removal is accomplished with the #2 carbide bur (**Fig. 10.13**) and spoon excavators.

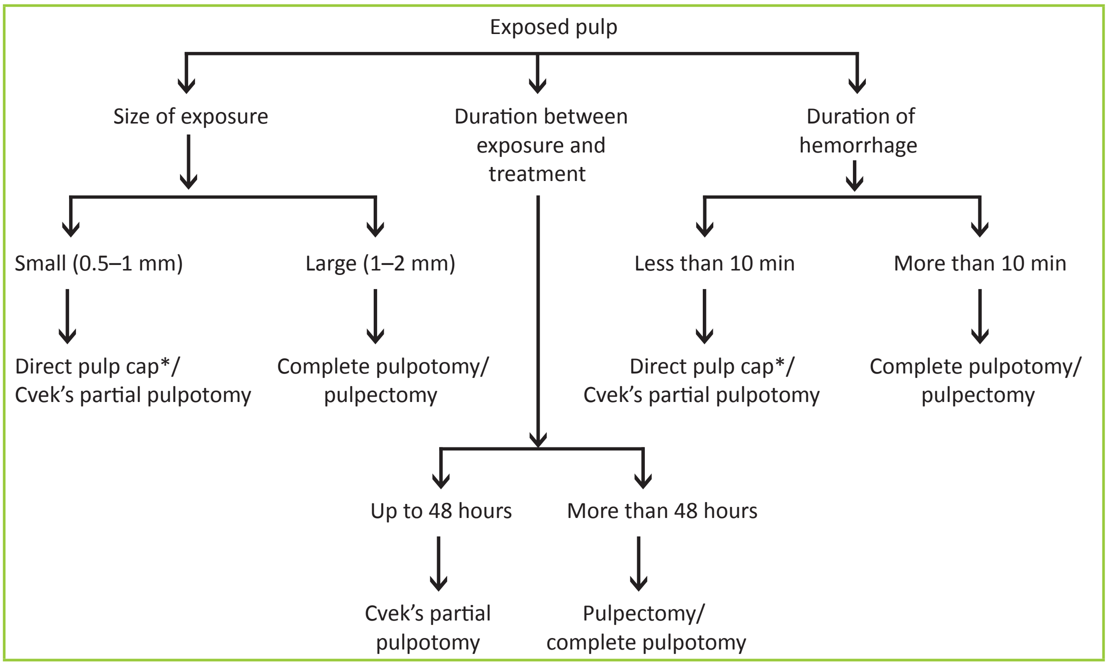
The flowchart for the clinical protocol for direct pulp capping is given in **Box 10.4**.

Clinical Note

- Direct pulp capping is not clinically recommended in cases of carious pulpal exposures.
- A minimum thickness of 1.5 mm of MTA is recommended to be placed over the site of exposure.

Figure 10.14 demonstrates a case report of direct pulp capping using Biodentine.

Box 10.3 Clinical Decision Making Chart for Management of Pulpal Exposure



*Direct pulp capping procedure is not recommended in cases of carious pulpal exposures.

Figure 10.13 Slow-speed carbide bur.

II. PULPOTOMY

Definition: *Pulpotomy is defined as a procedure in which a portion of the exposed coronal vital pulp is surgically removed as a means of preserving the vitality and function of the remaining radicular portion.*

This procedure is similar in concept to direct pulp capping except in the *amount* and *extent* of pulp tissue removal.

Objectives

- *Preservation of vitality of the radicular pulp*: Through the surgical excision of the coronal pulp, the infected and inflamed area is removed, leaving vital, uninfected pulpal tissue in the root canal.
- *Relief of pain in patients with acute pulpalgia and inflammatory changes in the tissue*: Removal of the inflamed portion of the pulp affords temporary, rapid relief of pulpalgia.
- *Ensuring the continuation of normal apexogenesis in immature permanent teeth by retaining the vitality of the radicular pulp*: The remaining pulp may undergo repair while completing apexogenesis, i.e., root-end development and calcification.

Rationale

The inflamed coronal portion of the pulp is removed and a dressing is placed over the pulp stump to protect it and to promote healing. The two most commonly used dressings contain either $Ca(OH)_2$ or MTA.

Chapter 11

Regenerative Endodontics

Two roads diverged in a wood, I took the one less traveled by,
And that has made all the difference.

—Robert Frost

Current endodontic therapy aims to maintain the health of the pulp in cases of inflammation, but a much-desired objective is the regeneration of a healthy pulp–dentin complex. The management of immature permanent teeth with open apices and pulpal necrosis is a significant challenge. Apexification procedures have been used traditionally for the management of these teeth. However, regenerative endodontic procedures have, of late, emerged as valuable alternatives. The significant contributions in the evolution of regenerative endodontic procedures are listed in **Box 11.1**.

Box 11.1 Historical Background of Regenerative Endodontics

- *Nygaard–Ostby, 1961*: Use of a revascularization procedure for regeneration of the pulp–dentin complex in immature teeth with pulpal necrosis
- *Rule DC, 1966*: Use of double antibiotic paste
- *Hoshino, 1993*: Use of triple antibiotic paste
- *Iwaya, 2001*: Evoked intracanal bleeding step
- *Banchs and Trope, 2004*: Case reports on immature mandibular premolars

Concept: Normal, sterile granulation tissue should be developed within the root canal for revascularization. This will stimulate the cementoblasts or the undifferentiated mesenchymal cells at the periapex and lead to formation of a calcific material at the apex and lateral dentinal walls. Conventional calcium hydroxide or mineral trioxide aggregate (MTA)–induced apexification resulted in the formation of a calcific barrier at the apex. On the contrary, regenerative procedures showed normal maturation of root in the radiograph.

Definitions:

- *Regenerative endodontics* are biologically based procedures designed to replace damaged structures, including dentin and root structures, as well as cells of the pulp–dentin complex.
- *Revascularization*, as defined by Andreasen, is the restoration of the vascularity to a tissue or organ.
- *Repair* is the restoration of tissue continuity without the loss of original architecture and function.
- *Revitalization* is described as an in-growth of vital tissue that does not resemble the original lost tissue.

The goals of regenerative endodontic procedures are as follows:

- *Primary goal*: Elimination of symptoms and the evidence of bony healing

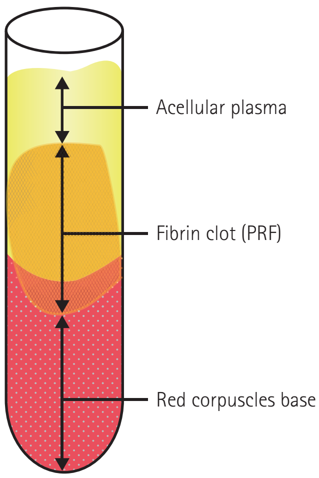
Box 11.3 Steps Involved in the Preparation of Platelet-Rich Fibrin (PRF)

Patient's own intravenous blood collected in a sterile test tube without an anticoagulant

↓

Centrifugation performed at 3000 rpm for 10 minutes

↓



The following three layers are formed:
(a) Upper straw-colored acellular plasma
(b) Lower fraction: Red-colored, containing red blood cells (RBCs)
(c) Middle fraction containing the fibrin clot

↓

The upper straw-colored layer is then removed and the middle fraction is collected which is platelet-rich fibrin

- *Stem cells in the periodontal ligament* can proliferate and grow into the apical end and within the root canal. They may deposit hard tissue both at the apical end and on the lateral root walls. The evidence in support of this hypothesis is presented by documentation of cementum and Sharpey's fibers in the newly formed tissues.
- The fourth possible mechanism of root development could be attributed to *SCAP* or to the *bone marrow*. Instrumentation beyond the confines of the root canal to induce bleeding can also transplant mesenchymal stem cells from the bone into the canal lumen. These cells have extensive proliferating capacity.
- The *blood clot* is a rich source of growth factors such as platelet-derived growth factor, vascular endothelial growth factor, platelet-derived epithelial growth factor, and tissue growth factor. These could play an important role in regeneration.

CLINICAL PROTOCOL

INDICATIONS

- Teeth with necrotic pulp and an immature apex
- Pulp space not needed for post/core, final restoration
- Patient compliance
- No allergy to the medicaments to be used

Boxes 11.4 and **11.5** depict the protocol for regenerative endodontic procedures.

Box 11.4 Regenerative Endodontic Therapy (First Appointment)

Local anesthesia, isolation under rubber dam, and access cavity preparation

↓

Irrigation with 20 mL of 1.5% NaOCl/5 mins and saline (20 mL/canal, 5 mins)

↓

Dry the canal with paper points

↓

Placement of intracanal medicament

↙ ↘

Calcium hydroxide OR Low concentration triple antibiotic paste

↘ ↙

Temporary seal with 3-4 mm of Cavit/IRM/glass ionomer

↓

Recall patient after 1–4 weeks

Box 11.5 Regenerative Endodontic Therapy (Second Appointment)

Assess response to initial treatment

↓ Signs/symptoms of infection persist
- ↓ Additional treatment time with antimicrobial paste
- ↓ Alternative antimicrobials should be considered

↓ No signs/symptoms

↓

Local anesthesia (3% mepivacaine without a vasoconstrictor) and rubber dam isolation

↓

Irrigation with 20 mL of 17% EDTA, drying the canal with paper points

↓

Intentionally evoked intracanal bleeding (K-file is passively extended 2 mm past the apical foramen)

↓

Canal filled with blood to the level of the CEJ

↓

Stop the bleeding at a level that allows for 3–4 mm of the restorative material

↓

Placement of a resorbable matrix over the blood clot

↓

White MTA/$CaOH_2$ as capping material covered with a 3–4 mm layer of GIC

ROLE OF ANTIBIOTIC PASTE

The success of the regenerative endodontic procedure depends on the effective disinfection of the canal. Antibiotic pastes are a combination of more than one antibiotic mixed into a consistency of a paste (**Table 11.1**). They are advocated as an effective alternative to calcium hydroxide that has been traditionally used for intracanal disinfection.

The triple antibiotic paste is the most commonly advocated type and the following guidelines have to be ensured when employing an antibiotic paste:

- It remains below CEJ (minimize crown staining).
- Concentration is adjusted to 0.1 mg/mL (100 µg of each drug/mL).
- The pulp chamber is sealed with a dentin-bonding agent to avoid the risk of staining.

Clinical Note

- Regenerative endodontic procedures rely on chemical disinfection rather than mechanical instrumentation of the root canal space.
- Aggressive shaping and cleaning procedures could damage the fragile and relatively thin root canals walls of immature incompletely developed permanent teeth.
- Lower concentration of NaOCl is recommended for irrigation due to the cytotoxic effects of higher NaOCl concentration on stem cells.
- A final rinse with 17% ethylenediaminetetraacetic acid (EDTA) is recommended during irrigation as it is found to promote the bioavailability of growth factors such as transforming growth factor-beta (TGF-β) and dentin sialoprotein (DSP) in the dentin matrix. These stimulates stem cell proliferation and differentiation.
- Owing to the discoloration potential of MTA, alternatives should be considered in teeth where there is an esthetic concern
  - *For anterior and premolar teeth*: Use of collatape/collaplug followed by placement of 3 mm of resin-modified glass ionomer (RMGI) and a composite restoration

Figure 11.3 represents a case of regenerative endodontics on an immature central incisor.

Chapter 12

Anatomy of Pulp Cavity and Its Access Opening

Of all the phases of anatomic study in the human system, one of the most complex is the pulp cavity morphology.

—M.T. Barrett

The journey of a thousand miles begins with a single small step.

—Lao Tzu

The external morphologic features of the crowns of teeth vary according to the shape and size of the head. The length of the crown differs with the size and gender of the person and is generally shorter in females than in males. As the external morphology of the tooth varies from person to person, so does the internal morphology of the crown and root. Changes in pulp cavity anatomy result from age, disease, and trauma. Although morphologic variations occur, clinical experience indicates that these changes usually follow a general pattern, and thus the study of pulp cavity morphology is an important undertaking.

PULP CAVITY

The pulp cavity is the central cavity within a tooth and is entirely enclosed by dentin except at the apical foramen (**Fig. 12.1**). The pulp cavity may be divided into the following:

- A coronal portion ➔ *pulp chamber*
- A radicular portion ➔ *root canal*

PULP CHAMBER

In anterior teeth, the pulp chamber gradually merges into the root canal, and this division becomes indistinct. In multirooted teeth, the pulp cavity consists of a single pulp chamber and usually three root canals, although the number of canals can vary from one to four or more.

- *Roof* of the pulp chamber consists of dentin covering the pulp chamber occlusally or incisally (**Fig. 12.1**).
- *Pulp horn* is an accentuation of the roof of the pulp chamber directly under a cusp or developmental lobe. The term refers more commonly to the prolongation of the pulp itself directly under a cusp.
- *Floor* of the pulp chamber runs parallel to the *roof* and consists of dentin bounding the pulp chamber near the cervical area of the tooth, particularly dentin forming the furcation area.

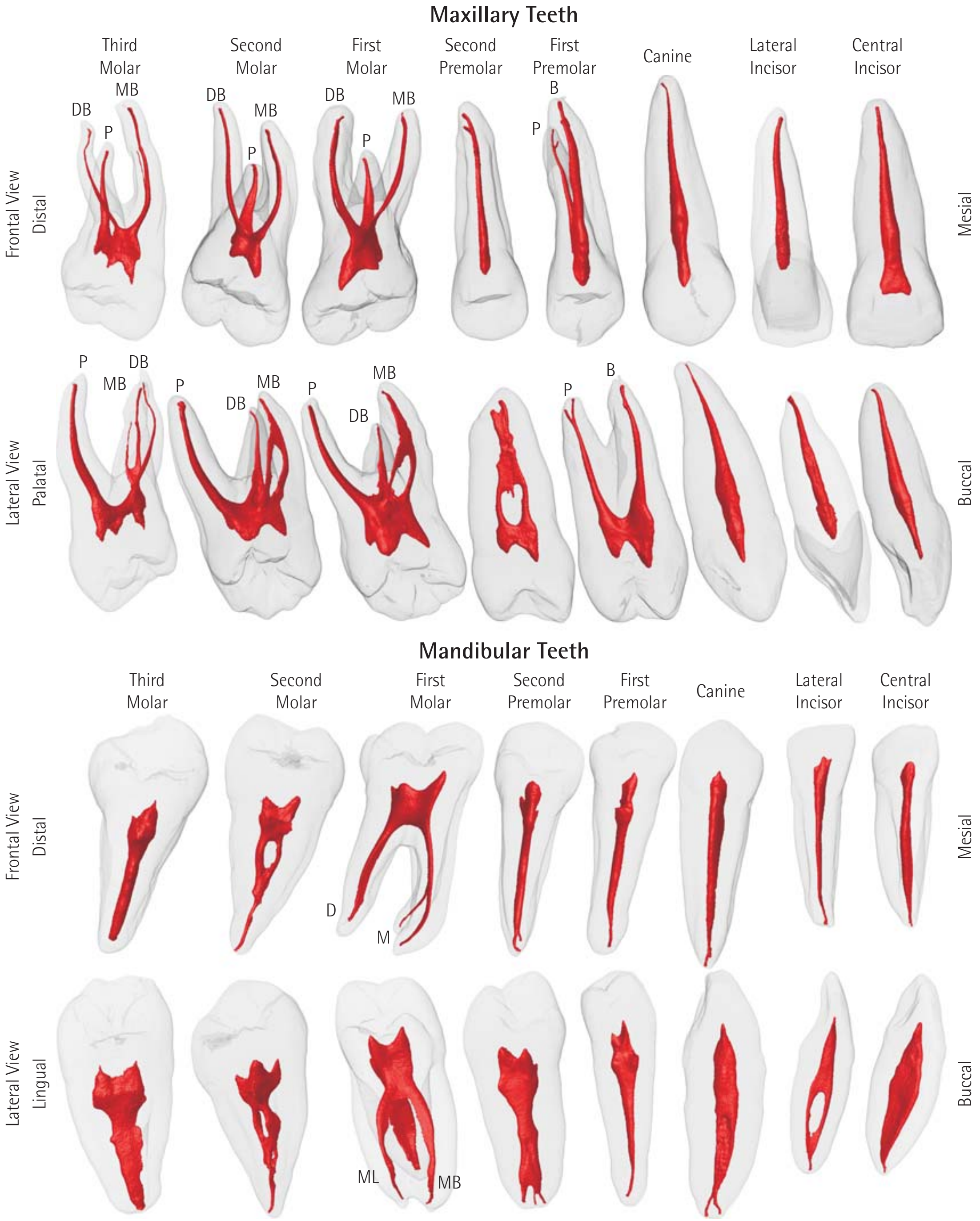


Figure 12.8 Micro-computed tomographic three-dimensional models of the most common root canal configurations in all groups of teeth. In most of the teeth, the common root canal morphology is the presence of one canal per root with the exception of the mandibular incisors, the maxillary premolars, the mesiobuccal root of maxillary first molar, and the mesial root of mandibular molars, which have two root canals. B, buccal; D, distal; DB, distobuccal; M, mesial; MB, mesiobuccal; P, palatal. (*Courtesy: Marco Versiani, Pecora and Sousa-Neto, Brazil.*)

Figure 12.9 Diamond burs with rounded cutting ends. (*Courtesy: Dentsply Maillefer*.)

Figure 12.10 Fissure carbide burs with non-end cutting safety tips. (*Courtesy: Dentsply Maillefer*.)

II. CLINICAL CONSIDERATIONS

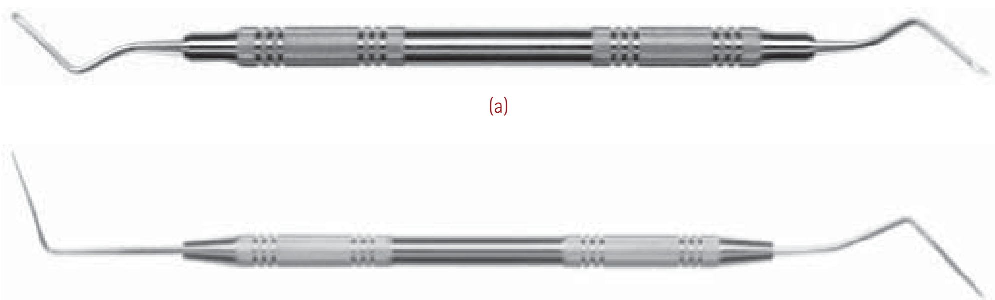
A. Complete Removal of Carious Tooth Structure and Other Restorative Material

While preparing the access cavity in a cariously involved tooth, start removing the carious tooth structure immaterial of its location. This would invariably lead into the pulp chamber. Hence, in case of a tooth with distal carious tooth structure, the access opening commences from the distal side towards the mesial pulp chamber.

B. Complete De-Roofing and Removal of Dentinal Shoulders

The overhanging roof of the pulp chamber misdirects the instrument, which results in ledge formation in the canal. Hence, complete de-roofing must be done to obtain unrestricted access to the canals. Removing the roof completely from the pulp chamber will bring canal orifices into view and allow immediate access to each orifice. Using a round bur and working from inside out will accomplish this end.

Removal of the dentinal shoulders present *between* root canal orifices will help in achieving straight line access and improve the clinical access to the root canals (**Fig. 12.15**).



(a)

(b)

Figure 12.11 (a) Endodontic excavator. (b) DG–16 endodontic explorer. (*Courtesy: Hu-Friedy Mfg Co., USA.*)

Figure 12.12 Start X ultrasonic tips 1, 2, 3, and 5 for access refinement. (*Courtesy: Dentsply Maillefer.*)

Chapter 13

Shaping and Cleaning of the Radicular Space: Instruments and Techniques

What we remove from the pulp space,
is far more important than what we replace it with...

Endodontic treatment can be divided into three main phases:

- Proper access preparation into the pulp space
- Shaping and cleaning of the root canal
- Obturation

The initial step for shaping and cleaning the root canal is proper access to the chamber that leads to straight-line penetration of the root canal orifices. The concepts of achieving proper access into the pulp space are elaborated in Chapter 12. The next step is exploration of the root canal, extirpation of the remaining pulp tissue or gross debridement of the necrotic tissue, and verification of the working length. This step is followed by proper instrumentation, irrigation, debridement, and disinfection of the root canal. Obturation completes the procedure.

Definitions:

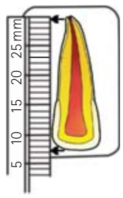
- *Shaping and cleaning* of the root canal consists of removing the pulp tissue and debris from the canal and shaping the canal to receive an obturating material.
- *Pulpectomy*, or pulp extirpation, is the complete removal of a normal or diseased pulp from the pulp cavity of the tooth. The operation is sometimes inappropriately referred to as *devitalization*.
- When food or other debris have accumulated in the pulp cavity, in addition to the residual necrotic pulpal debris, the removal of this material from the pulp cavity is referred to as *debridement*.

Using sequentially larger sizes of files and irrigating and disinfecting the canal to clear it of debris, one shapes the canal to receive a well-compacted filling that seals the root canal apically and laterally to prevent any leakage.

The importance of adequate canal shaping and cleaning, rather than reliance on antiseptics, cannot be overemphasized. Histologic examination of pulpless teeth in which root canal therapy has failed often shows that the canals were not completely cleaned. Obturation of an improperly cleaned canal would still lead to an endodontic failure irrespective of the quality of obturation (**Figs 13.1** and **13.2**).

Box 13.2 Ingle's Radiographic Method of Working Length Determination

Diagnostic radiograph used to *estimate* the working length of the tooth by measuring the tooth from a stable occlusal reference point till the radiographic apex

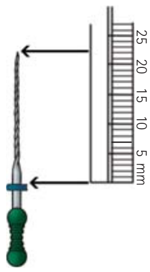


↓

Subtract atleast 1 mm from this length as

- Minor constriction is always present short of the anatomic apex
- Compensation for radiographic image distortion

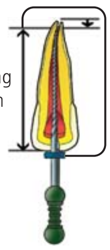
↓



↓

This measurement is transferred to a diagnostic instrument with a silicon stop, which is placed in the root canal and working length radiograph taken

↓



On the radiograph, measure the difference between the end of the instrument and the radiographic apex of the root

↓

Tip of the instrument ends 0.5 mm–1.0 mm from the radiographic root apex **(Working length established)**

Short of the radiographic apex by more than 1.0 mm

Add this value to the earlier estimated length and adjust stopper on the diagnostic instrument accordingly

Retake the working length radiograph

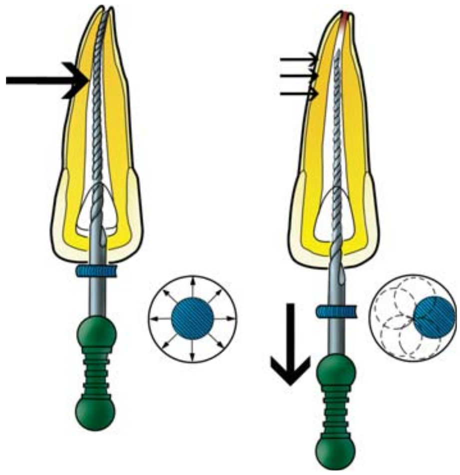
Beyond the radiographic apex

Reduce this value from the earlier estimated length and adjust stopper on the diagnostic instrument accordingly

Retake the working length radiograph

Box 13.3 Techniques of Shaping and Cleaning

1. Step-back technique
   (a) Conventional step-back
   (b) Passive step-back
2. Crown-down (step-down) technique and its modifications
   (a) Crown-down pressureless
   (b) Double flare
   (c) Balanced force
3. Hybrid technique



(a) (b)

Figure 13.32 Reaming motion is the technique of inserting a file into a canal and employing continuous quarter to half turn clockwise rotation and disengagement with a mild pulling motion. This procedure is performed around all the walls of the root canal.

Table 13.7 Summary of Techniques for Shaping and Cleaning the Root Canal System

Authors	Year	Name of Technique
Ingle	1961	Standardized technique
Clem, Weine, Schilder	1969–74	Step-back, serial preparation
Abou Rass	1980	Anticurvature filing
Marshall, Pappin	1980	Crown down pressureless
Goerig	1982	Step-down
Fava	1983	Double flare
Roane	1985	Balanced force
Torabinejad	1994	Passive step-back

Table 13.8 presents the summary of principle techniques of root canal instrumentation.

a. Step-Back Technique

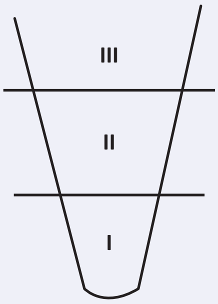
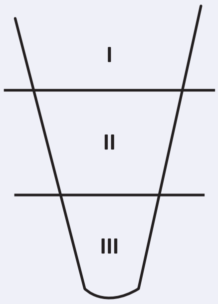
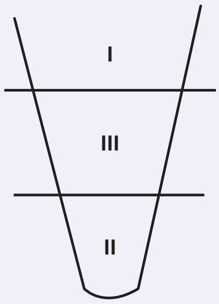
Conventional Step-Back (Telescopic) Technique

In the step-back preparation of the root canal, the canal is enlarged first in the apical third to at least

Box 13.4 Functional Motions of Instrumentation

- *Reaming:* The instrument is used with a clockwise rotating–pushing motion, limited to a quarter to a half turn, and disengaged with a mild pulling motion when bound (**Fig. 13.32**).
- *Filing:* Filing indicates a push–pull motion with the instrument. The instrument is placed into the canal at the desired length, pressure is exerted against the canal wall, and the rake of the flutes rasps the wall as the instrument is withdrawn without turning and the pressure is maintained throughout the procedure.
- *Watch winding:* The instrument is reciprocated back and forth in a clockwise–counterclockwise motion and then retracted to remove the debris.
- *Circumferential filing:* Following the cleaning and shaping of the root canal with a small reamer and reaming to the root apex (working length), the same-size file is inserted into the root canal to the apex, laterally pressed against one side of the canal wall and withdrawn with a pulling motion, to file the dentinal wall. The file is reinserted and the procedure is repeated circumferentially around the walls of the canal until the next-size reamer could be used. In narrow root canals, reamers are used alternately with files in sequence of sizes to produce a uniformly instrumented and enlarged canal.
- *Anticurvature filing:* This motion was described by *Abou Rass and Jastrab*. The furcal wall of the canals in the mesial roots of molars is prone to perforation during coronal enlargement of the canals. In order to prevent this error, anticurvature filing is advocated wherein the top of the handle of the instrument is *pulled into* the curvature while the shank end of the handle is *pushed away* from the inside of the curve (anticurvature). This motion balances the cutting flutes against the safer part of the root canal.

Table 13.8 Summary of Principal Techniques of Root Canal Instrumentation

Features	Step-Back	Step-Down	Hybrid
Author	Clem, Weine	Goerig	Recommended by us for use with stainless steel instruments
Concept	Involves preparation of the apical third initially followed by middle and coronal third of the canal using larger instrument sizes	Involves preparation of the coronal two-thirds of the canal first followed by middle and apical third of the canal	Involves a combination of crown-down and step-back techniques
Sequence of instrumentation	 Phase I: Apical-third instrumentation Phase II: Middle third Phase III: Coronal third	 Phase I: Coronal-third instrumentation Phase II: Middle third Phase III: Apical third	 Phase I: Coronal-third instrumentation Phase II: Apical third Phase III: Middle third
Recommended instruments	Hand instruments	Hand and rotary instruments	Hand and rotary instruments
Principle motion of instrumentation	Coronal instrumentation with reaming motion and apical instrumentation with circumferential filing	Reaming motion	Coronal instrumentation with reaming motion and apical instrumentation with circumferential filing
Advantages	• Popular technique employed with 2% standardized SS files • Ability to prepare a proper apical stop prior to preparation of the middle third and coronal third of the root canal	• Shaping is easier • Elimination of the bulk of the tissue, debris, and microorganisms from coronal and middle third before apical shaping • Minimizes debris extrusion • Better access and control over apical enlarging instruments • Better penetration of irrigants	• Ability to shape the canal predictably with hand instrumentation using stainless steel instruments • Optimizes the advantages of crown-down and step-back techniques
Limitations	• Extrusion of debris into the periapex • Tendency to straighten in the canal • Loss of working length	• Gauging of the apical third is done as the last phase of the procedure	• Middle third preparation has to be done carefully in order to prepare a continuous tapered canal preparation

Chapter 15

Obturation of the Radicular Space

Perfection is not attainable, but if we chase perfection we can catch excellence.

—Vince Lombardi

Definition: According to the American Association of Endodontists *"Obturation is the method used to fill and seal a cleaned and shaped root canal using a root canal sealer and core filling material."*

The function of a root canal filling is to obturate the canal and eliminate all portals of entry between the periodontium and the root canal. The better the seal, the better the prognosis of the tooth. Achieving the ideal seal, however, is as complex as the anatomy of the root canal system itself. Because all root canal fillings must seal all foramina leading into the periodontium, an ideal filling must be well compacted, must conform and adhere to the shaped canal walls, and must end at the juncture of the root canal and the periodontium (**Box 15.1**).

Clinical Note

- Naidorf has stated that inadequate obturation of the root canal exposes it to periradicular tissue fluids, which provide material for growth of microorganisms or localization of bacteria in such dead spaces.
- According to a study by Ingle and Beveridge, 58% of endodontic failures can be attributed to incomplete obturation of root canals (**Fig. 15.1**).

Box 15.1 Grossman's Requirements for an Ideal Root Canal Filling Material

- The material should be easily introduced into the root canal.
- It should seal the canal laterally as well as apically.
- It should not shrink after being inserted.
- It should set slowly.
- It should be impervious to moisture.
- It should be bactericidal or, at least, should discourage the growth of bacteria.
- It should be radiopaque.
- It should not stain the tooth structure.
- It should not irritate periradicular tissues or affect the tooth structure.
- It should be sterile, or easily and quickly sterilized immediately before insertion.
- It should be easily removable from the root canal if necessary.

WHEN TO OBTURATE THE ROOT CANAL

A root canal may be obturated when the tooth is asymptomatic and the root canal is reasonably dry. Obturation after obtaining a negative culture and closure of an existing sinus tract have been suggested in the past. However, this concept is *no longer valid.*

Figure 15.4 Resilon (Real Seal System). (*Courtesy: SybronEndo.*)

Box 15.4 Techniques of Obturation

1. Cold lateral compaction
2. Warm compaction (warm gutta-percha)
   (a) Vertical
   (b) Lateral
3. Continuous wave compaction technique
4. Thermoplasticized gutta-percha injection
5. Carrier-based gutta-percha
   (a) Thermafil thermoplasticized
   (b) SimpliFill sectional obturation
6. McSpadden thermomechanical compaction
7. Chemically plasticized gutta-percha
8. Custom cone

defined as the ability to deform and to flow away from a force directed at its mass.

Each technique is designed to force the gutta-percha filling to flow into the root canal, compress against its walls, fill fine tortuous canals, seal the various foramina exiting into the periodontium, and finally, compact into a solid core filling. The cold lateral compaction method of filling uses spreaders by inserting these instruments alongside the gutta-percha and compressing them laterally and apically.

Clinical Note

- The vertical compaction technique uses vertical force combined with applied heat to drive the gutta-percha apically and laterally.
- Thermoplastic techniques use more heat to increase the plasticity of gutta-percha and thereby enable the operator to fill the root canal by using less pressure.

I. COLD LATERAL COMPACTION TECHNIQUE

This has been one of the most commonly practiced obturation techniques (**Fig. 15.5**). However, in contemporary endodontics, it is not the best technique to achieve a three-dimensional seal. The stepwise technique is given in **Box 15.5**.

Clinical Considerations

1. *Sealer considerations:* Sealer application on the canal walls can also be performed using a lentulo sprial (**Fig. 15.7**) or with the master gutta-percha cone itself.
2. *Spreader considerations (**Figs 15.8** and **15.9**):*
   - The size of the spreader is determined by the width of the prepared canal and the lateral fit of the primary cone; the greater the space between the canal wall and the butt end of the gutta-percha, the larger (wider) the spreader used.
   - The spreader size should reach within 1–2 mm of the working length in order to obtain optimal apical compaction. This can be ensured by placing a silicon stopper on the spreader.
3. *Master cone considerations:*
   - Selection of the master cone should be similar to the master apical file size.
   - Minimal judicious force should be used on the spreader during the compaction process in order to avoid root fractures.

Figure 15.7 Lentulo spiral.

Box 15.5 Technique of Cold Lateral Compaction

Isolation and drying the canal with paper points (**Fig. 15.6**) → Selection of master cone (same size as Master Apical File) → Checking for apical **"TUG BACK"** (**Fig. 15.5**)

↓

Radiographic verification of master cone fit

Inadequate fit - Beyond the apex

↓

Beyond the apex
If the master cone extends beyond the working length, the tip should be cut off so that the reinserted primary cone fits snugly at the working length or the next larger size gutta-percha cone is inserted and verified radiographically.

(→ back to Radiographic verification of master cone fit)

Inadequate fit - Short of the apex

↓

Short of the apex
If the initial fit is short of the working length, then patency has to be established to the corrected length followed by sequential irrigation, recapitulation, and shaping of the canal to the master apical file size. Another primary gutta-percha cone is fitted to the corrected working length for radiographic verification.

(→ back to Radiographic verification of master cone fit)

↓

At working length

↓

Sealer manipulation and coat the canal with sealer using the master cone or with a lentulo spiral (**Fig. 15.7**)

↓

Master cone inserted till working length and a hand or finger spreader (**Fig. 15.8**) is inserted alongside the master cone to a level 1 mm short of the working length

↓

The spreader is disengaged from the cone by rotating it between the fingertips or by rotating the handle in an arc

↓

Placement of sequential accessory cones by lateral compaction until complete obturation of the radicular pulp space (**Fig. 15.5**)

↓

Postobturation radiograph (**Fig. 15.9**)

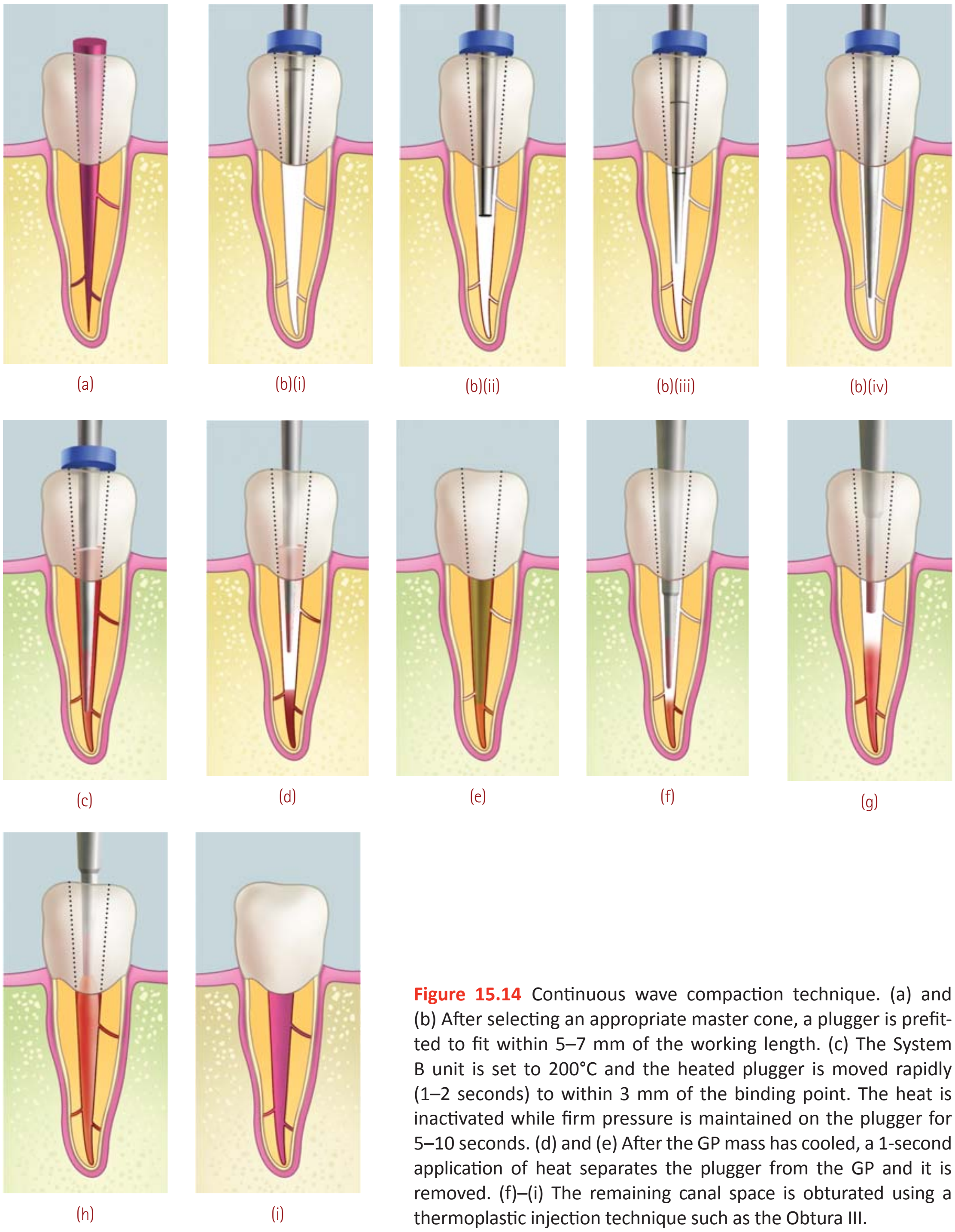


Figure 15.14 Continuous wave compaction technique. (a) and (b) After selecting an appropriate master cone, a plugger is prefitted to fit within 5–7 mm of the working length. (c) The System B unit is set to 200°C and the heated plugger is moved rapidly (1–2 seconds) to within 3 mm of the binding point. The heat is inactivated while firm pressure is maintained on the plugger for 5–10 seconds. (d) and (e) After the GP mass has cooled, a 1-second application of heat separates the plugger from the GP and it is removed. (f)–(i) The remaining canal space is obturated using a thermoplastic injection technique such as the Obtura III.

Chapter 17

Prosthodontic Considerations in Endodontically Treated Teeth

Our objective should be the perpetual preservation of what remains than the meticulous restoration of what is missing.

—M. M. De Van

A successful endodontic treatment has to be complemented with an adequate postendodontic restoration to make the pulpless tooth function indefinitely as an integral part of the oral masticatory apparatus. Endodontically treated teeth fail principally due to one of the following two reasons:

- Persistent intraradicular infection
- Postendodontic restorative difficulties

Careful postendodontic restoration is required, as the cumulative loss of tooth structure due to caries, trauma, and endodontic procedures combined with the loss of structural integrity contributes to the fracture of the tooth. Ideally, the final restoration should be planned before the root canal treatment is begun, though the restorative plan may be modified as the treatment progresses.

ASSESSMENT OF RESTORABILITY

An endodontically treated tooth must be evaluated before definitive restorative procedures are initiated. Evaluation factors (**Fig. 17.1**) are used to determine whether the endodontically treated tooth is restorable, unrestorable, or restorable after successful retreatment. Definitive restorative treatment should not be initiated if the treated tooth exhibits any of the following:

- Poor root canal filling
- Active inflammation
- Pressure sensitivity
- Exudate
- Fistula (or parulis)
- Periodontal disease (moderate or severe periodontitis)
- Severe loss of sound tooth structure (tooth would not benefit from crown lengthening or orthodontic extrusion)

In short, seven categories of infection, trauma, inflammation, unacceptable endodontics, or lack of restorability, as listed, can delay or end up in no definitive restorative treatment (**Figs 17.2** and **17.3**).

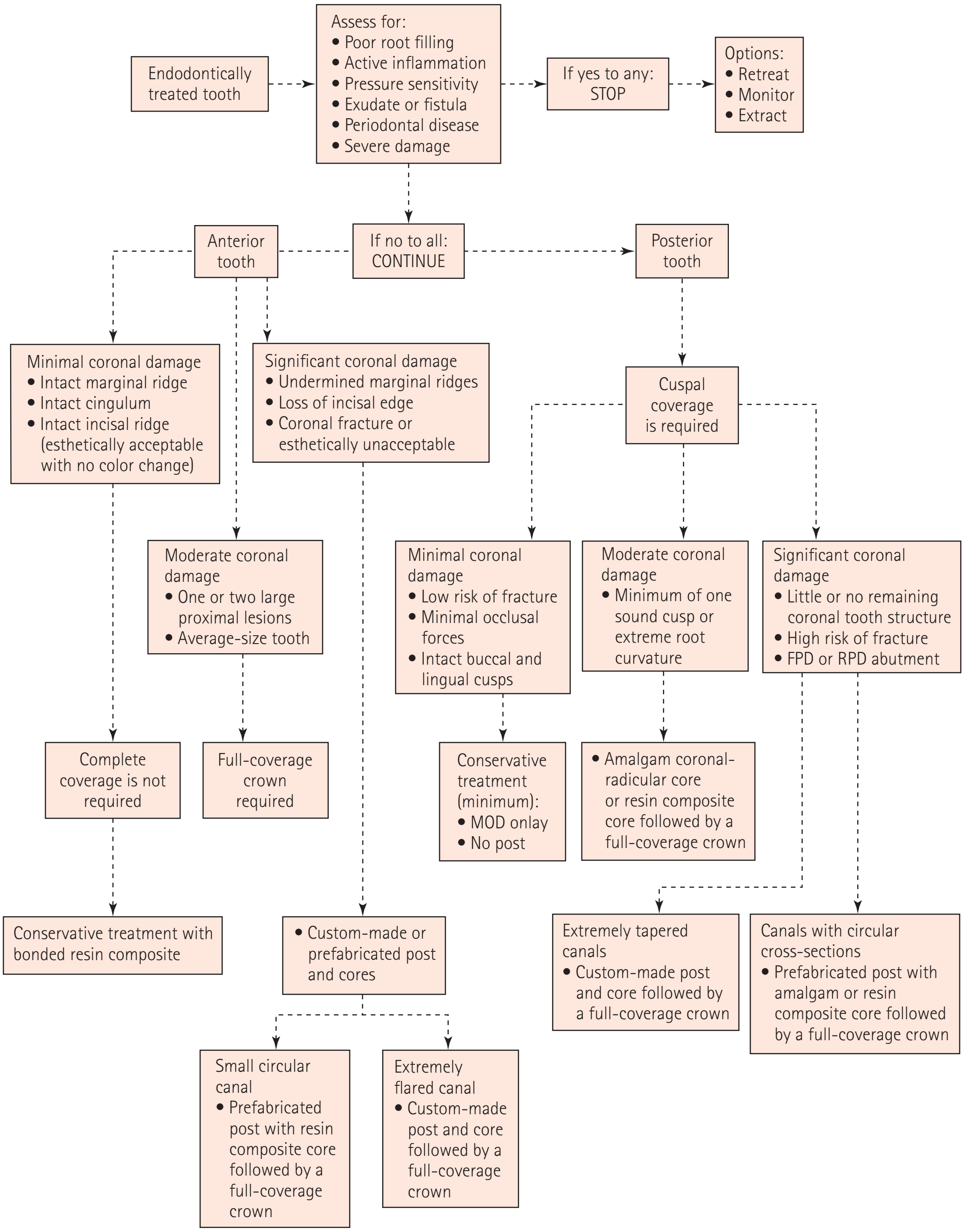


Figure 17.1 Restorative decision-making chart. FPD, fixed partial denture; RPD, removable partial denture; MOD, mesio-occlusal-distal.

The amount of coronal tooth structure, along with the position of the tooth in the arch, will dictate the type of core indicated; whether a prefabricated post or a cast post and core is indicated; and whether a crown is needed.

Clinical Note

The clinician should ensure that the restoration margin does not impinge onto the biologic width as it would cause periodontal breakdown.

PROTECTING THE REMAINING CORONAL TOOTH TISSUE—CREATING THE FERRULE

A ferrule is defined as a band of extracoronal material at the cervical margin of a crown preparation that encompassess the tooth and provides resistance form to the tooth. This is usually provided by the crown that is placed over the post and core system. It is of paramount importance that as much coronal or supragingival tooth tissue is preserved as possible, as this significantly improves the prognosis of the tooth and restoration. *One to two millimeters of tooth tissue coronal to the finish line of the crown preparation significantly improves the fracture resistance of the tooth* and is more important than the type of core and post material (**Fig. 17.6**).

The word *ferrule* is thought to be derived from the Latin word *ferrum*, meaning iron, and *viriola*, meaning bracelet. Thus, the ferrule effect occurs because of the crown bracing against the remaining supragingival tooth tissue (**Fig. 17.7**). Some authors have questioned the benefit of the ferrule; however, majority of the literature would support its importance in reducing the probability of tooth fracture.

Clinical Note

- Barkhordar et al. compared restored teeth prepared with and without a ferrule and showed that the ferrule reduced the incidence/possibility of vertical root fracture by one-third.
- When failure occurred in teeth with a ferrule, it was most commonly due to horizontal fracture compared to the vertical root fracture seen in teeth with no ferrule. Thus, the teeth were more likely to be retrievable.

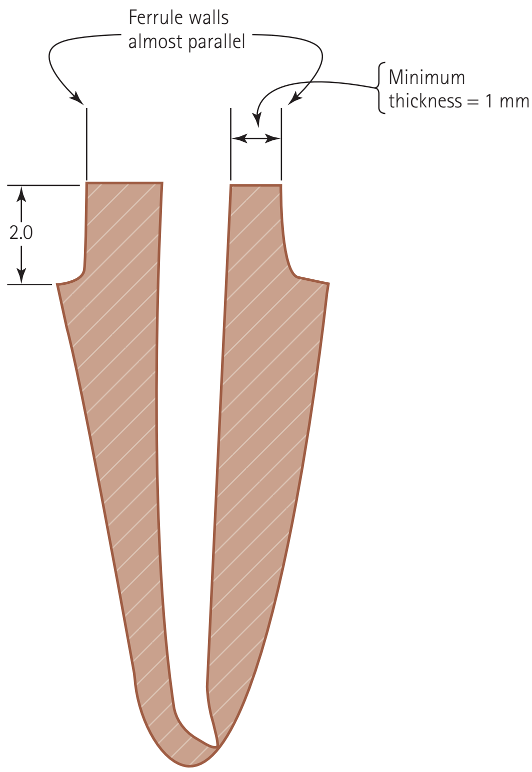


Figure 17.6 Schematic diagram illustrating the ferrule.

Figure 17.7 Cast post and core in the maxillary lateral incisor with sufficient crown ferrule.

- A study by Libman and Nicholls investigating the effect of cyclic loading on cast post and cores with ferrules 0.5, 1, 1.5, and 2 mm high has shown that the 1.5- and 2-mm ferrules are clinically recommended.

Clinical Note

- The primary function of a post is to provide *retention* of the core material.
- A post does not strengthen or increase the fracture resistance of a tooth.

FACTORS DETERMINING POST SELECTION

An ideal post system should have the following features:

- Provide maximal retentiveness to the core
- Physical properties compatible to dentin
- Maximum retention with minimal removal of dentin
- Even distribution of functional stresses along the root surface
- Esthetic compatibility with the definitive restoration and surrounding tissue
- Minimal stress during placement and cementation
- Resistance to displacement
- Easy retrievability
- Material compatibility with core
- Ease of use, safety, and reliability
- Reasonable cost

The clinician should be knowledgeable in selecting the right type of post and core systems to meet the biological, mechanical, and esthetic needs for each individual tooth. The principles which are to be taken into consideration during treatment planning for a post and core restoration are as follows:

I. Post length
II. Tooth anatomy
III. Post width
IV. Canal configuration and post adaptability
V. Post design
VI. Luting cement

I. POST LENGTH

The length and shape of the remaining root determines the length of the post. It has been suggested that root length should be considered for the selection of the ideal post length. It has been demonstrated that *the greater the post length, the better the retention and stress distribution.* However, it may not always be possible to use a long post, especially when the remaining root is short or curved. Several studies suggest that it is important to preserve 4–6 mm of apical gutta-percha to maintain the apical seal. Also, the post length that should be equal to the length of the crown or two-thirds the length of the root, whichever is greater (**Figs 17.10** and **17.11**).

When the root length is short, the clinician must decide whether to use a longer post or to maintain the recommended apical seal and use a parallel-sided cemented post. For molars with short roots, the placement of more than one post will provide additional retention for the core foundation restoration.

Clinical Note

- In long-rooted teeth, the post can be as long as possible without disturbing the apical gutta-percha seal (even three-fourths the length of the root).
- In average to short-rooted teeth, the post length is determined by retaining at least 4 mm of apical gutta-percha in order to ensure apical biological seal. The remaining canal space is utilized as the post length.

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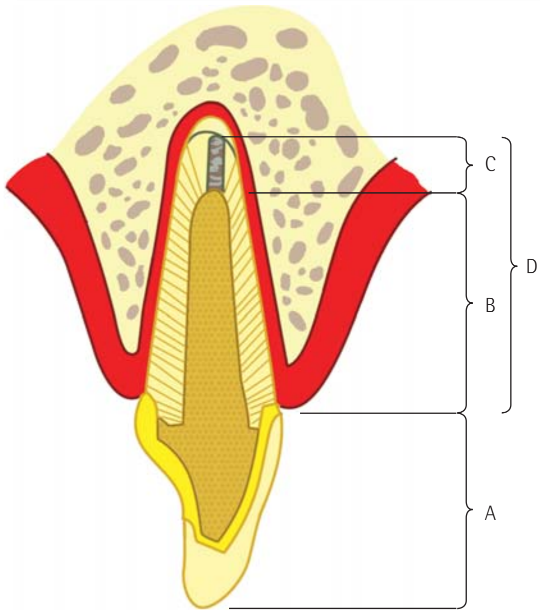


Figure 17.10 To provide optimal retention, the post should equal the crown in length (A = B), or be two-thirds the length of the root (B = D), whichever is greater. The length of gutta-percha remaining at the apex (C) should be a minimum of 4 mm.

Chapter 18

Treatment of Traumatized Teeth

Healing is a matter of time, but it is sometimes also a matter of opportunity.

—Hippocrates

Trauma of the oral and maxillofacial region occurs frequently and comprises 5% of all injuries for which people seek dental treatment. Among all facial injuries, dental injuries are the most common, of which crown fractures and luxations occur most frequently. Trauma to the teeth may result either in injury of the pulp, with or without damage to the crown or root, or in displacement of the tooth from its socket. When the crown or root is fractured, the pulp may recover and survive the injury, it may succumb immediately, or it may undergo progressive degeneration and ultimately die.

CAUSES AND INCIDENCE OF DENTAL INJURIES

Traumatic injuries to the teeth can occur at any age. Young children learning to walk or falling from a chair are subject to anterior tooth injuries. Frequently, child abuse results in facial and dental trauma. Sports accidents and fights affect teenagers and young adults, whereas automobile accidents affect all age groups. As many dental accidents are sports related, every precaution should be taken to protect the teeth of children and teenagers from such accidents by conducting educational programs in addition to mouth guards.

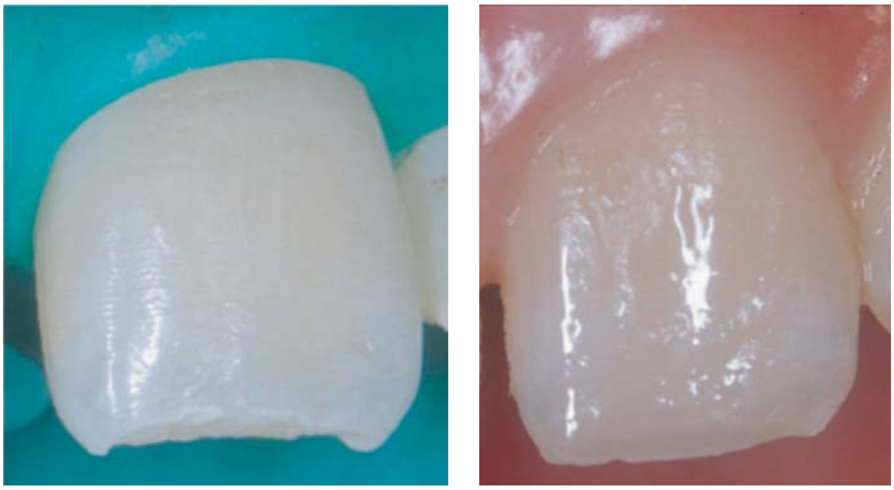
The common causes of traumatic injuries to the teeth include the following:

- Sports accidents
- Automobile accidents
- Fights and assaults
- Domestic violence
- Inappropriate use of teeth
- Biting hard items

Clinical Note

- The incidence of tooth fractures is about 5%.
- The following age groups are most prone to dental accidents:
  - Children 8–12 years of age
  - Children 2–4 years of age
  - Boys have about two to three times as many fractured teeth as girls

(continued)



(a) (b)

Figure 18.2 (a) Enamel fracture. (b) Restoration with direct composite restoration.

The objective in treating a tooth with a fractured crown without pulp exposure is threefold:

- Elimination of discomfort
- Preservation of the vital pulp
- Restoration of the fractured crown

Clinical Features

The tooth is not tender on percussion. If tenderness is observed, evaluate the tooth for possible luxation or root fracture injury. Normal mobility is observed and pulp sensibility test is usually positive.

Radiographic Findings

The enamel–dentin loss is visible. Radiographs recommended: periapical, occlusal, and eccentric exposure to rule out tooth displacement or possible presence of root fracture. Radiograph of lip or cheek lacerations suggested to search for tooth fragments or foreign materials.

Treatment

In an uncomplicated fracture of the crown without pulpal exposure, a *remaining dentinal thickness of 2 mm is sufficient to shield the pulp and ensure a good prognosis*. Inflammatory response in the form of pain on percussion is usually transient as long as the vascular supply to the pulp remains intact. Composite resin restoration is the preferred restorative procedure in such cases. In certain cases, the fractured segments can be approximated and bonded back with the help of dentin bonding agents and composite resins (**Fig. 18.3**). The use of indirect veneering procedures at a later date is another approach to improve the esthetics.

Follow-Up

Clinical and radiographic control at 6–8 weeks and 1 year. The tooth should be periodically tested with the electric pulp tester or Endo Ice. If the pulp continues to respond normally during this time, the pulp can be assumed to have recovered. If progressively more current is necessary to elicit a vitality response, the pulpal prognosis is unfavorable, and the pulp will probably become necrotic necessitating endodontic treatment.

D. Enamel–Dentin Fracture with Pulpal Exposure

Definition: *A fracture involving the enamel and dentin with loss of tooth structure and exposure of pulp.*

Clinical Features

Normal mobility. The tooth is not tender on percussion, however if tenderness is observed, evaluate for possible luxation or root fracture injury. Exposed pulp is sensitive to stimuli.

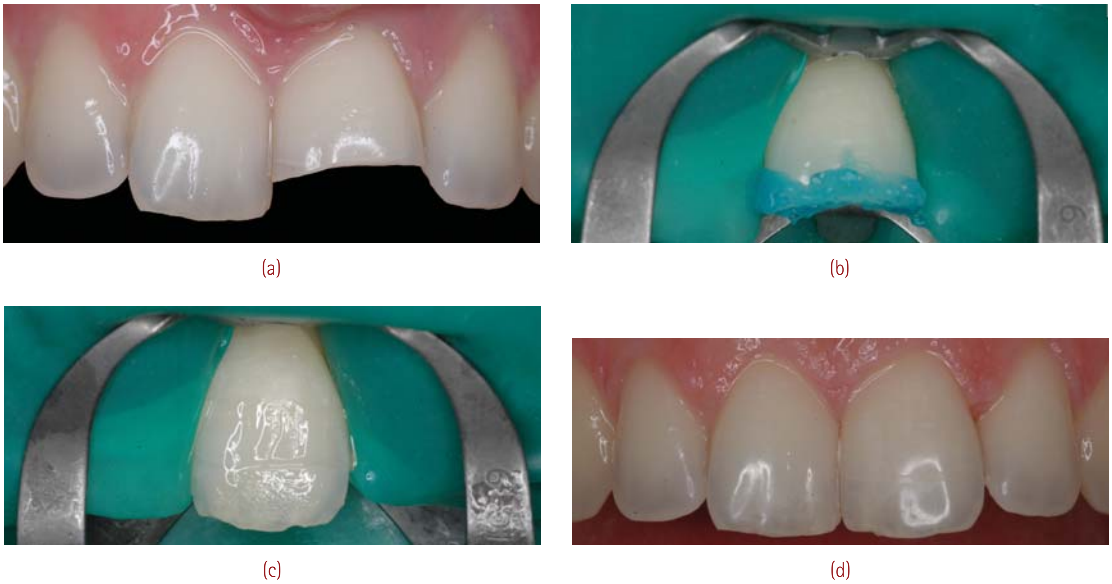


Figure 18.3 (a) Preoperative image showing the mesiodistal crown fracture of vital 21. (b) Rubber dam isolation, beveling, and acid etching performed. (c) Composite contouring. (d) Postoperative view. (*Courtesy: Gianluca Plotino, Italy.*)

Radiographic Findings

The loss of tooth structure is visible.

Treatment

The primary aim for a fractured crown presenting with a pulpal exposure is to maintain the pulpal vitality. For a tooth with a fractured crown with pulp exposure, four kinds of treatment are possible:

- Direct pulp capping
- Pulpotomy (if radicular pulp is vital)
- Regenerative endodontics/apexification
- Pulpectomy (endodontic treatment)

Clinical Note

- Mechanical exposure of the pulp due to trauma has a better prognosis than carious exposures. Every attempt must be made to minimize bacterial contamination of the exposure.
- The extent of fracture and the stage of root development are the two critical factors that would determine the treatment plan.

For more details on direct pulp capping, pulpotomy, and apexification, the student is referred to Chapter 10 and to Chapter 11 for details of regenerative endodontics.

Follow-Up

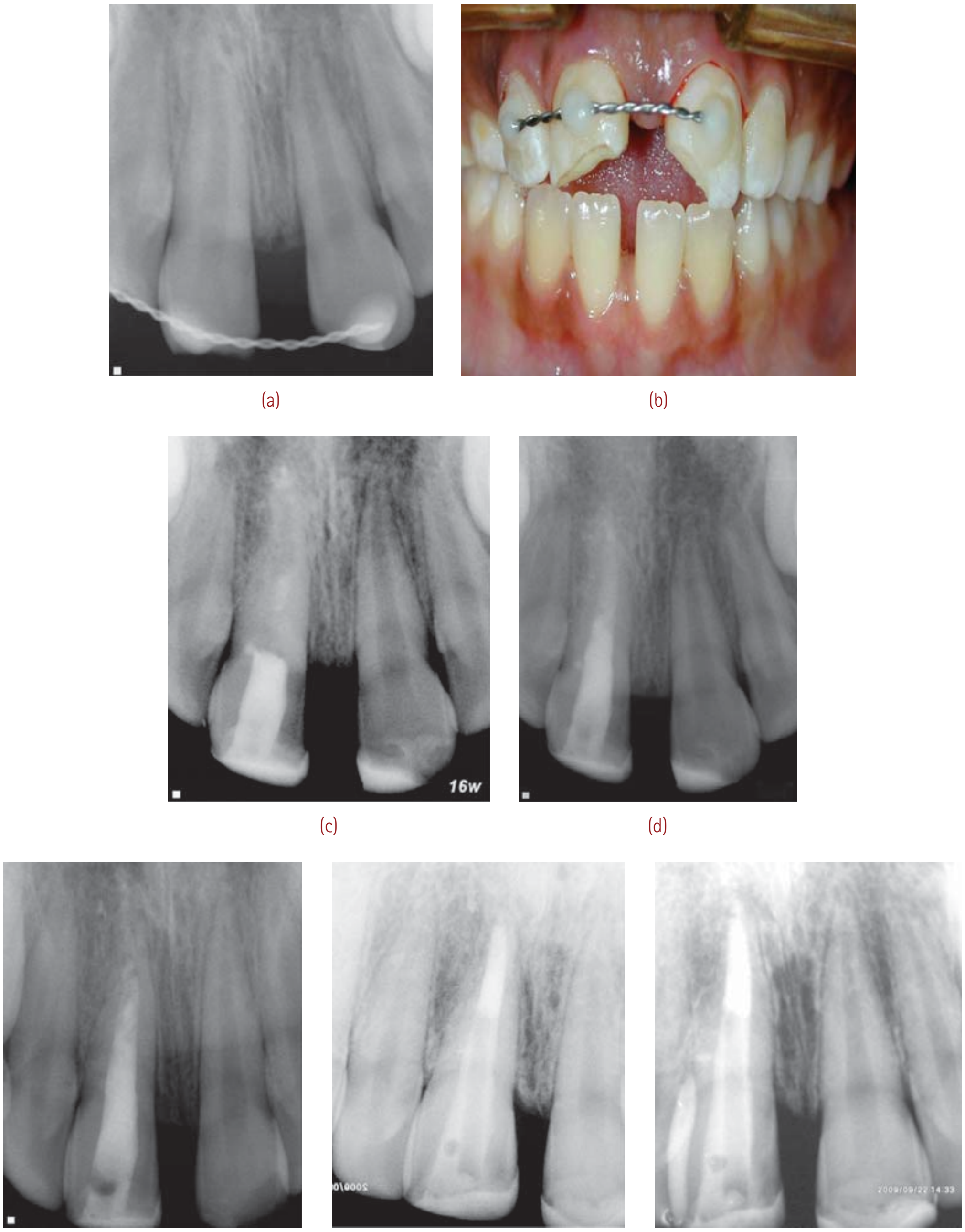
Clinical and radiographic control at 6–8 weeks and 1 year.

E. Crown–Root Fractures

i. Crown–Root Fractures Without Pulpal Involvement

Definition: *A fracture involving enamel, dentin, and cementum with loss of tooth structure, but not exposing the pulp.*

Clinical Features This kind of traumatic dental injury is characterized by an oblique fracture line that usually begins few millimeters incisal to the marginal gingiva and extends beyond the gingival crevice. These resemble a crown fracture but are more complex to treat as the fracture involves the root also. Clinically, the displacement of the coronal fracture segment is minimal as fractured segments are held together by the underlying periodontal ligament.



(a) (b) (c) (d) (e) (f) (g)

Figure 18.13 (a) Avulsion of maxillary central incisor of an 8-year-old boy. Avulsed tooth was kept in dry gauze for 45 minutes before replantation. (b) Nonrigid splint was placed for 10 days. (c) Pulp was extirpated and $Ca(OH)_2$ was placed as intracanal medicament. (d) and (e) Calcium hydroxide intracanal medicament refreshed every 3 months till periodontal ligament could be traced around most of the root surface. (f) Obturation was done with MTA in the apical third. Glass fiber post was cemented with resin ionomer. (g) At 15-month recall, the tooth was asymptomatic and functional with no sign of further replacement resorption. (*Courtesy: Sashi Nallapati, Jamaica.*)

Box 18.2 Transport Medium for an Avulsed Tooth

The choice of storage media for preserving the avulsed tooth is extremely important for the success of future replantation. Suggested storage media are as follows:

1. HBSS (Hank's balanced salt solution)
2. Patient's own saliva
   (a) Vestibule of the mouth
   (b) Container into which the patient spits
3. Milk
4. Coconut water
5. Propolis
6. Viaspan

tooth will appear to be in an infraocclusal position. Radiographic evidence of resorption (inflammatory, infection-related resorption, or ankylosis-related replacement resorption).

RESPONSE OF PULP TO TRAUMA

The pulpal response to dental trauma is dependent on three critical factors:

- Intensity of the trauma
- Stage of root development
- Presence or absence of bacteria

Box 18.3 Management of Avulsed Teeth with an Extraoral Dry Time of Less Than 60 Minutes

Extraoral dry time
LESS THAN 60 minutes

↓

Administer local anesthesia and irrigate the socket with saline. Examine the socket for possible fracture and reposition. Two periapical radiographs from mesial and distal angulation are recommended while CBCT should be considered to confirm the reposition of the tooth and rule out of alveolar bone fracture(s).

CLOSED APEX

↓

Apply a flexible splint for 2 weeks

↓

Initiate RCT within 7–10 days of replantation and before splint removal
(*Optional—Intracanal corticosteroid medicament for 2 weeks*)

↓

Calcium hydroxide intracanal medicament for 4 weeks followed by obturation

OPEN APEX

↓

Soak the root in doxycycline/minocycline (1 mg/20 mL saline) for 5 minutes

↓

Apply a flexible splint for 2 weeks

↓

Do not initiate RCT unless there are signs of pulp necrosis

↓

When pulp necrosis occurs

↙ Attempt revascularization

↘ RCT/apexification

Chapter 20

Endodontic Surgery

We are what we repeatedly do. Excellence, then, is not an act, but a habit.

—Aristotle

The scope of endodontic surgery has extended beyond root-end resection to include other forms of periradicular surgery, fistulative surgery, corrective surgery, and intentional replantation. Root-end resection is still the most common form of periradicular surgery.

In general practice, the number of cases being indicated for root-end surgery has drastically reduced over a period of time. This may be due to the fact that today the science of endodontics has a better understanding of the biological principles of shaping and cleaning. In the last few decades, endodontics was more of a biological science than mere chemomechanical debridement. There has been a tremendous improvement in the available materials and instruments for shaping and cleaning. With the present knowledge of internal anatomy of pulp space, microbiology, disinfection of the pulp space, and also with the introduction of rotary and microendodontic instrumentation, clinicians are now better equipped to produce a more predictable disinfection of the pulp space.

There has been a gradual paradigm shift from surgical to nonsurgical treatment over the past few decades. However, nonsurgical management may not be always successful. Even if nonsurgical treatment is unsuccessful, the current concept is to do an introspection of the quality of nonsurgical treatment before selecting surgical intervention. If the initial endodontic treatment of a tooth is not satisfactory, then one should attempt nonsurgical retreatment of that tooth first.

The view that endodontic surgery is the last resort is based on past experience with instruments that were unsuitable. Also, the vision available at the surgical site was inadequate and incidence of postoperative complications was high. Fortunately, today the endodontist is equipped with better magnification, illumination, and instruments. The present era of microsurgery is with surgical operating microscopes, ultrasonic tips for retropreparation, low-speed high-torque motors, and miniaturized surgical instruments for root-end surgery, and all these have resulted in better success rates.

Clinical Note

The success rate of surgical endodontics is high, about 73–99%, depending on the criteria used for evaluating success.

OBJECTIVES AND RATIONALE FOR SURGERY

- *Curettage:* Effective curettage of the pathologically affected periradicular tissue which cannot be accessed in an orthograde approach. This includes therapy-resistant granuloma, true cysts, and foreign body reactions.
- *Resection:* Surgical resection of root apex in cases where the apical ramifications cannot be eliminated in a nonsurgical endodontic treatment or surgical resection of a root in cases of poor periodontal support.
- *Inspection:* Inspection of the periradicular area to ascertain causes of failure, inspection of isthmus, and trace accessory canals in nonsurgical endodontic cases that are clinically failing.

INDICATIONS

Evidence-based endodontic literature has led to substantial reduction in the indications for root-end surgery. *It is recognized that nonsurgical treatment is the choice in most cases.* However, the following indications may have to be considered (**Fig. 20.1**):

- *Failure of nonsurgical endodontic treatment:* Persistence of symptoms in teeth in which radiographically adequate nonsurgical endodontic

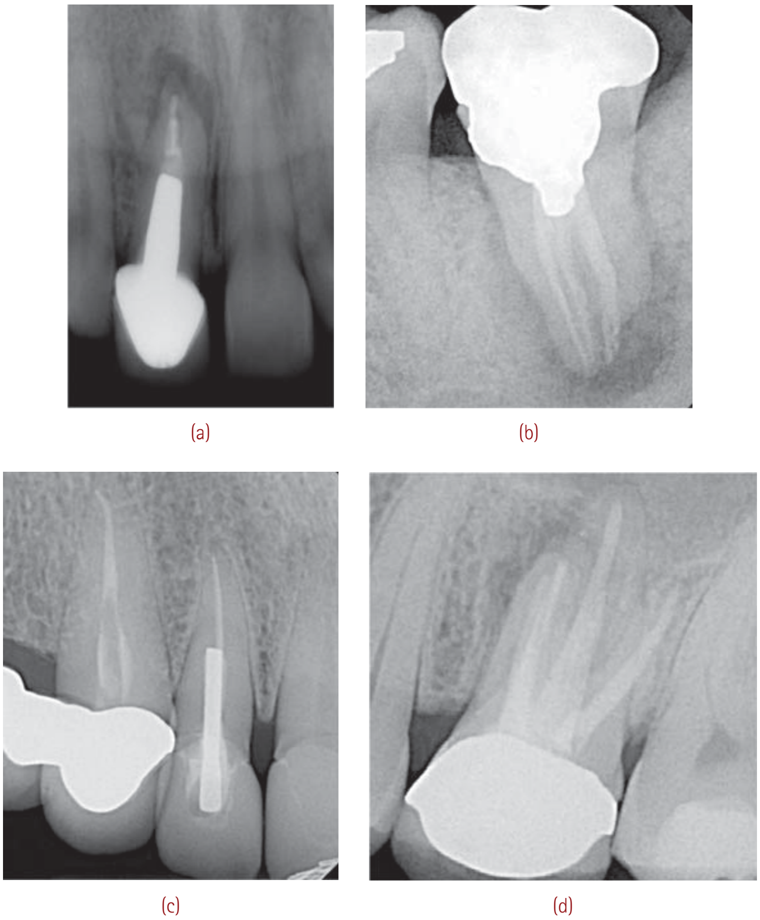


Figure 20.1 Cases illustrating indications for endodontic surgery: (a) and (b) Persistent periradicular pathology in root canal–treated teeth. (c) Perforation of the root due to improper post placement. (d) Persistent pain due to overfilling of the canals.

Box 20.2 Gutmann's Classification of Endodontic Surgery

1. Fistulative surgery
   (a) Incision and drainage (I&D)
   (b) Cortical trephination
   (c) Decompression procedures
2. Periradicular surgery
   (a) Curettage
   (b) Root-end resection
   (c) Root-end preparation
   (d) Root-end filling
3. Corrective surgery
   (a) Perforation repair
      (i) Mechanical (iatrogenic)
      (ii) Resorptive
   (b) Periodontal management
      (i) Root resection
      (ii) Tooth resection
   (c) Intentional replantation

Box 20.3 Kim's Classification of Microsurgical Cases (Fig. 20.8)

- *Class A*: Represents a tooth with no periradicular lesion, no mobility, and normal pocket depth. The clinical symptoms have not resolved, though nonsurgical options have been exhausted. Clinical symptoms are the only reason for the surgery.
- *Class B*: Represents a tooth with a small periradicular lesion with clinical symptoms. The tooth has normal periodontal probing depth and no mobility. The teeth in this class are ideal candidates for microsurgery.
- *Class C*: Represents a tooth that has a large periradicular lesion, progressing coronally; without periodontal pocket and mobility.
- *Class D*: Represents a tooth that is clinically similar to that in Class C, but has deep periodontal pockets.
- *Class E*: Represents a tooth that has a large periradicular lesion with an endodontic–periodontal communication to the apex, but no obvious fracture.
- *Class F*: Represents a tooth with an apical lesion and complete denudation of the buccal plate, but no mobility.

Clinical Note

- With its ability to produce profound and prolonged anesthesia and low potential for allergic reactions, lidocaine (Xylocaine) is the choice of anesthetic for periradicular surgeries. Lidocaine (2%) with 1:50,000 epinephrine is administered. Further lidocaine has a history of high clinical success rate.
- The amide group of local anesthetics including lidocaine (Xylocaine), mepivacaine (Carbocaine), prilocaine (Citanest), bupivacaine (Marcaine), etidocaine (Duranest), and articaine (Ultracaine) undergo a complex metabolic breakdown in liver.
- Patients with known liver dysfunction should be administered amide local anesthetic agents with caution due to their potential for a high systemic blood concentration of the drug. It is also administered with caution in patients with renal dysfunction.
- If the amide anesthetic agent is an absolute contraindication, then the ester agents such as procaine and propoxycaine with levonordefrin (procaine with neo-cobefrin) are the only choice.

Effective hemostasis is critically important during endodontic microsurgery because uncontrolled bleeding in the surgical site obscures the anatomical landmarks guiding the surgeon. It is therefore not surprising that one of the most frequently asked questions about endodontic microsurgery is on effective management of bleeding in the osteotomy site and inside the bony crypt.

Effective hemostasis is a prerequisite for endodontic microsurgery and successful hemostasis begins with effective local anesthesia. Surgeons must understand the normal clotting mechanism and normal clotting time of human blood; it takes several minutes for the blood to begin clotting.

VASOCONSTRICTORS

To obtain hemostasis, *vasoconstrictors* are always a constituent of local anesthetics used in periradicular surgeries. The vasoconstrictor agent used in local anesthetics will have an effect in both the duration of anesthesia and the quality of hemorrhage control in the surgical area.

Clinical Note

- Epinephrine is the vasoconstrictor of choice and is the most efficient and widely used vasoconstrictor agent in local anesthetics. The advantage of including epinephrine outweighs any potential deleterious effects of the agents.
- Normally, profound anesthesia with an agent containing 1:50,000 parts epinephrine is adequate to achieve a blood-free field.

(continued)

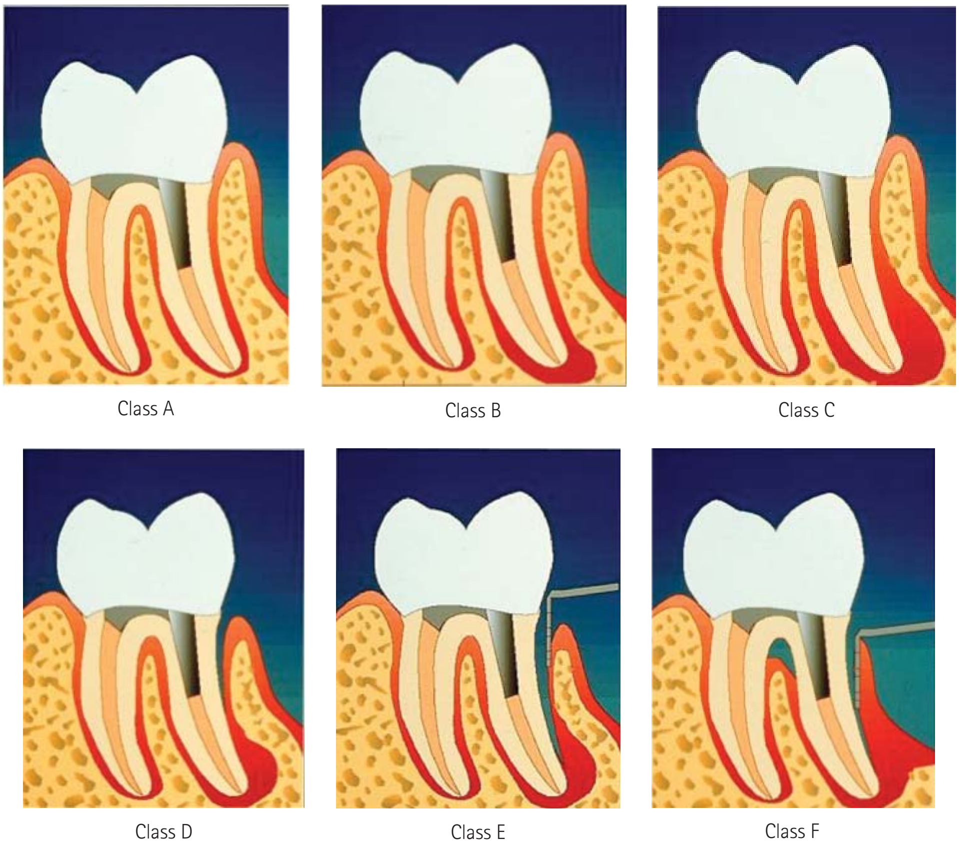


Figure 20.8 Classification of microsurgical cases. (*Courtesy: Syngcuk Kim, University of Pennsylvania, USA*.)

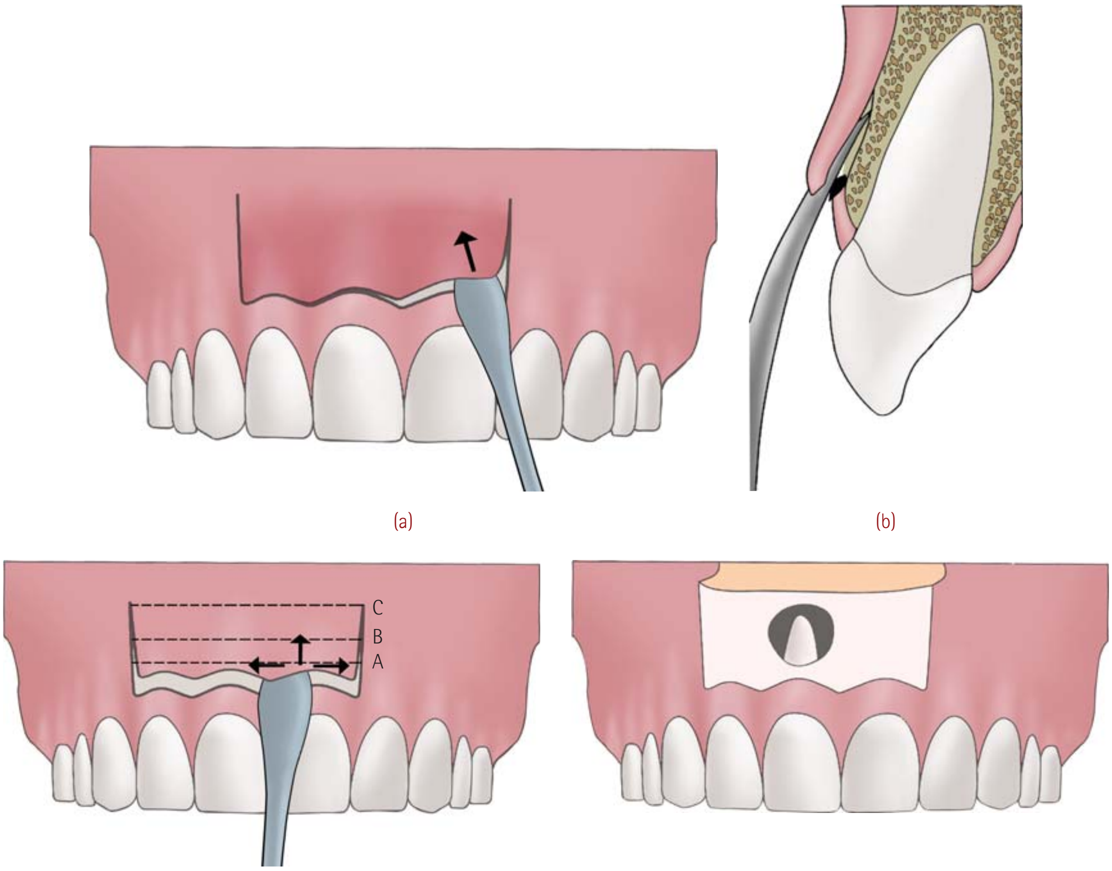
(continued)

- Both buccal and lingual or palatal injections are required to achieve profound anesthesia and effective hemostasis.
- According to Miliam et al., profound nerve block anesthesia can be achieved with local anesthetic containing dilute 1:100,000 or 1:200,000 epinephrine. However, at times, an additional local infiltration of local anesthetic with a higher concentration of epinephrine (1:50,000) in the anesthetic solution is always required to obtain local hemostasis.
- *Safety limit:* According to the American Dental Association, the maximal permissible safety dosage of epinephrine for a healthy adult is 200 µg/day. Thus, it requires 10 carpules of 1:50,000 epinephrine containing 2% lidocaine to reach the danger limit.

It is also to be well understood that infiltration sites for periradicular surgery are always multiple and involve deposition of anesthetic throughout the entire surgical area in the alveolar mucosa just superficial to periosteum at the level of root apices. Apart from the routine anesthetic techniques of nerve block anesthesia, other standard techniques may be observed to obtain profound local anesthesia.

CLINICAL MANAGEMENT OF HEMORRHAGE IN A NORMAL PATIENT

- Incision planning
- Use of hemostats
- Hemostasis through application of pressure
- Hemostatic agents (**Fig. 20.9**)
- Hypotensive anesthesia and vasoconstrictors



(a) (b) (c) (d)

Figure 20.12 (a) and (b) Raising a Luebke-Ochsenbein flap: The elevator edge, with its concave surface facing the bone, cleaves the periosteum from the bone apically and laterally until the bone above the lesion is exposed. (c) The periosteal elevator should be moved laterally and apically without losing contact with the bone. (d) The extent of the flap should be sufficient enough to expose bone above, below, and around the lesion.

retractors are available and are designed to have wider and thinner working ends than standard retractors.

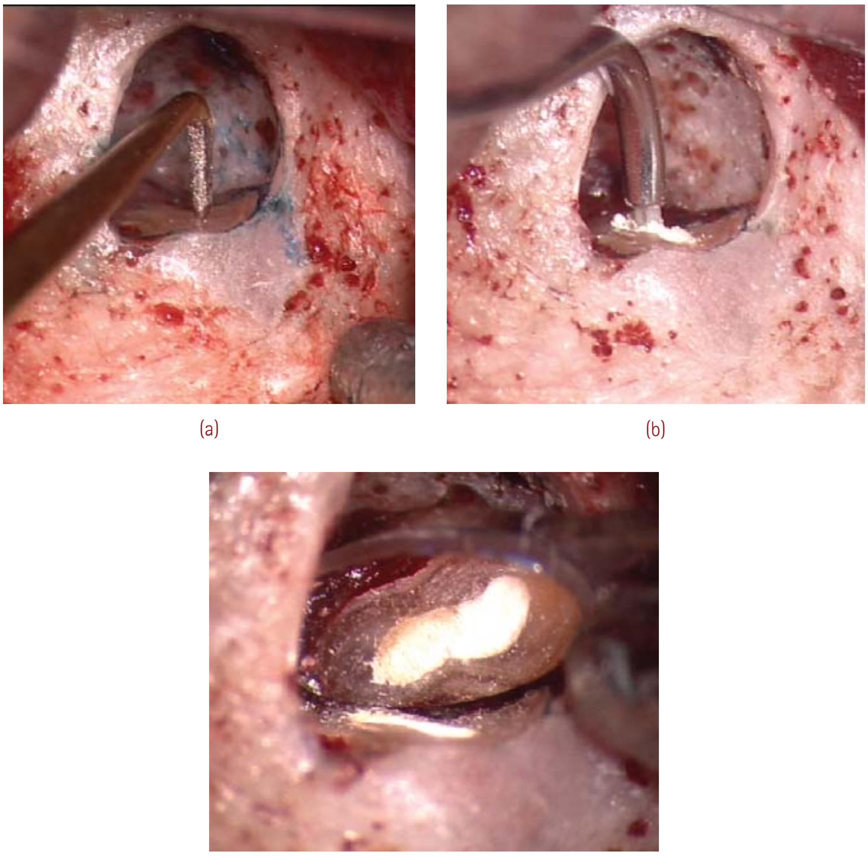
HARD TISSUE CONSIDERATIONS

OSTEOTOMY

Osteotomy involves the removal of cortical plate to expose the root end in microendodontic surgical procedures. Once the flap has been elevated and placed in retracted position, the surgical area is taken into control.

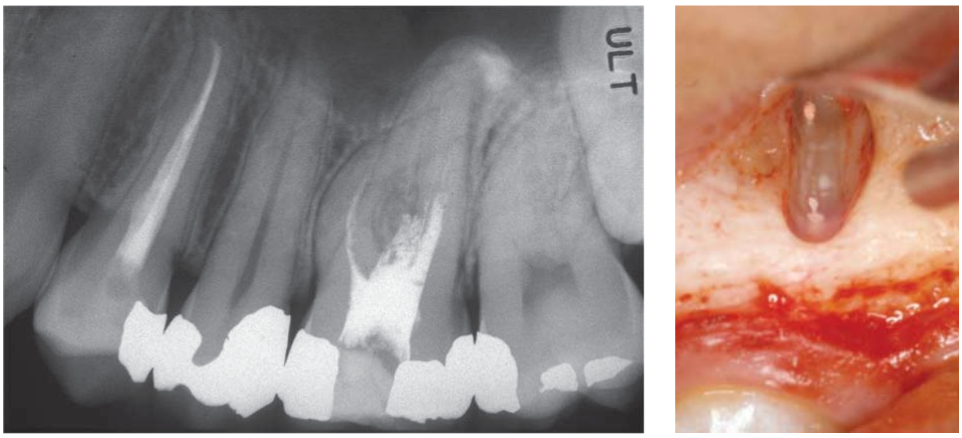
Technique

1. Hemostasis is the primary issue at this stage of surgery.
2. In most of the clinical cases, there is a breach in the cortical plate and this can be located around the root apex by gently probing with a DG16 explorer, and if the breach is located, the explorer will sink and this could be the starting point for an efficient osteotomy. However, in most cystic pathosis, the cortical plate is thinned out due to the growth of the cyst and has an eggshell crackling appearance. In these situations, the cortical plate can be peeled off leaving the



(a) (b) (c)

Figure 20.19 (a) Ultrasonic retrotip being employed to create a 3-mm retropreparation. (b) Placement of the retrofill material. (c) Postoperative view. (*Courtesy: Arnaldo Castelluci, Italy*.)



(a) (b)

Figure 20.20 (a) Preoperative radiograph of an endodontically treated maxillary molar requiring endodontic microsurgery. (b) After root resection of all the three roots. *(continued)*

Chapter 21

Bleaching of Discolored Teeth

We live only to discover beauty. All else is a form of waiting.

—Kahlil Gibran

Esthetics is an important factor in a patient's decision to undergo endodontic treatment. A frequent question is, "Will my tooth turn black?" The usual response is a "qualified no," with the explanation that modern treatment and procedures are designed to avoid crown staining and tooth discoloration. Nevertheless, teeth can and do discolor, sometimes before endodontic treatment and sometimes afterward, in spite of all precautions taken to prevent color changes. When teeth discolor, bleaching should be considered as a means of restoring tooth esthetics.

The color of teeth is determined by the translucency and thickness of the enamel, the thickness and color of the underlying dentin, and the color of the pulp. Alterations in the color may be physiologic or pathologic and endogenous or exogenous in nature.

With age, the enamel becomes thinner because of abrasion and erosion, and the dentin becomes thicker because of the deposition of secondary and reparative dentin, which produce color changes in teeth during one's life.

Clinical Note

- The normal color of primary teeth is bluish white.
- The color of permanent teeth is grayish yellow, grayish white, or yellowish white.
- Teeth of elderly persons are usually more yellow or grayish yellow than those of younger persons.

CLASSIFICATION OF TOOTH DISCOLORATION

Tooth discoloration can be classified as either extrinsic or intrinsic.

I. EXTRINSIC DISCOLORATIONS

Extrinsic discolorations are found on the outer surface of teeth and are usually of local origin, such as tobacco stains. Some extrinsic discoloration, such as the green discoloration associated with the Nasmyth's membrane in children and tea and tobacco stains (**Fig. 21.1**), can be removed by scaling and polishing during tooth prophylaxis.

Figure 21.1 Extrinsic tobacco stains. (*Courtesy: Priya Ramani, India.*)

Table 21.1 Tooth Discoloration: Causes and Colors (Abbott, 1997)

Cause of Tooth Discoloration	Color
Extrinsic discoloration	
Cigarettes, pipes, cigars, chewing tobacco, marijuana	Yellow-brown to black Dark brown to black rings
Coffee, tea, foods	Brown to black
Poor oral hygiene	Yellow or brown shades
Extrinsic and intrinsic discoloration	
Fluorosis	White, yellow, brown, gray, black
Aging	
Intrinsic discoloration	
Genetic conditions	
Amelogenesis imperfecta	Brown, black
Dentinogenesis imperfecta	Brown, blue
Systemic conditions	Blue-green, brown, purple-brown
Jaundice	
Porphyria	
Medications during tooth development	Brown, gray, black
Tetracycline	
Fluoride	
Body by-products	
Bilirubin	Blue-green, brown
Hemoglobin	Gray, black
Pulp changes	
Pulp canal obliteration	Yellow
Pulp necrosis	
With hemorrhage	Gray, black
Without hemorrhage	Yellow, gray-brown
Iatrogenic causes	
Trauma during pulp extirpation	Gray, black
Tissue remnants in pulp chamber	Brown, gray, black
Restorative dental materials	Brown, gray, black
Endodontic materials	Gray, black

V. FILLING MATERIALS

Discoloration from filling materials depends on the kind of filling used. Silver amalgam produces a stain ranging from slate gray to dark gray; copper amalgam produces a bluish black to black stain; stains from amalgam are likely to occur when the dentinal wall is thin, and the filling material almost shimmers through the enamel. Microleakage of the old resin composite restorations might cause dark discoloration of the margins and may stain the dentin over time. Metal post can be seen through the translucent enamel or may release

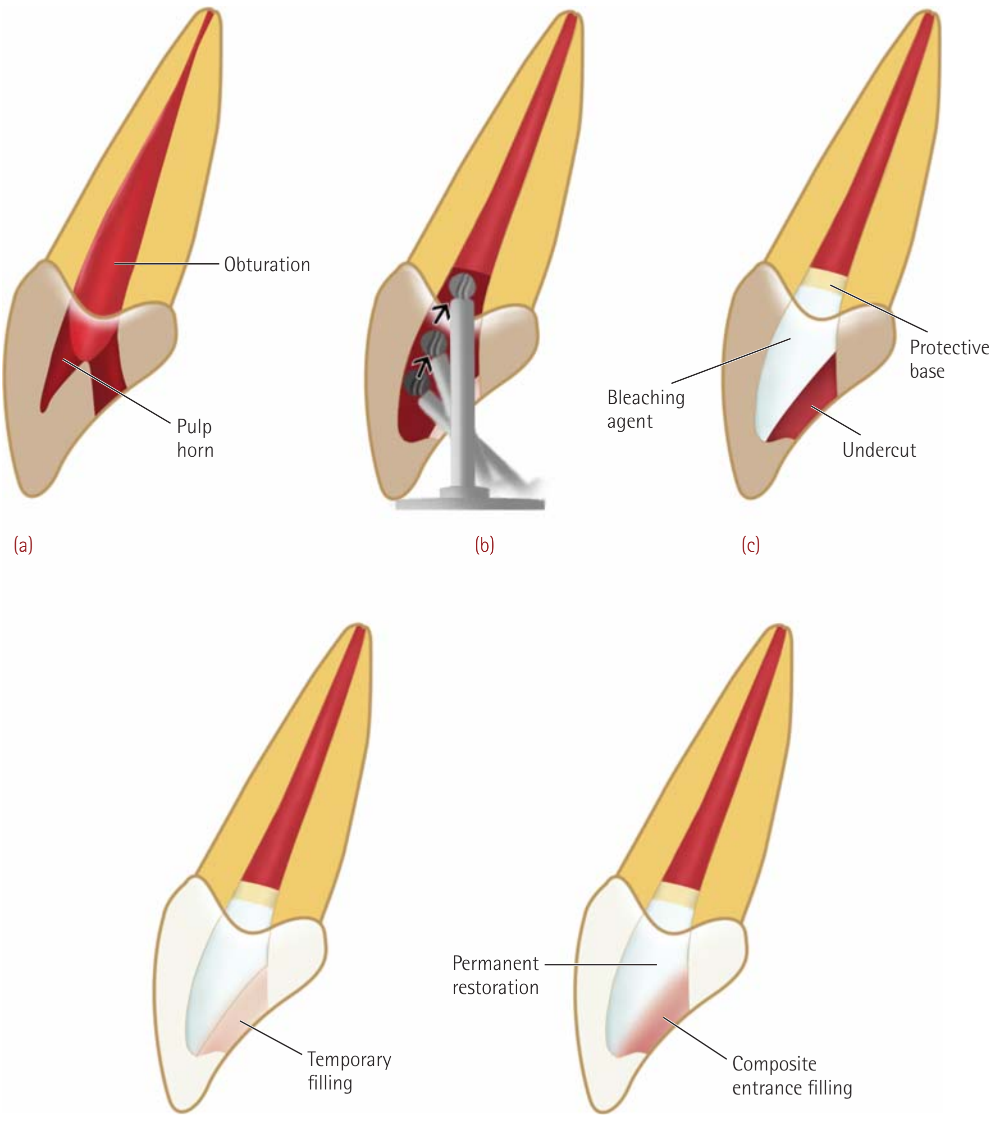


Figure 21.9 Walking bleach: (a) Internal staining of the dentin caused by the remnants of obturating materials in the pulp chamber, as well as by materials and tissue debris in the pulp horns. (b) Coronal restoration is removed completely, access preparation is improved, and gutta-percha is removed apically to just below the cervical margin. Next, the pulp horns are cleaned with a round bur. (Shaving a thin layer of dentin from the facial wall is optional and may be attempted at later appointments if discoloration persists.) (c) A protective cement base is placed over the gutta-percha, not extending above the cervical margin. After removal of sealer remnants and materials from the chamber with solvents, a paste composed of sodium perborate and water (mixed to the consistency of wet sand) is placed. The incisal area is undercut to retain the temporary restoration. (d) A temporary filling seals the access. (e) At a subsequent appointment, when the desired shade has been reached, a permanent restoration is placed. Acid-etched composite restores lingual access and extends into the pulp horns for retention and to support the incisal edge.

Figure 21.12 (a) Documentation with photographs and shade tab. It is often difficult to ascertain tooth shade when hypoplastic bands are present. In these situations, the cervical tooth color is recorded. (b) Perform oral prophylaxis and clean the enamel surface using pumice slurry to remove surface debris. (c) Application of gingival liquid dam to prevent chemical burn. (d) Bleaching gel applied on the labial surfaces of teeth and activated using laser light to catalyze the bleaching reaction. (e) Immediate postbleaching appearance. (f) One week after in-office bleaching procedure and postbleaching care using CPP-ACP. Note the change of tooth color indicated by the shade tab. (*Courtesy: Krithika Datta, India.*)

containing hydrogen peroxide may be used instead of the aqueous solution.
- Apply heat with a heating device or a light source. The temperature should be maintained between 125 and 140°F (52–60°C).
- The treatment time should not exceed 30 minutes even if the result is not satisfactory. Remove the heat source and allow the teeth to cool down for at least 5 minutes.
- Pumice is used on the teeth to remove the residual exposed gel from the enamel surface.
- Remove the bleaching agent and irrigate thoroughly.
- Dry the teeth and gently polish them with a composite resin polishing cup. Apply neutral sodium fluoride gel for 3–5 minutes.
- Instruct the patient to use a fluoride rinse daily for 2 weeks.

Appendix A

Radiographic Technique for Endodontics

The most pathetic person in the world is someone who has sight but no vision.

—Helen Keller

Radiographs are indispensable diagnostic and prognostic aids in endodontics and are one of the most reliable methods of monitoring endodontic treatment. They provide an important visual method of gaining clinical knowledge of teeth and periradicular tissues; therefore, they are essential to the practice of endodontics.

Proper positioning and stabilization of the radiographic film during endodontic procedures becomes difficult because of the interference from the protruding rubber dam clamp or root canal instruments or interference from the obturating material protruding from the access cavity. The visualization of the tooth for proper film positioning and cone angulation is impeded by the presence of the rubber dam. This makes the process of taking a radiograph a difficult proposition.

RADIOGRAPHIC TECHNICAL REQUIREMENTS

1. The image of the tooth being evaluated or undergoing endodontic therapy should be in the center of the radiograph.
2. Radiographs should show at least 5 mm of bone surrounding the apex of the tooth being evaluated or undergoing endodontic therapy.
3. If a periradicular lesion is too large to fit in one periapical film, supplemental diagnostic radiographs must be made.
4. A single radiograph taken from one direction only may not provide sufficient diagnostic information in multirooted teeth or in teeth with curved roots. Under these circumstances, at least two periapical radiographs should be taken to help gain a three-dimensional perspective. One radiograph should be taken at normal vertical and horizontal angulation, while the other should be taken at a 20° change in the horizontal angle from either the mesial or the distal direction (**Fig. A.l**).
5. If a sinus tract is present, a tracing radiograph should be taken. This procedure is accomplished by carefully threading a gutta-percha cone into the tract and by taking a radiograph to identify the origin of the tract. This technique is also useful for localization and depth marking of certain periodontal defects.

Figure A.8 Alignment for correct radiographic angulation for maxillary incisors.

Figure A.9 Alignment for correct radiographic angulation for mandibular incisors.

(e) Make the exposure.
(f) Replace the rubber dam frame.

RADIOGRAPHIC TECHNIQUE FOR POSTERIOR TEETH

1. *Assembly of the endodontic film holder*
   (a) Select an appropriate film holder and posterior rod assembly.
   (b) Slide the beam-alignment ring onto the rod and push it within 2 inches of the film-holding portion of the instrument (**Fig. A.10**). Be sure that the film is centered in the ring and the long axis of the film is parallel to the posterior rod (**Fig. A.11**).

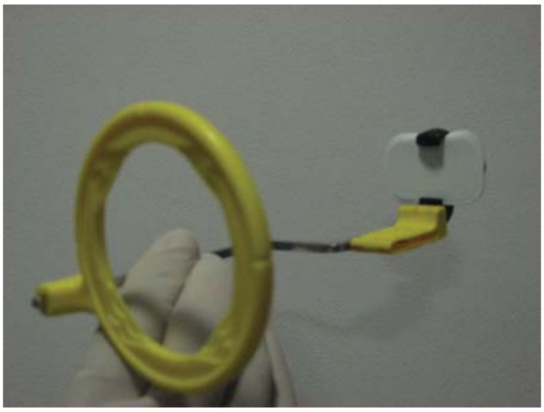


Figure A.10 Beam-alignment ring in place for radiographs of posterior teeth.

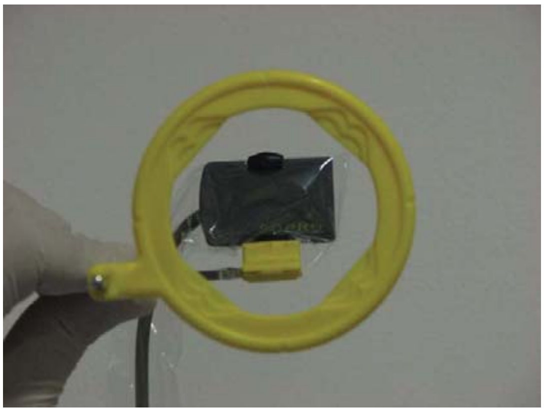
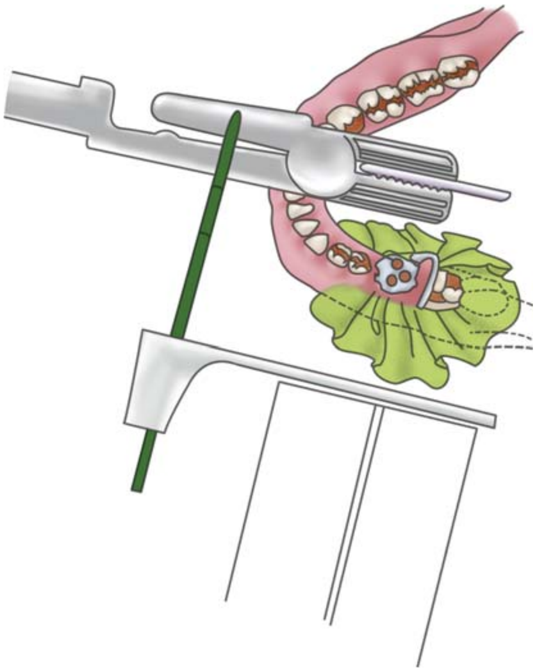
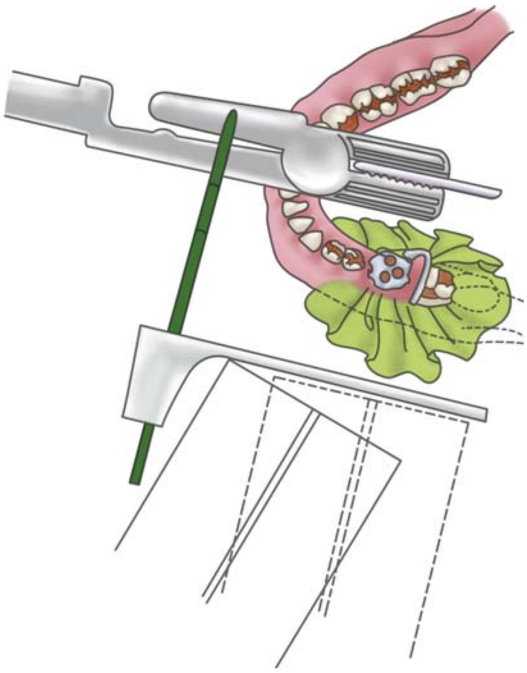


Figure A.11 Ensure that the film is centered in the beam-alignment ring. The long axis of the film is parallel to the posterior rod. *Note.* The film positioning device can also accommodate a digital sensor.

2. *Taking the radiograph*
   (a) Remove the rubber dam frame.
   (b) Insert the assembled instrument and make sure that the tooth is in the center of the film and the film is parallel to the long axis of the tooth (**Fig. A.12**).
   (c) For mandibular radiographs, position the film between the teeth and the tongue and make sure that the lower edge of the film does not impinge on the muscle attachments in the floor of the mouth. Care should be taken that the patient does not displace the film by moving the



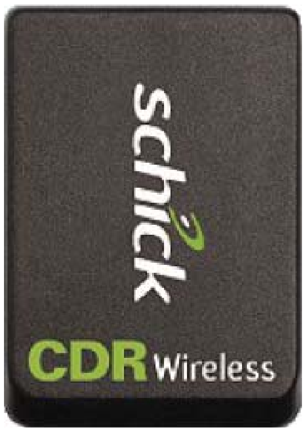
(a)



(b)

Figure A.14 Angulated radiographs. (See the text for details.)

(a)



(b)

Figure A.15 Sensor plate used to capture the image: (a) Sensor with a wire. (b) Wireless sensor.

manipulated in different dimensions with the help of software, which includes enhancement, contrast, magnification, colorize, and reversing (**Fig. A.16**). The image is stored in the computer for records.

Appendix B

Root Canal Configuration

The palest ink is better than the best memory.

—Chinese Proverb

Table B.1 Root Canals and Apical Foramina in Maxillary First Premolars

Investigator	One Canal and One Foramen (%)	One Canal and Two Foramina (%)	Two Canals and One Foramen (%)	Two Canals and Two Foramina (%)	Three Canals (%)
Pineda and Kuttler	26.2	7.7	23.9	41.7	0.5
Green	8.0	–	26.0	66.0	–
Cams and Skidmore	9.0	–	13.0	72.0	6.0
Vertucci and Gegauff	8.0	7.0	18.0	62.0	5.0
Bellizzi and Hartwell	6.2	–	–	90.5	3.3

Table B.2 Root Canals and Apical Foramina in Maxillary Second Premolars

Investigator	One Canal and One Foramen (%)	One Canal and Two Foramina (%)	Two Canals and One Foramen (%)	Two Canals and Two Foramina (%)	Three Canals (%)
Pineda and Kuttler	62.8	8.9	19.0	9.3	–
Green	72.0	–	24.0	4.0	–
Vertucci and colleagues	48.0	–	27.0	24.0	1.0
Bellizzi and Hartwell	40.3	–	–	58.6	1.1

Table B.3 Root Canals and Apical Foramina in Maxillary First Molars: Mesiobuccal Root

Investigator	One Canal and One Foramen (%)	One Canal and Two Foramina (%)	Two Canals and One Foramen (%)	Two Canals and Two Foramina (%)
Weine	48.5	–	37.5	14.0
Pineda and Kuttler	39.0	–	12.5	48.5
Pineda	41.0	–	17.0	42.0
Seidberg and colleagues	38.0	–	37.0	25.0
Pomeranz and Fishelberg	72.0	–	17.0	11.0
Vertucci	45.0	–	37.0	18.0

Table B.4 Root Canals and Apical Foramina in Maxillary Second Molars: Mesiobuccal Root

Investigator	One Canal and One Foramen (%)	One Canal and Two Foramina (%)	Two Canals and One Foramen (%)	Two Canals and Two Foramina (%)
Pineda and Kuttler	64.6	14.4	8.2	12.8
Pomeranz and Fishelberg	62.1	–	13.8	24.1
Vertucci	71.0	–	17.0	12.0

Table B.5 Root Canals and Apical Foramina in Mandibular Incisors

Investigator	One Canal and One Foramen (%)	One Canal and Two Foramina (%)	Two Canals and One Foramen (%)	Two Canals and Two Foramina (%)
Green	80.0	–	7.0	13.0
Rankine-Wilson and Henry	60.0	–	35.0	5.0
Green	79.0	–	17.0	4.0
Madeira and Hetem	88.5	–	11.0	0.5
Benjamin and Dowson	59.0	–	40.0	1.0
Vertucci	92.5	–	5.0	2.5

Table B.6 Root Canals and Apical Foramina in Mandibular Canine

Investigator	One Canal and One Foramen (%)	One Canal and Two Foramina (%)	Two Canals and One Foramen (%)	Two Canals and Two Foramina (%)
Pineda and Kuttler	81.5	–	13.5	5.0
Green	87.0	–	10.0	3.0
Vertucci	80.0	–	14.0	6.0

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