15 Obturation and Temporization

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CHAPTER OUTLINE

LEARNING OBJECTIVES

After reading this chapter, the student will be able to:

1. Explain the objectives of root canal obturation.
2. Explain the rationale for single-visit versus multi-visit endodontic treatment and identify cases when each approach would be indicated.
3. Explain the rationale for smear layer removal.
4. List the ideal properties of an obturation material.
5. Identify obturation materials that have been used historically and explain why these materials are no longer used.
6. Describe the properties, advantages, and disadvantages of gutta-percha.
7. List the ideal properties of a root canal sealer.
8. Identify types of sealers available on the market and describe their properties.
9. Explain how to perform different obturation techniques using gutta-percha as an obturation material.
10. Explain the advantages and disadvantages of different obturation techniques used with gutta-percha.
11. Describe how obturation materials and techniques are evaluated through research studies.
12. Describe how the results of obturation are clinically evaluated and the impact of obturation on treatment outcomes.
13. Explain the rationale for intraorifice barriers and identify materials used as barriers.
14. Explain the importance of restoration following endodontic treatment and list materials used for temporization.

Objectives of Obturation

Success in endodontic therapy is dependent on adequate instrumentation, disinfection, and obturation of the root canal system. The objective of obturation is to create a watertight seal along the length of the root canal system from the orifice to the apical termination. Obturation prevents leakage of microorganisms and their byproducts into the root canal system from a coronal direction and leakage of periapical tissue fluids into the root canal system from an apical direction. This seal allows for prevention and healing of apical periodontitis (Question 15.1). After adequate obturation, an adequate coronal restoration is also necessary and significantly affects the healing of apical periodontitis and the success of root canal therapy.[1]

Interestingly, a periapical lesion may heal at least temporarily after root canal débridement without obturation.[2] Research has shown that when bacteria are eliminated from the root canal system before obturation, healing of a periapical lesion occurs regardless of the quality of obturation.[3] However, if bacteria remain before obturation, healing is related to the quality of obturation.[3] Although failure to obturate or poor obturation are not desirable treatment options, these results demonstrate the important concept that what is removed from the root canal system is more important than how it is filled.

When to Obturate

One versus Two Visits

The endodontic community has long debated the number of visits in which root canal therapy should be completed. Should a tooth be obturated during the same visit when it is instrumented? Factors influencing the answer to this question include the pulpal and periapical diagnoses, the radiographic presentation, the patient's signs and symptoms, the degree of difficulty, patient management issues, and logistic concerns. In some cases, the degree of difficulty of the case dictates that the treatment be completed in more than one visit, for example, very calcified cases when additional time is needed to locate

and instrument canals. Patient management or medical issues may also dictate that treatment be completed in more than one visit, for example, a patient who cannot recline for an extended period of time. Finally, logistic issues may dictate that treatment be completed in more than one visit, for example, a patient presents on an emergency basis, and the dentist has limited time in their schedule to treat the patient.

Opinions vary regarding the advantages and disadvantages of single- versus multiple-visit endodontic treatment when it comes to pulpal and periapical diagnoses, radiographic presentation, and patient signs and symptoms. Consensus exists that a tooth with a vital pulp may have root canal therapy completed in one visit (if time permits), because the canals are not infected. Cases with a vital pulp include those with a pulpal diagnosis of symptomatic irreversible pulpitis, asymptomatic irreversible pulpitis, reversible pulpitis, or a normal pulp. When root canal therapy is performed using proper infection control and disinfection protocols, completing treatment in one visit further precludes the possibility of recontamination of the root canal system caused by coronal leakage between visits. Consensus also generally exists that root canal therapy should not be completed in one visit when the patient has swelling associated with an acute apical abscess, or when the canal cannot be dried as a result of exudate draining from the periapical tissues. In these cases, the clinician should wait until the swelling has resolved and the canal can be dried completely before obturation.

There is disagreement on whether teeth with a necrotic pulp and asymptomatic apical periodontitis, symptomatic apical periodontitis, or a chronic apical abscess should be treated with single- or multiple-visit root canal therapy. The debate centers on the importance of disinfection of the root canal system. The rationale for completing treatment in two visits is that the intracanal medicament placed between visits facilitates disinfection of the root canal system (Question 15.2). This approach is supported by evidence from clinical studies looking at microbial sampling of the root canal system. In a study investigating the role of infection at the time of obturation in teeth that were treated in one visit, teeth were sampled for bacteria before obturation, and all teeth were treated in one visit.[4] After 5 years, complete healing occurred in 94% of cases with a negative culture and in 68% of cases with a positive culture before obturation. These results highlight the importance of completely eliminating bacteria from the root canal system before obturation, which may be aided by an intracanal medicament between visits.

Despite the microbiologic rationale for completing root canal therapy of necrotic teeth in multiple visits using an intracanal medicament, the available outcomes studies do not support an improved prognosis with two-visit treatment. Multiple systematic reviews have found no significant difference in radiologic success of root canal therapy between single- and multiple-visit treatment.[5,6] However, there is some evidence that patients having single-visit root canal therapy may be more likely to experience pain or flare-up and use analgesics in the short-term after treatment.[5,6] Unfortunately, the overall quality of the evidence is poor, because many studies have limitations including low power and risk of bias.[5-7] Thus the debate is ongoing, and the decision to treat in one visit or two is ultimately at the discretion of the clinician for each individual case.

Smear Layer Removal

The smear layer is a combination of organic and inorganic debris present on the root canal walls after instrumentation. When viewed under scanning electron microscope, the smear layer has an amorphous, irregular appearance that represents dentinal shavings, tissue debris, odontoblastic processes, and bacteria and their byproducts.[8] Historically, whether or not to remove the smear layer has been debated; though there is now generalized agreement that the smear layer should be removed before obturation. This is because the smear layer may contain microbes and their byproducts, which would remain in the canal if not removed, and because the smear layer may inhibit adhesion of filling materials to the dentin walls and penetration into dentinal tubules, thereby compromising the seal (Question 15.3). The smear layer is typically removed by irrigation with ethylenediaminetetraacetic acid, which serves as a chelating agent. Proprietary formulations may also be used (e.g., MTAD, SmearClear, QMix).[9]

Obturation Materials

Ideal Properties of an Obturation Material

Grossman suggested the ideal properties of an obturation material[10] (Box 15.1). Currently, no material or combination of materials satisfies all of these criteria.

Core Obturating Materials

Core obturating materials are the primary materials used in obturation and occupy the bulk of the space within the root canal system. Core obturating materials are classified as either solid or semisolid. Solid materials are introduced into the canal as a solid, and they require a sealer to completely seal the canal. Semisolid materials are introduced into the canal in a liquid, paste, or softened form, and then set up within the canal.

Gutta-Percha

Gutta-percha has been used as a root canal filling material for over 160 years.[11,12] It is by far the most popular core obturation material (Video 15.1).

Composition

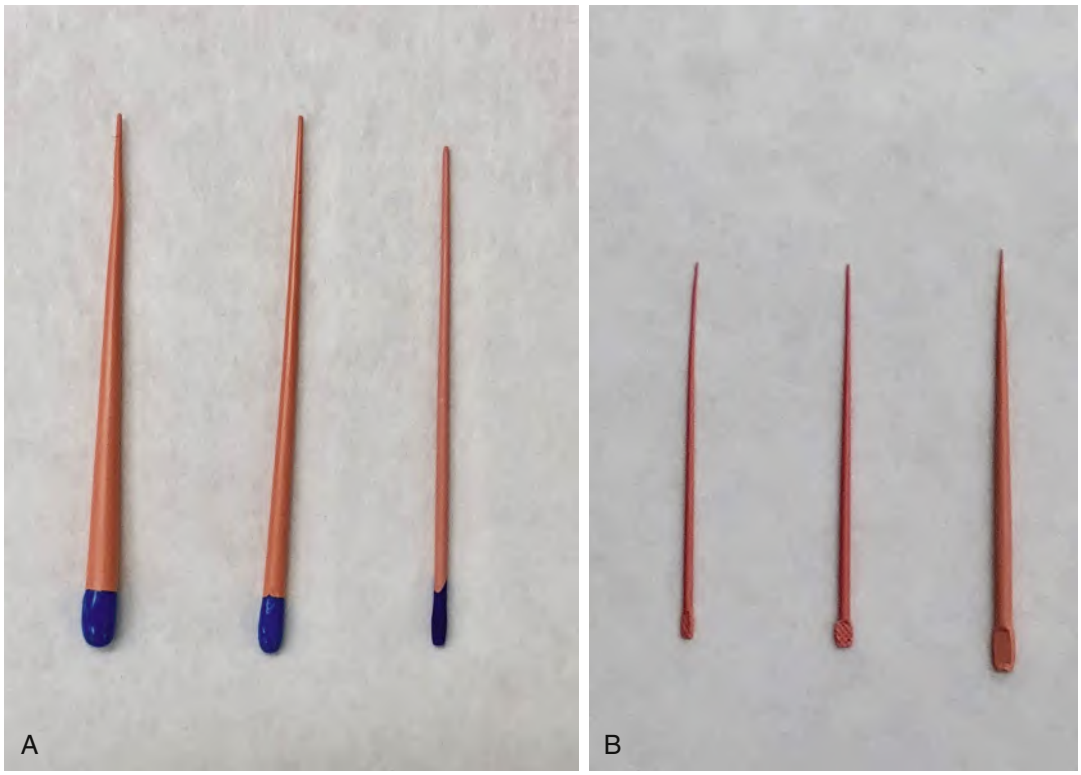
Commercial gutta-percha contains the following ingredients: zinc oxide 59% to 76%, gutta-percha 18% to 22%, waxes and resins 1% to 4%, and metal sulfates 1% to 18%.[13] The gutta-percha is the matrix, and the zinc oxide is the filler. The waxes and resins are the plasticizers, and the metal sulfates, such as barium sulfate, provide the necessary radiopacity.

The stereochemical structure of gutta-percha is 1,4 *trans* polyisoprene, whereas the stereochemical structure of natural rubber is 1,4 *cis* polyisoprene.[14,15] Even though gutta-percha and natural rubber have similar stereochemical structures, studies have shown that there is no cross-reactivity of gutta-percha and natural rubber latex in individuals who have a latex allergy.[16,17]

• BOX 15.1 Desirable Properties of Obturating Materials

Grossman suggested that the ideal obturation material would have the following properties:

- Be easily introduced into the canal
- Seal the canal laterally and apically
- Not shrink after insertion
- Be impervious to moisture
- Be bactericidal, or at least not promote bacterial growth
- Be radiopaque
- Not stain tooth structure
- Not irritate periapical tissues or affect tooth structure
- Be sterile or easily sterilized
- Be easily removed from the root canal



• **Fig. 15.1** Gutta-percha cones are available in a variety of tip sizes and tapers. **(A)** International Organization for Standardization size 30 tip size gutta-percha cones of tapers of 0.02, 0.04, and 0.06. **(B)** Nonstandardized gutta-percha cones with feathered tips.

Gutta-percha has two crystalline forms, alpha and beta.[14,18] Depending on the temperature, gutta-percha can be in different crystalline forms and exhibit different physical characteristics. Commercial gutta-percha comes in the beta crystalline form at room temperature. When the beta form is heated to 42°C to 49°C, it transitions into the alpha phase. When alpha phase gutta-percha is heated above 53°C to 59°C, it transitions into the amorphous phase. This is important when the clinician needs the amorphous form of gutta-percha to flow into all parts of the root canal system utilizing thermoplastic techniques.[19-22]

Shapes

Gutta-percha is formed into either standard or nonstandard cones of different tip sizes and tapers (Fig. 15.1). Standardized cones conform to the requirements of the International Organization for Standardization (ISO) or the American Dental Association/American National Standards Institute (ADA/ANSI). Nonstandardized (conventional) gutta-percha cones do not conform to the standards set by ISO or ADA/ANSI. Standardized gutta-percha cones are manufactured to have the same tip size and taper as the corresponding endodontic instruments used in the preparation of the root canal system. The original specifications called for gutta-percha to have a taper of .02 mm per millimeter increase in length. With the advent of various tapers in endodontic files, gutta-percha cones now come in various tapers, including .04, .06, and so on. Nonstandardized gutta-percha cones end in a feathered tip. Gutta-percha used with thermoplasticizing devices is manufactured as pellets or contained in cartridges (Fig. 15.2). The pellets or cartridges are inserted into a thermoplasticized gutta-percha injection system, and the gutta-percha is heated before dispensing.

• **Fig. 15.2** Gutta-percha for use in thermoplasticized injection systems is manufactured in cartridges and pellets that fit into their corresponding injection systems.

Advantages

Gutta-percha is by far the most popular and widely accepted root canal filling material. Although it does not meet all of the criteria for an ideal filling material, it satisfies most of them. Gutta-percha has a number of advantages. First, because of its plasticity, gutta-percha adapts well when compacted into prepared root canals, especially when thermoplasticized. Second, gutta-percha has good handling characteristics and is easy to manipulate with multiple obturation techniques. It is relatively stiff and easily placed into canals. Third, gutta-percha is relatively easy to remove from the root canal system, either to create post space or for retreatment. Fourth, gutta-percha is regarded as a very acceptable material with good biocompatibility with the periapical tissues (Question 15.4).

Sealability

To produce an adequate seal, gutta-percha must be used with a sealer.[10] Gutta-percha does not adhere to canal walls, so the space between the gutta-percha and the canal wall must be sealed with a root canal sealer. Additionally, the application of heat or solvents to gutta-percha during different obturation techniques can cause gutta-percha to shrink, further increasing the space between the canal wall and gutta-percha core.

Other Additives to Gutta-Percha

Other ingredients have been added to some brands of gutta-percha to increase its antibacterial properties. Calcium hydroxide has been added to gutta-percha points by Coltene/Whaledent (Langenau, Germany). Activ Point (Coltene/Whaledent, Langenau, Germany) contains chlorhexidine. Other gutta-percha has been introduced that contains iodine-polyvinylpyrrolidone. Although these additives to gutta-percha have been shown to be effective against various bacteria,[23-27] long term clinical studies have not been conducted.

Carrier-Based Gutta-Percha

Several brands of carrier-based gutta-percha are on the market (Fig. 15.3). Carrier-based obturators are composed of gutta-percha surrounding a carrier that is heated and then placed into the canal. The handle of the carrier is cut off and removed, leaving the gutta-percha and carrier in the canal. Many obturators are designed to fit corresponding file systems. Several carrier-based obturators are marketed by Dentsply Sirona (York, PA), including GuttaCore, GuttaCore for WaveOne Gold, WaveOne Gold Obturators, ProTaper Next Obturators, ProTaper Universal Obturators, Thermafil Plus Obturators, Vortex Obturators, GT Obturators, and GT Series X Obturators. Soft-Core is a similar carrier-based obturator marketed by Kerr Endodontics (Orange, CA). SimpliFill (Kerr Endodontics) is a 5-mm apical plug of gutta-percha on the end of a metal carrier. It has the advantage of not leaving the carrier in the canal, as the carrier is twisted off and removed, leaving only the apical plug of gutta-percha. SuccessFil is a carrier-based gutta-percha system that is combined with the UltraFil thermoplasticizied injection system to create what is marketed as the Trifecta System (Coltene/Whaledent, Langenau, Germany). JS Quick-Fill (JS Dental Manufacturing, Inc, Ridgefield, CT) is an alpha phase gutta-percha coated titanium core in ISO sizes 15 to 60. The carrier-based material is spun into the canal at low speed, and the core may be left in the canal or slowly removed.

Mineral Trioxide Aggregate

Mineral trioxide aggregate (MTA) is a bioactive calcium silicate material that has many clinical applications in endodontics, including vital pulp therapy, perforation repairs, and root end surgery.[28,29] MTA is used as an obturation material in cases of immature or open apices[29] (Fig. 15.4). Attributes of MTA include biocompatibility, sealability, and a history of documented positive clinical outcomes. Similar to MTA, some of the more recently introduced bioceramic materials can also be used as obturation materials in this fashion. Teeth with open apices where obturation with MTA or other bioceramic material would be indicated are considered moderate or high level of difficulty cases, and referral to a specialist is typically recommended (Video 15.2).[30,31]

• **Fig. 15.3** Most obturators consist of a carrier core surrounded by gutta-percha. The obturator is warmed and inserted into the canal. **(A)** GuttaCore obturators. (Courtesy Dentsply Sirona.) **(B)** SimpliFill is a type of carrier-based obturator that is not heated. The metal carrier is twisted off, leaving only an apical plug of gutta-percha. SimpliFill is available in large apical sizes. (Courtesy Kerr Endodontics.)

Silver Points

Silver points were used historically in the mid-1900s and were manufactured to match the size and taper of endodontic hand files used in canal preparation at that time (Fig. 15.5). Thus silver points had a 0.02 taper. Silver points fulfilled some of Grossman's requirements of an ideal obturation material. They were easy to insert and had good length control. However, they did not seal well laterally or apically as a result of their lack of plasticity.

• **Fig. 15.4** Four-year follow-up radiograph of tooth #9 that was obturated with MTA when the patient was 7 years old. The patient experienced trauma, and the tooth became necrotic before the apex had fully matured.

• **Fig. 15.5** Silver points had a 0.02 taper and were manufactured in a variety of tip sizes to match endodontic hand files.

Silver points did not adequately fill all of the canal space and could not be compacted into voids within the root canal system. The shape of silver points remained round after insertion, and canals are rarely prepared to a perfectly round shape. The remaining space was filled with sealer, leading to leakage. This leakage allowed for corrosion of the silver points and the formation of silver salts, which were found to be cytotoxic.[32-36] With modern techniques, instrumentation and obturation of smaller canals with gutta-percha is predictable, so the use of silver points declined as a result of their disadvantages. Silver points are not recommended for use in modern endodontic therapy.[37] The characteristic appearance of silver points make them easily identifiable on patients' periapical radiographs (Fig. 15.6). These teeth may require retreatment if pathosis is present or post space is needed; however, prophylactic retreatment of teeth obturated with silver points is not indicated.[37]

Resin

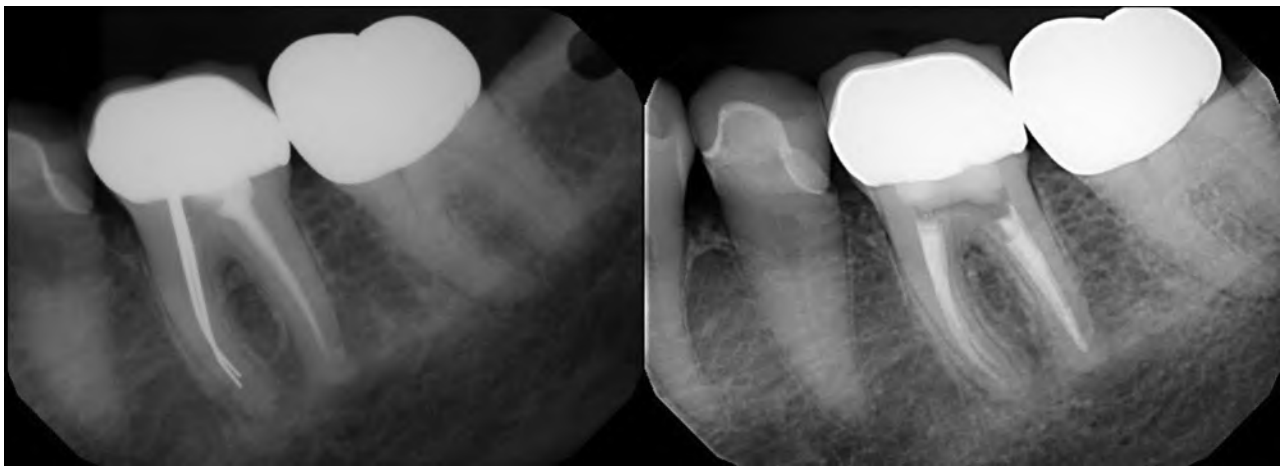
Resin-based obturation materials were used in the early 2000s. Resilon and RealSeal were composed of a polycaprolactone core material with difunctional methacrylate resin, bioactive glass, bismuth and barium salts as fillers, and pigments. These products were used with a resin sealer (Epiphany or RealSeal) that was packaged with the core filling material. The rationale for the product was to create a "monoblock," consisting of a resin sealer with resin tags that enter and bond to dentinal tubules on the canal wall, and which also adhesively bonds to the core material. The product was light cured and sealed coronally as well. The system consisted of a primer, a sealer, and synthetic polymer points or pellets. Research has shown no advantage of these materials over gutta-percha,[38-44] and resin-based obturating materials are no longer on the market.

Pastes (Semisolids)

Pastes are a type of semisolid material that have been used as a core filling material. Zinc oxide is a major component of most paste materials. Because of the solubility of zinc oxide, these pastes do not make effective core filling materials. Other disadvantages of pastes include difficult length control, shrinkage of the material, voids in obturation, and toxic ingredients in some pastes.

One paste filling material is a resorcin-formaldehyde paste, which is a type of phenol-formaldehyde or Bakelite resin.[45,46] Because this material has been widely used in Eastern European countries, and because it stains teeth a characteristic dark red color, it is commonly referred to as *Russian Red* (Fig. 15.7). This material has the advantage of being very antimicrobial, but has the disadvantage of shrinkage once placed in the canal. Additionally, retreatments can be very difficult if the resin sets completely and there is sufficient bulk to the material[46] (Fig. 15.8).

Paraformaldehyde-based pastes are another type of paste fill. The rationale for adding paraformaldehyde to pastes is to provide antimicrobial and mummifying effects. However, paraformaldehyde has severe toxicity to host tissues, and this negates the benefit of any antimicrobial effects it may possess in endodontic materials. These pastes are known as N2 (Indrag-Agsa, Losone, Switzerland), Sargenti, or RC2B, and are made of a liquid and powder. The powder contains zinc oxide, bismuth nitrate, bismuth carbonate, paraformaldehyde, and titanium oxide. The liquid consists of eugenol, peanut oil, and rose oil.[47] N2 has changed in response to studies identifying toxic substances, such as lead oxide, and organic mercury.[48] However, it still contains 4% to 8% paraformaldehyde.[49] N2 is extremely toxic,[50,51] and because it is used as a paste, the extrusion of this material has caused permanent damage in many cases. The material affects bone and soft tissue and can cause permanent neurologic damage resulting in paresthesia, dysesthesia, and pain. Because of the toxicity, risks to patients, legal issues, and the fact that there are numerous other acceptable obturating materials available that provide a better outcome, the use of these materials in modern day endodontics is not acceptable. The Food and Drug Administration lists N2 as an unapproved drug that is not legally imported or shipped across interstate lines, and the ADA does not approve of its use.[52,53] In summary, use



• **Fig. 15.6** The mandibular left first molar was initially obturated with silver points, and the tooth was retreated decades later when the patient presented with symptomatic apical periodontitis. Note the characteristic appearance of the silver points in the mesiobuccal and mesiolingual canals of the preoperative radiograph on the left. The postoperative radiograph on the right is the tooth after retreatment and filling with gutta-percha. (Courtesy Dr. Patrick Mullally.)

of paraformaldehyde-containing endodontic filling materials and sealers is below standard of care, as they have been shown to be both unsafe and ineffective.[54]

Sealers

Sealer is used in conjunction with a core obturating material and is necessary to fulfill the objective of creating a watertight seal in the root canal system (Question 15.5). In addition to the basic requirements for core filling materials, Grossman also identified the ideal requirements for a root canal sealer (Box 15.2).[10] As with core obturation materials, no sealer currently satisfies all of these criteria.

Additionally, the following two requirements could be added to Grossman's original basic requirements: it should not provoke an immune response in periradicular tissues,[55-58] and it should be neither mutagenic nor carcinogenic. [59,60]

Types of Sealers

The primary sealers in use today are those based on zinc oxide eugenol (ZOE), resin, calcium hydroxide, or bioceramics.

Zinc Oxide Eugenol Sealers

Zinc oxide eugenol (ZOE)-containing sealers have been widely used with success for many years. There are many formulations and brands of sealers with zinc oxide as the primary ingredient, differing only by other added components. ZOE sealers allow for the addition of chemicals, such as paraformaldehyde, rosin, Canada balsam, and others, all of which may increase the toxicity of that particular sealer.[49] Grossman's original formula contained zinc oxide, hydrogenated or Staybelite resin, bismuth subcarbonate, barium sulfate, and sodium borate (anhydrous), with eugenol as the liquid component.[61] It has been marketed as Proco-sol sealer (StarDental, Lancaster, PA), as well as other product names. Roth's 801 and 811 sealers (Roth's International LTD, Chicago, IL) were essentially the same as Grossman's original formulation, with the substitution of bismuth subnitrate for bismuth subcarbonate. Despite its popularity, production of Roth's sealer recently ceased.

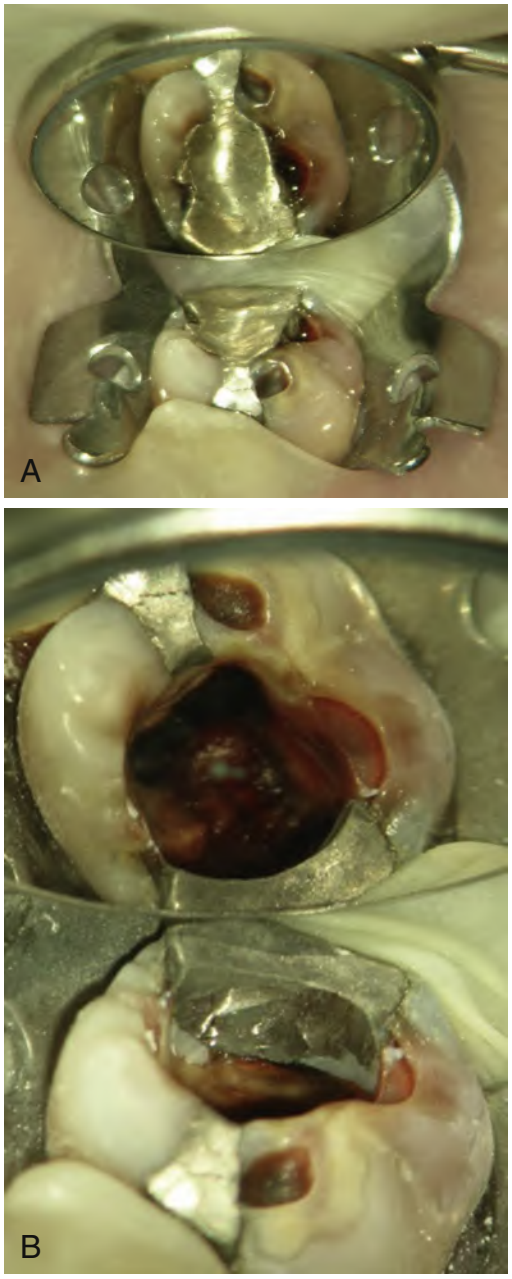
Rickert's was one of the first zinc oxide sealers. The powder contains zinc oxide, silver, resins, and thymol iodide. The liquid is eugenol, and Canada balsam. One disadvantage is that the silver used to provide radiopacity can also cause staining of tooth structure. Another disadvantage is its rapid setting time in areas of high humidity and heat. Rickert's sealer is marketed as Kerr Pulp Canal Sealer (Kerr Endodontics, Orange, CA), which has traditionally been popular with clinicians who use the warm vertical obturation technique. Pulp Canal Sealer Extended Working Time (EWT) (Kerr Endodontics, Orange, CA), with a working time of 6 hours, was introduced to lengthen the setting time over Kerr Pulp Canal Sealer.[62]

Tubli-Seal (Kerr Endodontics, Orange, CA) was developed as a nonstaining alternative to the silver containing Pulp Canal Sealer. Tubli-Seal comes as two separate tubes. One tube contains a zinc oxide-base paste with barium sulfate for radiopacity, mineral oil, cornstarch, and lecithin. The catalyst tube contains polypale resin, eugenol, and thymol iodide. Tubli-Seal is easy to mix and has a short setting time.[62] Tubli-Seal EWT was developed to provide extended working time.

Wach's cement is made up of a powder of zinc oxide, bismuth subnitrate, bismuth subiodide, magnesium oxide, and calcium phosphate. The liquid consists of oil of cloves, eucalyptol, Canada balsam, and beechwood creosote. Wach's cement has a distinctive odor of an old-time dental office.[62] It has a smooth consistency, and the Canada balsam makes the sealer tacky. Medicated Canal Sealer (Medidenta, Woodside, NY) contains iodoform for antibacterial purposes and is to be used with MGP gutta-percha, which also contains 10% iodoform.[63]

Calcium Hydroxide Sealers

Sealapex (Kerr Endodontics, Orange, CA) is a noneugenol polymeric sealer that contains calcium hydroxide. It is packaged in two tubes, one of which is a base, and the other a catalyst. Sealapex has zinc oxide in the base plus calcium hydroxide. It also contains butyl benzene, sulfonamide, and zinc stearate. The catalyst tube has barium sulfate and titanium dioxide for radiopacity, and a proprietary resin, isobutyl salicylate, and AEROSIL R792.[62] Sealapex has similar sealing ability as Tubli-Seal.[64] Apexit



• **Fig. 15.7** This mandibular molar was treated with a resorcinol-formaldehyde resin paste. Dark red-stained dentin can be seen both through the occlusal surface and upon access. The dentin is solid.

(Ivoclar Vivadent, Schaan, Liechtenstein) is a calcium hydroxide sealer with salicylates also incorporated into the formula. CRCS (Calciobiotic Root Canal Sealer, Coltene/Whaledent, Mahwah, NJ) is a calcium hydroxide-containing sealer that has a zinc oxide-eugenol and eucalyptol base. CRCS is a rather slow-setting sealer, especially in dry or in humid climates. It may require up to 3 days to fully set.[62] The set sealer is quite stable, which improves its sealing qualities, but may mean that calcium hydroxide is not as readily released and the stimulation of cementum and bone formation may be severely limited.

Resin Sealers

Epoxy resin sealers have been used in endodontics for some time, including AH26, and its successor AH Plus (Dentsply Sirona, York, PA). AH26 is a sealer that has been used for many years. It is a bisphenol epoxy resin sealer that uses hexamethylenetetramine (methenamine) for polymerization.[45,65] A major disadvantage of AH26 was that the methenamine gave off formaldehyde as it set. It would also stain tooth structure and had an extended working time. One advantage of AH26 is it was not affected by moisture.[62] AH Plus and ThermaSeal Plus (Dentsply Sirona, York, PA) are formulated with a mixture of amines that allows for polymerization without the unwanted formation of formaldehyde.[65,66] They have the advantages of AH26, which include increased radiopacity, low solubility, slight amount of shrinkage, and tissue computability. AH Plus is an bisphenol epoxy resin that also contains adamantine.[45] AH Plus comes in a two paste system, unlike the liquid-powder system of AH26, and has a working time of 4 hours and a setting time of 8 hours. Additional improvements of AH Plus over AH26 include thinner film thickness and decreased solubility.

Bioceramic Sealers

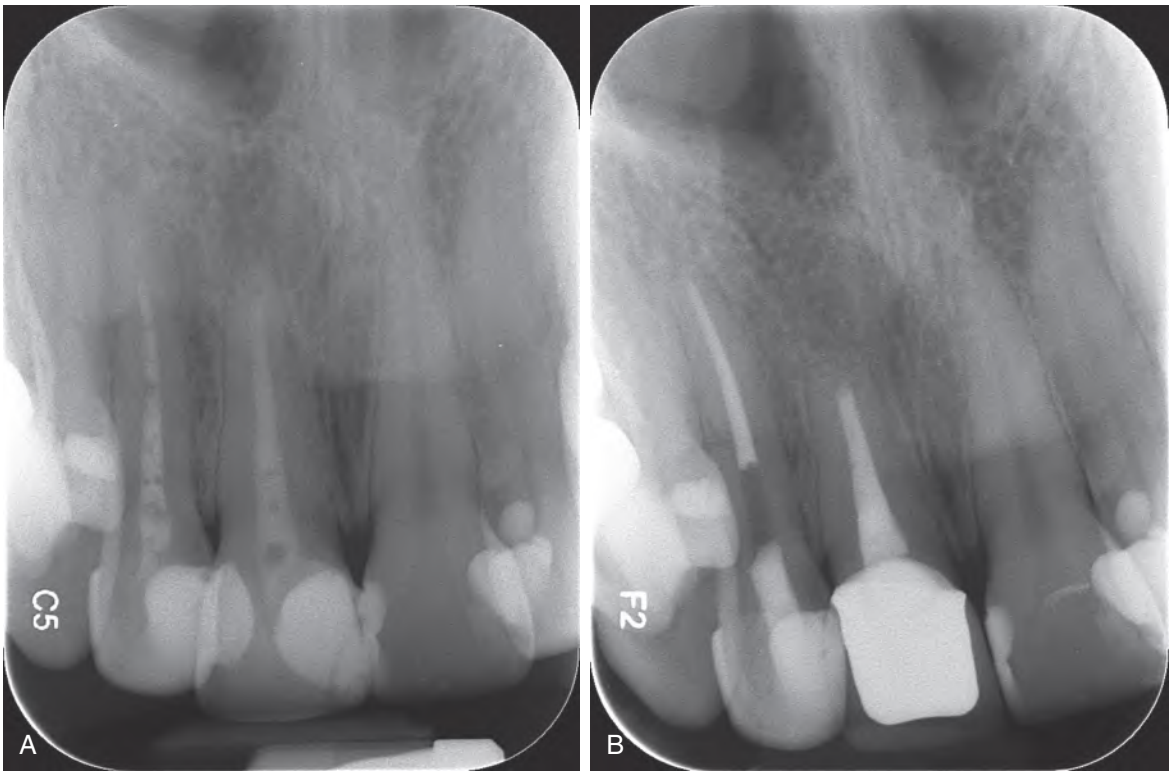
Mineral trioxide aggregate (MTA) is a calcium silicate bioceramic material, which has many applications in endodontics. MTA has been a very successful material because of its biologic and physical characteristics. MTA is extremely biocompatible and provides a good seal. Because of these biologic and physical attributes, several bioceramic sealers are now on the market. ProRoot Endo Sealer (Dentsply Sirona, York, PA) is an MTA-based sealer manufactured in a powder and gel form. The powder is MTA with enhanced radiopacity, which contains tricalcium silicate, dicalcium silicate, calcium sulfate, bismuth oxide, and a small amount of tricalcium aluminate. The gel is a viscous aqueous solution of a water soluble polymer. MTAFillapex (Angelus, Londrina, PR, Brazil) is a dual paste system. It contains salicylate resin, diluent resin, natural resin, bismuth oxide, nanoparticulate silica, MTA, and pigments. Endosequence BC Sealer (Root SP) (Brasseler USA, Savannah, GA) is a calcium silicate based sealer manufactured as a single paste system. It contains zirconium oxide, calcium silicates, calcium phosphate monobasic ($CaH_2P_2O_8$), calcium hydroxide, filler, and thickening agents. iRoot SP (Innovative BioCeramix Inc., Vancouver, Canada) is another calcium silicate based sealer that contains zirconium oxide, calcium silicates, calcium phosphate, calcium hydroxide, filler, and thickening agents.

Silicone Based Sealers

Silicone based sealers provide adhesion, a moisture resistant seal, and stability.[45] Lee Endo-Fill (Lee Pharmaceuticals, El Monte, CA) is a silicone based root canal sealer. RoekoSeal (Coltene/Whaledent, Langenau, Germany) is a polyvinylsiloxane that is a white paste-like sealer and will polymerize without shrinkage, which results in less leakage.[45,67] It utilizes platinum as a catalyzing agent.[45] GuttaFlow (Coltene/Whaledent, Langenau, Germany) is a polyvinylsiloxane that has finely milled gutta-percha particles added to the RoekoSeal sealer. GuttaFlow additionally contains silicone oil, paraffin oil, platin catalyst, zirconium dioxide, nano-silver as a preservative, and a coloring agent. It does not contain eugenol. GuttaFlow is a cold flowable gutta-percha filling system for the obturation of root canals. GuttaFlow is triturated in its cannula and passively injected into the canal and then used with single or multiple gutta-percha points.

Urethane Methacrylate Sealers

EndoREZ (Ultradent, South Jordon, UT) is a hydrophilic urethane dimethacrylate (UDMA) resin sealer that reportedly has



• **Fig. 15.8** The maxillary right lateral and central incisor were treated with a resorcinol-formaldehyde resin paste. **(A)** The teeth have characteristic voids visible radiographically in the obturation, especially tooth #7, as seen in this preoperative radiograph. All of the paste could not be removed during nonsurgical retreatment of tooth #8, so root-end surgery was performed. **(B)** Tooth #7 was later successfully retreated nonsurgically, as shown in this postoperative radiograph.

• BOX 15.2 Requirements for an Ideal Root Canal Sealing Material

1. It should be tacky when mixed to provide good adhesion between it and the canal wall when set.
2. It should make a hermetic [sic] seal.
3. It should be radiopaque so that it can be visualized on the radiograph.
4. The particles of powder should be very fine so that they can mix easily with the liquid.
5. It should not shrink upon setting.
6. It should not stain tooth structure.
7. It should be bacteriostatic or at least not encourage bacterial growth.
8. It should set slowly.
9. It should be insoluble in tissue fluids.
10. It should be tissue tolerant, that is, nonirritating to periapical tissues.
11. It should be soluble in a common solvent, if it is necessary to remove the root canal filling.

good canal wetting and flow into dentinal tubules.[67] The hydrophilic property improves its sealing abilities if some moisture is still in the canal at obturation.[45] EndoREZ is introduced into the canal with a narrow 30-gauge NaviTip needle (Ultradent). A single gutta-percha point, or the lateral compaction obturation technique, may be utilized. EZ Fill (Essential Dental Systems, South Hackensack, NJ) is a noneugenol epoxy resin sealer that is placed with a bidirectional spiral rotating in a hand piece. It may be used with a single gutta-percha point technique. It is nonshrinking on setting and is hydrophobic, rendering it resistant to fluid degradation.

Evaluation and Comparison of Sealers

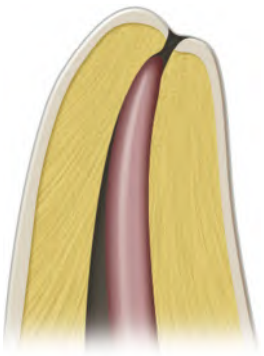
Orstavik[45,68] has listed the various evaluation parameters for testing endodontic sealers. They include technologic tests that have been standardized by the ISO and ADA/ANSI internationally and in the United States. These technological tests include flow, working time, setting time, radiopacity, solubility and disintegration, and dimensional change after setting. Additionally, biologic tests, usage testing, and antibacterial testing are useful. Clinical testing should be included to establish outcomes of treatment.

Study Questions

1. What is the primary objective of obturation?
2. What is the rationale for completing root canal therapy in two visits versus one visit?
3. Why is the smear layer removed before obturation?
4. What are the advantages of gutta-percha as a core obturation material?
5. Why must a sealer be used when obturating with gutta-percha?

Obturation Techniques with Gutta-Percha

Gutta-percha is the most widely used and clinically acceptable obturation material, thus the techniques described in this chapter will focus on the use of this material. Gutta-percha is available in many different forms and sizes, both gutta-percha cones and gutta-percha for thermoplasticized injection systems (see Figs. 15.1 and 15.2). The choice of obturation method is primarily based on clinician training and preference, as well as the specific anatomy of each case. There are



• **Fig. 15.9** The master cone should have slight frictional fit in the most apical portion of the canal.

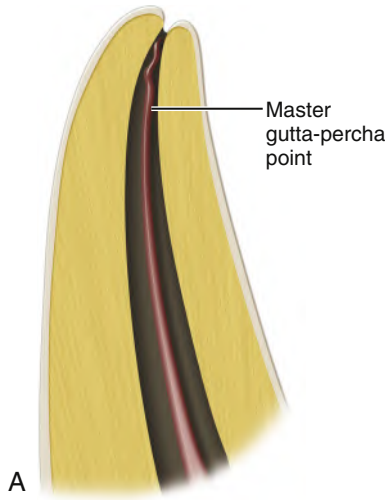
attributes and limitations of each technique, but no significant difference in outcomes has been demonstrated between contemporary obturation techniques using gutta-percha (Video 15.1).[69,70]

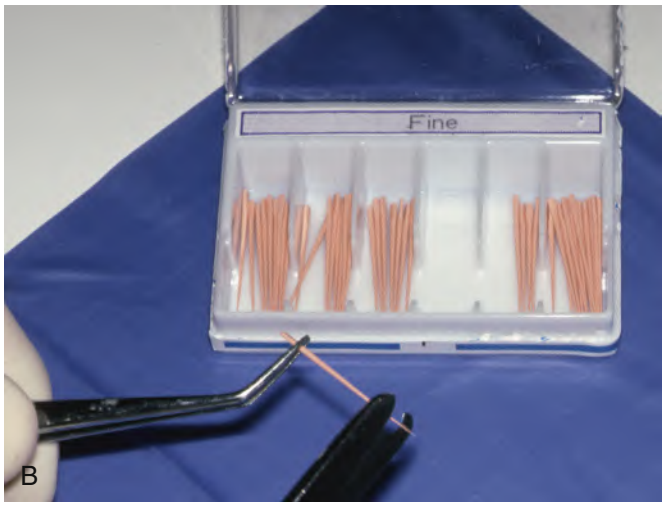
Cold Lateral Condensation

Cold lateral condensation (commonly referred to as lateral condensation or lateral compaction) is the most common obturation technique taught to predoctoral dental students.[71] Advantages of lateral condensation are that it can be used in a wide variety of cases, does not require specialized equipment, and has a track record of clinical success. In addition, lateral condensation is safe and simple to learn for novice clinicians; it is less technique-sensitive than other methods and has predictable length control (less likely to overfill). A disadvantage of lateral condensation is that it requires more time than some filling techniques.[72] In addition, it is challenging to use in some clinical cases (e.g., very curved canals, internal resorption, wide open apices, or other anomalous canal anatomy) (Question 15.6). However, these cases are considered "high difficulty" and are typically referred to a specialist for treatment.[30,31]

The technique for lateral condensation, and all obturation techniques, varies slightly from clinician to clinician. The following is a description of a traditional lateral condensation technique.

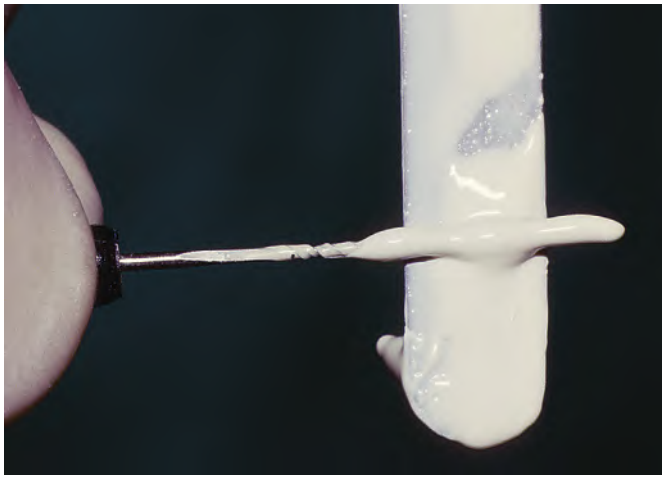
1. The canal is dried. A paper point placed to working length should come out of the canal dry, with no irrigant, blood, or exudate on it.
2. A master gutta-percha cone is selected. Gutta-percha cones should be handled using cotton pliers (locking are preferred), and measured using a millimeter ruler. In classic cold lateral condensation, the master cone is a 0.02 taper cone and has a tip size that matches the master apical file size to which the canal has been prepared. The selected cone should seat to working length, not be able to be pushed beyond working length, and exhibit a sensation of slight resistance when removing the cone from the canal. This resistance (referred to as *tug-back*) indicates that the cone is binding the walls of the canal (Fig. 15.9). A master cone that does not seat all the way to working length is too large (i.e., it is binding short of working length). A master cone that can be pushed beyond working length is too small (i.e., it is not binding at working length and overfilling will result). A master cone that does not display any resistance upon removal is also too small (i.e., it is not snug at working length), though this sensation can be difficult to detect. Careful inspection should catch any cone that buckles when placed to working length and removed; this indicates that the cone does not fit well. A cone that buckles near the tip may be too small (Fig. 15.10). A cone that buckles more coronally may be too large (it will appear that the cone is seating to working length because the cotton pliers seat to the reference point, but the cone will be short as a result of the buckling). Variations of selecting a master cone preferred by some clinicians include using a 0.04 taper cone or a nonstandardized cone with the tip cut to a custom diameter. Specialized instruments are available on the market to help cut the tip of gutta-percha cones to a specific diameter (Fig. 15.11). Often the clinician may try multiple master cones, even of the same size, before selecting the master cone they want to use for obturation of a canal. As a result of manufacturing variations, there will be variations in gutta-percha cone actual sizes, even among those labeled as the same ISO size and taper.[73]
3. Sealer is placed in the canal. Different methods have been used to apply sealer to the walls of the canal. These include using a hand file place to length and spinning counterclockwise, using a lentulo spiral drill, and using the master cone (Fig. 15.12). The goal is to have a thin layer of sealer on all walls of the canal. In most cases, sealer is placed both in the canal before seating the master cone, and on the master cone itself before seating it. The choice of sealer type is up to the discretion of the clinician.





• **Fig. 15.10** **(A)** A master cone that buckles near the tip when inserted into the canal is too small. **(B)** A larger cone should be selected or clipped to form a larger size at the tip.

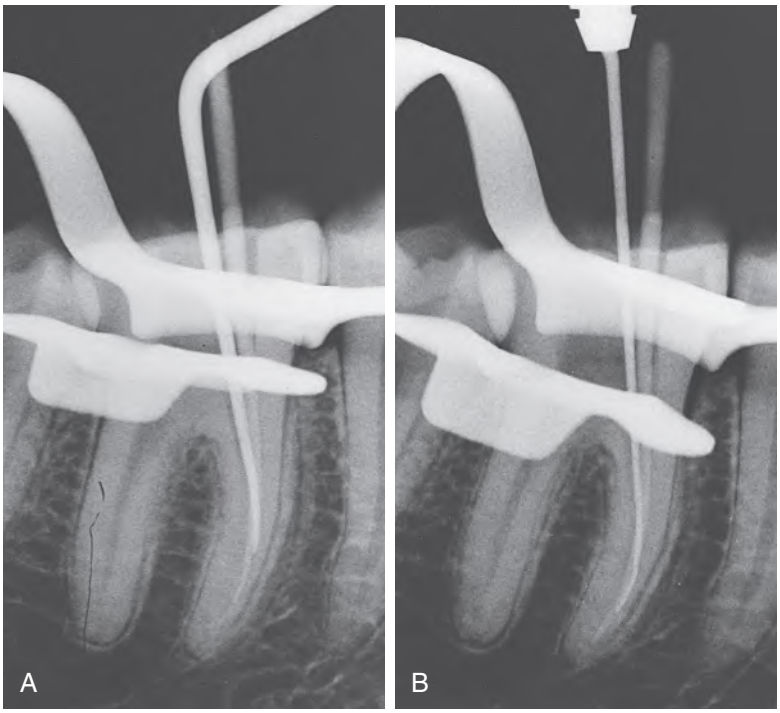
• **Fig. 15.11** Specialized instruments for cutting gutta-percha cones to a customized International Organization for Standardization tip size are commercially available. **(A)** Gutta Gauge. (Courtesy Dentsply Sirona.) **(B)** Tip Snip. (Courtesy Kerr Endodontics.)



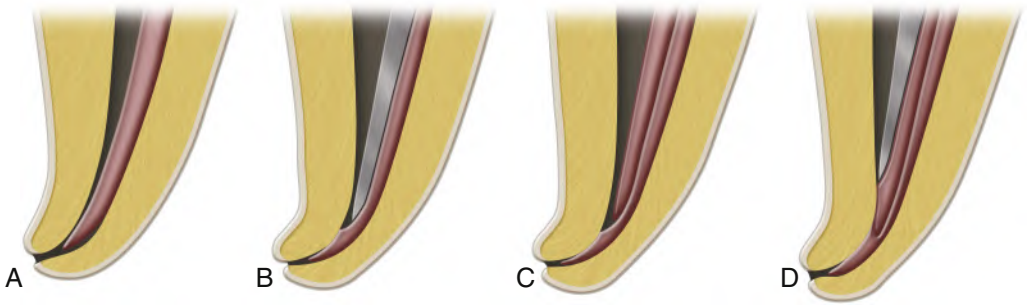
• **Fig. 15.12** A simple, effective method of sealer application. A hand file covered with sealer is inserted into the canal and spun counterclockwise to coat the canal walls.

• **Fig. 15.13** Size 30 finger spreader. (Courtesy Dentsply Sirona.)

4. Sealer is placed on the master cone, and the master cone is seated in the canal to working length. The cone is seated using gentle, continuous pressure. If the cone does not seat to length on the first attempt, it should be pulled out a few millimeters and slowly reseated. The master cone may need to be gently "pumped" up and down a few times to get the cone to seat to the desired working length.
5. A spreader is selected for use in lateral condensation. The length, size, and degree of taper varies between spreaders. Nickel-titanium finger spreaders or stainless steel hand spreaders may be used (Fig. 15.13). Nickel-titanium finger spreaders have the advantages of being able to be inserted into the canal to a greater depth while exerting less force on the canal walls[74-76] (Fig. 15.14). Finger spreaders also are preferred by many because they are gripped and used in a fashion similar to finger files, and they may be easier to access difficult areas of the mouth. The chosen spreader should be able to be placed in the canal to within approximately 1 to 2 mm of the working length.
6. The spreader is placed into the canal and rotated using a back-and-forth motion, keeping the long axis of the spreader in the same plane, to create lateral space within the canal. Moderate pressure is applied in an apical direction, while rotating the handle through an arc of approximately 30 degrees. The apical force is kept on the long axis of the spreader. The spreader will feel looser as it is moved in this motion. The spreader is removed from the canal also using a back-and-forth motion. During removal of the spreader, it is recommended to hold the tip of the cone(s) that have already been seated in the canal, to prevent the master cone and any accessory cones from being dislodged from working length.
7. Accessory cones are added in the space created by the spreader (Fig. 15.15). Different types of accessory cones may be used, and the cones are matched to the spreader size. Commonly, nonstandardized cones or size 25, 0.02 taper standardized cones are used as accessory cones. In very large canals, larger accessory cones and a larger size spreader may be used. Caution must be exercised during lateral condensation not to use too much force in the canal during the condensation process (this same caution should be used during other techniques as well). It is recommended that the force used should be no more than 2.5 lbs, in order to avoid vertical root fracture[77,78] (Fig. 15.16).
8. Most clinicians choose to expose a radiograph after the master cone is seated in the canal. The purpose for the "master cone radiograph" is to check that the gutta-percha is seated to the desired working length (not short and not long). Alternatively, the clinician may choose to add one to two



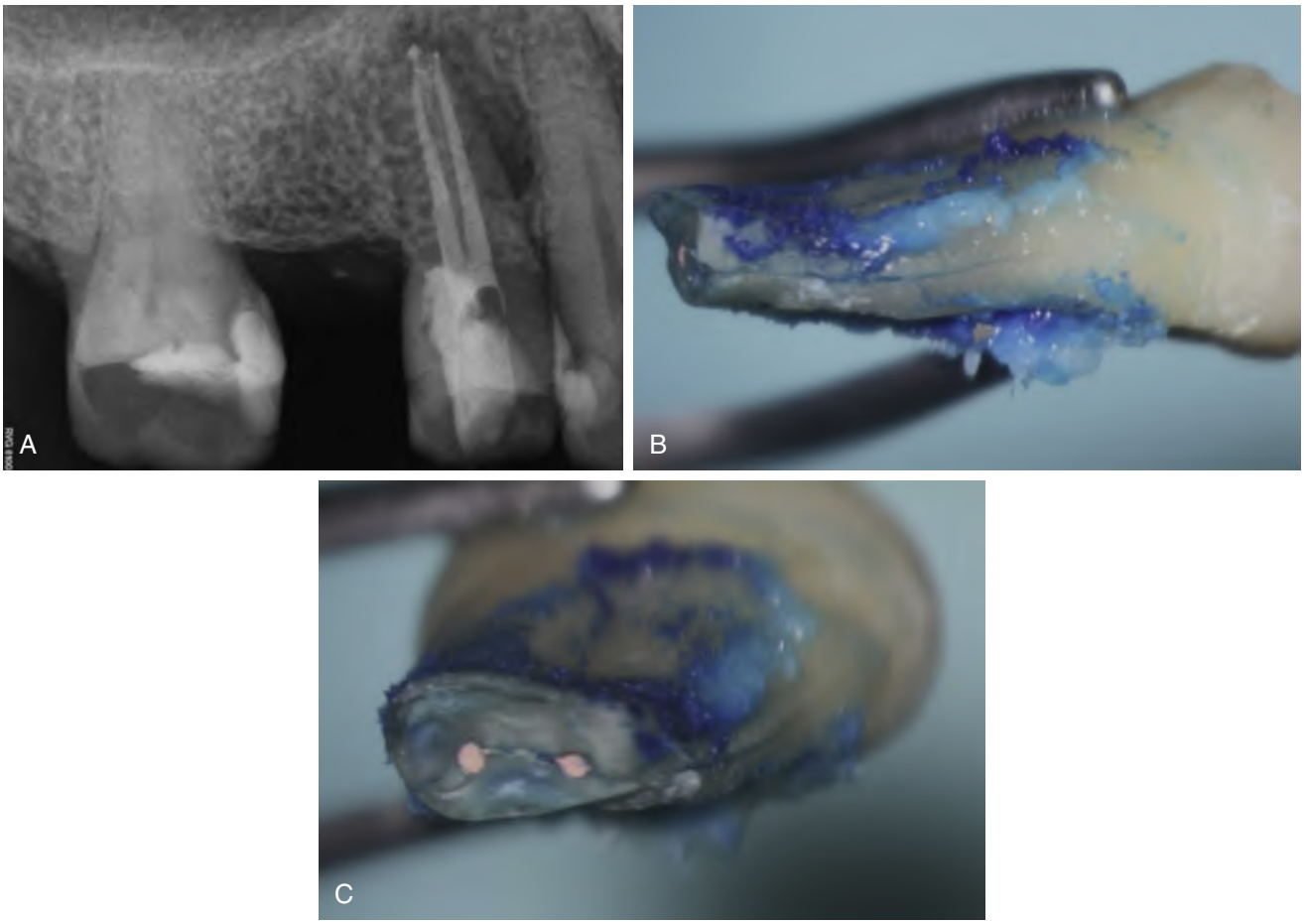
• **Fig. 15.14** Comparison of hand spreader with finger spreader. **(A)** The stiff, more tapered hand spreader will not negotiate the curve. **(B)** The smaller, more flexible finger spreader permits deeper penetration and produces less force on the canal wall.



• **Fig. 15.15** The steps of lateral condensation. **(A)** The master cone is fit. **(B)** A spreader is inserted, ideally to 1 to 2 mm from working length. **(C)** The spreader is rotated and removed, and an accessory cone is placed in the space created. **(D)** The process is repeated.

accessory cones before exposing the radiograph. This "initial condensation radiograph" is used to check the length of the gutta-percha, that the master cone is not dislodged during the initial condensation, and that no voids are present in the apical third of the canal. If an error is detected on the master cone or initial condensation radiograph, it is still possible to easily remove the cone(s) from the canal, before they have been seared off, and correct the error or chose a new master cone. Cones are removed by slowly pulling the gutta-percha from the canal.

9. If the master cone or initial condensation radiograph is acceptable, then lateral condensation continues (Fig. 15.17). The spreader is used, and subsequent accessory cones are also coated in sealer before placement in the canal. As more accessory cones are added, the spreader will seat less and less deep in the canal. Condensation should continue until the spreader can no longer be placed more than approximately 4 mm below the level of the orifice (Fig. 15.18).
10. When the appropriate level of obturation is reached, the gutta-percha cones are seared off at the desired level. An electrically heated plugger can be used to sear off the cones (Fig. 15.19). Historically, a Bunsen burner or alcohol torch with a hand plugger were used and may be used if an electrically heater plugger is not available. A cold hand plugger is used to plug the remaining gutta-percha vertically, filling any coronal voids and creating a smooth surface of gutta-percha in the coronal aspect of the canal (Fig. 15.20). If an intraorifice barrier is to be placed, the desired level of gutta-percha is 1 to 2 mm apical to the level of the facial cemento-enamel junction (CEJ) or the pulp chamber floor (in a molar). The 1 to 2 mm space is then filled with the intraorifice barrier material. If an intraorifice barrier is not placed, then the gutta-percha is brought to the level of the facial CEJ or the pulp chamber floor. If post space is needed, additional gutta-percha may be removed to a level as appropriate for the post space.



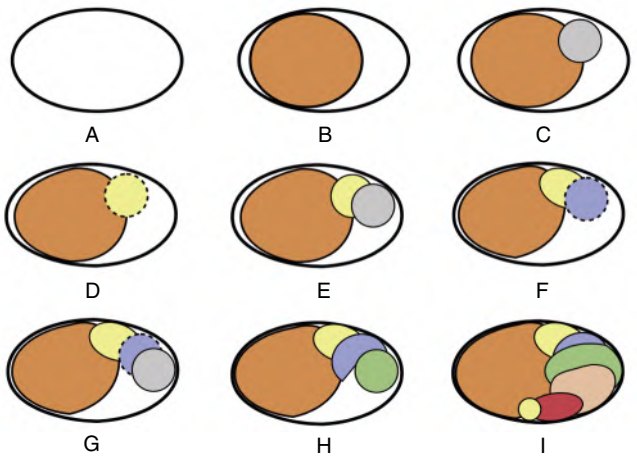
• **Fig. 15.16** Excessive force used during lateral condensation, or any obturation technique, can lead to vertical root fracture. **(A)** Periapical radiograph of tooth #4 with a vertical root fracture. **(B)** The vertical root fracture is visualized extending up the buccal surface from an apical direction. The root has been stained with methylene blue for better visualization. **(C)** The fracture extends into the buccal canal, as seen from the apical direction. (Courtesy Dr. Alex Hanley.)

Warm Vertical Condensation

Warm vertical condensation (also known as warm vertical compaction or the Schilder technique) is another widely used obturation method. The technique is commonly credited to Dr. Herb Schilder,[79,80] although modifications have been made to the original technique over the years as technology has advanced. The main advantage of warm vertical condensation is that warmed gutta-percha can be adapted to the canal walls, which is particularly desirable in irregularly shaped canals, such as cases of internal resorption. Disadvantages of warm vertical condensation compared with lateral condensation are that it is more technique-sensitive, and length control is particularly difficult (higher risk of overfilling).[70,81] Warm vertical condensation also requires additional instruments and equipment, and it is difficult to visualize the level of gutta-percha in the canal unless a dental operating microscope is used during treatment (Question 15.7).

As with lateral condensation, the technique used for warm vertical condensation varies slightly from clinician to clinician. A basic tenet for warm vertical condensation is that the preparation should be a continuously tapering funnel with the apical foramen kept as small as possible. A description of a basic warm vertical condensation follows, starting with a dried canal.

1. A master gutta-percha cone is selected. The cone usually replicates the canal taper (e.g., if a canal is prepared to a 0.04 taper, a 0.04 taper master cone is chosen). The cone should seat short of the desired working length, up to 2 mm short. The warm vertical condensation technique is expected to push the gutta-percha apically to the desired working length during condensation. Some clinicians opt to select a master cone that seats snugly at working length.
2. Sealer is applied and the master cone is seated.
3. The coronal portion of the cone is seared off at the orifice level using an electrically heated plugger.
4. The remaining gutta-percha is plugged apically in the canal, using a prefit cold hand plugger. The plugger should not bind the sides of the canal during condensation. If the plugger is too large, it will bind the walls of the canal, creating excess force on the walls and risking vertical root fracture. If the plugger is too small, it will poke indentations in the mass of gutta-percha, rather than compacting it in an apical direction. The plugger is used to circumferentially plug the gutta-percha in the canal.
5. The gutta-percha mass is seared off again, at a deeper level in the canal, and a "bite" of gutta-percha is removed from the canal by inserting the heat source a few millimeters into the gutta-percha. The gutta-percha mass is plugged apically again using a cold hand plugger.
6. This process is repeated until the apical portion of the canal is filled with an "apical plug" to a level 4 to 6 mm from working length. As the gutta-percha is plugged apically, the mass of



A. Prepared canal
B. Master cone inserted
C. Spreader placed
D. Placement of accessory cone (shown as dashed circle)
E-H. Continuation of lateral compaction
I. Completion of obturation

• **Fig. 15.17** Schematic of the steps of lateral condensation. Each insertion of the spreader to its most apical extent laterally compacts the gutta-percha cone toward the opposing wall. At the completion of obturation, the canal is filled with a series of cones that have been cold-welded together with sealer. (Courtesy Dr. J. Schweitzer.)

gutta-percha is pushed to working length and into any canal irregularities. Note that caution must be exercised when using an electrically heated plugger in the canal to avoid transmitting dangerous levels of heat to the periodontal ligament.[82,83]

7. The remainder of the canal is then backfilled with thermoplasticized gutta-percha from an injection system (Fig. 15.21). The warm injection tip is first placed in contact with the apical plug of gutta-percha, to warm the existing gutta-percha before more is added to the canal. Thermoplasticized gutta-percha is then injected, as the instrument is "backed out" of the canal. The injected gutta-percha is plugged apically with a cold plugger, with apical pressure being applied as the gutta-percha cools, to minimize shrinkage. The backfill may be accomplished in one or more segments, depending on the length of the canal. Before thermoplasticized gutta-percha injection systems were commercially available, small segments of gutta-percha were added back to the canal, heated, and condensed.
8. The backfilled gutta-percha is seared off at the desired level, as with lateral condensation. The backfill may be stopped short, or not completed at all, if post space is desired.

Continuous Wave

The continuous wave of condensation is a variation of warm vertical compaction.[84] Continuous wave primarily differs from warm vertical in the down pack procedure (*down pack* may refer to both the procedure for removing coronal gutta-percha from the canal, and the apical plug of gutta-percha that results). Classic warm vertical obturation accomplishes the down pack in multiple steps of heating, removing gutta-percha, and plugging vertically. In contrast, the continuous wave technique employs one continuous motion for the down pack. Once the master cone is seated, a prefit plugger is chosen. Electrically heated plugger tips that match the taper of the canal are used (Fig. 15.22). The warmed plugger is moved apically through the gutta-percha in one motion over 1 to 2 seconds, until the desired level of the down pack is achieved. The heat plugger is inactivated, and pressure is applied apically for 5 to 10 seconds, to reduce shrinkage of the cooling gutta-percha. A burst of heat is then applied, as the plugger is moved side-to-side, to separate the plugger from the apical gutta-percha. The plugger is then removed from the canal, and any excess gutta-percha coronal to the down pack level should be removed from the canal on the plugger. The apical portion of gutta-percha is plugged apically with a cold plugger, and the canal is backfilled, as in warm vertical condensation. The advantage of the continuous wave technique is the reduced amount of time needed to obturate.[72] A disadvantage is that the method is quite technique-sensitive: the down pack of apical gutta-percha may be removed with the plugger, or the coronal gutta-percha may not be removed with the plugger. As with warm vertical compaction, length control is more difficult with the continuous wave technique versus cold lateral condensation.

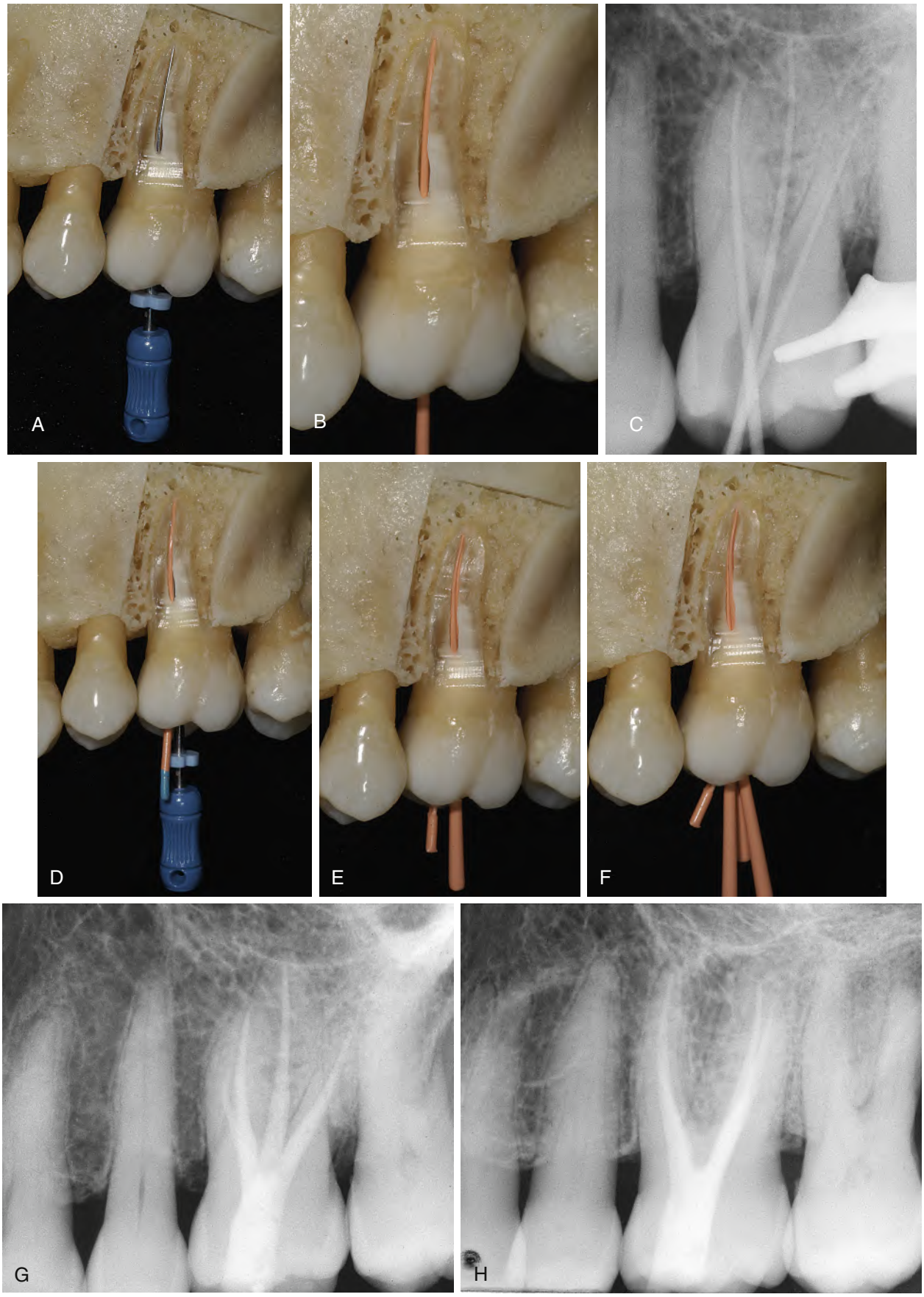
Formed Cones

The use of a custom formed master cone is a variation used in obturation. Formed cones are most commonly employed in conjunction with cold lateral condensation but may also be used with warm vertical techniques. The technique involves selecting a gutta-percha cone that is larger than the apical preparation of the canal, then softening the tip of the cone in chloroform so that an "impression" of the apical few millimeters of the prepared canal is created. Chloroform softens the outer skin of the gutta-percha. The cone is then reseated after sealer has been placed in the canal.

Some clinicians choose to use the formed cone technique on every case. Others employ it only in specific cases. Cases where the formed cone would be indicated include those with a large apical foramen, an irregularly shaped apical preparation, lack of an apical stop, or as a trouble-shooting technique when the master cone is not seating to working length (Question 15.8). The formed cone should fit like a key in a lock when root canal sealer is applied and the cone is placed back into the canal in the same orientation in which it was removed after making the impression. As condensation continues, the use of a spreader and/or plugger will cause the softened gutta-percha to move into irregularities in the root canal system. The disadvantages of any gutta-percha solvent technique are the time needed to form the cone and the potential for shrinkage of the gutta-percha as the chloroform evaporates. In vitro testing suggests the possibility of shrinkage after use of chloroform, but no clinical studies have shown shrinkage to be a clinically significant problem.

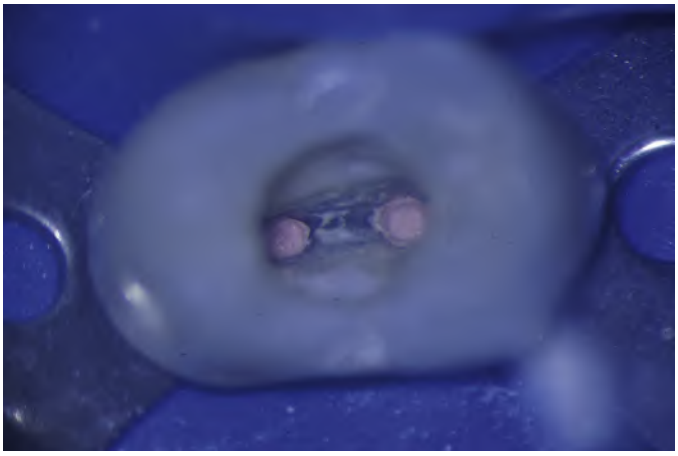
The formed cone technique is as follows:

1. An oversized gutta-percha master cone (that does not seat to working length) is selected. This is most commonly a 0.02 taper cone but could be a larger taper cone depending on the case and clinician preference. The cone should seat approximately 1 mm short of working length when placed in the canal with gentle pressure. This is typically a cone that is one to two sizes larger than the master apical file size.
2. The cone is grasped with a locking cotton plier at the appropriate working length. The apical 3 to 4 mm of the cone is quickly dipped into chloroform (for approximately 1 second). Other solvents may also be used.
3. The cone is seated with gentle but continuous pressure. The cone is pulled out a few millimeters and gently reseated in the canal to mold or adapt the apical portion. The cone should seat to working length.
4. Measure to confirm that the cone seats to working length. If the cone is short of working length, the cone may be dipped again in



• **Fig. 15.18** Lateral condensation. **(A)** A hand file matching the size of the master apical file is inserted to ensure it seats to working length. **(B)** Standardized gutta-percha cones are seated to working length. **(C)** The position of the cones is verified radiographically. **(D)** Once the sealer has been placed and the cone seated to length, the spreader is inserted along the side of the cemented cone (here, in the mesiobuccal canal). **(E)** An accessory cone is placed in the space created by the spreader. **(F)** The process is repeated (i.e., reinsertion of the spreader, followed by placement of another accessory cone) until the spreader does not penetrate beyond the middle third of the canal. The cones are removed at the orifice with heat, and the coronal mass then is vertically compacted. **(G)** The remaining canals are obturated in the same manner. **(H)** The final radiograph demonstrates four canals properly obturated. (Courtesy Dr. W. Johnson.)

• **Fig. 15.19** An electrically heated plugger can be used to sear off gutta-percha during obturation with lateral condensation, as well as carry heat into the canal to remove gutta-percha during warm obturation techniques. The Touch 'n Heat was the first mass marketed electrically heated plugger, and is still on the market today. (Courtesy Kerr Endodontics.)



• **Fig. 15.20** The gutta-percha has been seared off and vertically compacted with a cold hand plugger at the level of the orifice in this maxillary premolar. (Courtesy Dr. Kyle Countryman.)

chloroform and reseated using gentle continuous pressure, or a new cone may be used. If the cone buckles, it should be discarded.

5. The tip of the cone is examined to make certain that the cone has adapted to the apical canal (Fig. 15.23). If the cone has properly formed, "skid marks" will be visible where the softened cone has touched the canal wall. Smooth, uninterrupted areas that look like the fresh cone are an indication that the cone is too small and is not contacting the canal in all dimensions. If this occurs, a new, larger cone should be formed, or the tip of the softened cone should be trimmed and reformed.
6. After the master cone is formed, sealer is applied, and obturation is completed using the preferred technique.

Carrier-Based Obturation

Carrier-based obturation utilizes an "obturator" composed of a core carrier material surrounded by a gutta-percha coating that is used to fill the root canal system. The earliest version of an obturator had a metal core, but later versions have utilized plastic as the core material. The most recently introduced core material is a crosslinked version of gutta-percha (see Fig. 15.3, *A*). Obturators are available in standardized sizes designed to match a designated master apical file size, and some endodontic rotary files are marketed with corresponding carriers as a "system."

When the canal is ready to obturate, it is dried and sealer is applied. The obturator is heated using a time- and temperature-controlled oven, which softens the gutta-percha surrounding the carrier (Fig. 15.24). The obturator is inserted into the canal to the appropriate working length. The carrier portion of the obturator is rigid enough to carry the gutta-percha to working length but flexible enough to be placed around common canal curvatures. The handle of the carrier must then be removed, typically using a long-shank round bur, and the coronal gutta-percha is smoothed using a plugger.

The advantages of carrier-based obturation are time efficiency and the ability of warmed gutta-percha to fill canal irregularities.[85] Disadvantages include length control (overfilling is a risk), and stripping of the gutta-percha off the carrier during seating.[86] As such, carrier-based obturation can be technique-sensitive. In addition, post space preparation and retreatment are difficult, as retrieving the carrier from the canal may be challenging or impossible in some cases (Question 15.9).

A variation on carrier-based obturation uses a metal carrier with an apical plug of gutta-percha attached (see Fig. 15.3, *B*). After the gutta-percha is seated to working length, the metal carrier is twisted off and removed from the canal, leaving an apical plug of gutta-percha. This type of carrier is not heated.

Single Cone Obturation

Growing attention has been given in recent years to the use of a "single-cone" obturation technique. In this technique, the canal is obturated with a single gutta-percha cone that is designed to match the size and taper of the canal preparation. For example, a canal prepared to a master apical file of size 40/.04 would be obturated with a single gutta-percha master cone of size 40/.04. Some clinicians advocate using a master cone one size smaller than the master apical file size. The advantages of this technique are time efficiency and length control. The main disadvantage is that the gutta-percha does not adapt to an irregularly shaped canal and voids may be present along the length of the canal. The sealer is expected to fill any irregularities in the canal. The technique has been popularized in recent years in conjunction with the use of a bioceramic sealer. Despite the growing popularity of the single-cone technique, there is little clinical research published evaluating its use.[87]

Evaluation of Obturation

How Obturation Materials and Techniques Are Evaluated in Research

Obturation materials and techniques are commonly evaluated in research using in vitro studies.[88] The quality or density of fill created by different obturation methods can be compared by filling extracted or artificial teeth using different methods. The teeth are then sectioned at different levels of the root, and the cross-sectional areas filled by gutta-percha, sealer, or voids are measured.[72,81] Microcomputed tomography imaging may be used in similar studies, where three-dimensional volumetric measurements can be made both before and after obturation of the root canal system; the volume of filled space can then be measured.[89] Benchtop studies may also be used to investigate the fracture resistance of teeth or the presence of dentin microcracks after obturation with different methods or materials.[90] In vitro studies are also employed to assess the sealability of obturation techniques

• **Fig. 15.21** Thermoplasticized gutta-percha injection systems. **(A)** The Obtura system uses pellets of gutta-percha, similar to a glue gun. (Courtesy Obtura Spartan.) **(B)** The Calamus Dual has both a heat source and a gutta-percha injection hand piece on one console. The gutta-percha handpiece utilizes cartridges of gutta-percha made to specifically fit in the handpiece. (Courtesy Dentsply Sirona.) **(C and D)** The Elements Free and Gutta Smart systems are cordless, and each has both a heat source handpiece and a gutta-percha injection handpiece with corresponding cartridges of gutta-percha made to fit each product. Both cordless hand pieces share a charging base in each system. (Courtesy Kerr Endodontics and Dentsply Sirona.)

or materials, where ability of bacteria to penetrate an obturated canal is measured.[91] Further, biocompatibility and antimicrobial effectiveness of obturation materials are also tested by in vitro cell culture and microbiologic research assays.[92-94]

How Obturation Is Evaluated Clinically—Radiographic Evaluation

In clinical cases, obturation is commonly evaluated using periapical radiographs. The length, taper, and density of obturation are assessed. Radiographic evidence of errors include obturation short or beyond the desired working length and voids in the obturation. Radiographic evaluation of a previously treated tooth may provide information about not only the quality of the previous treatment (e.g., presence of voids) but the type of filling material used (e.g., silver points have a different radiographic appearance compared with gutta-percha) (see Fig. 15.6). Cone beam computed tomography (CBCT) is not usually a helpful method to evaluate voids in obturation, as a result of the scatter produced by the obturation materials. However, the obturation observed on a CBCT image may show important information, such as when a canal has been missed or transported (Fig. 15.25).

It is important to understand that the obturation as assessed on a postoperative periapical radiograph may also reflect the quality

• **Fig. 15.22** Specialized heated pluggers available in a variety of tapers are advocated for use in the continuous wave of condensation technique. (Courtesy Kerr Endodontics.)

• **Fig. 15.23** The chloroform-dipped master gutta-percha cone is seated to working length and removed. The cone should show an impression of the apical preparation of the canal.

of instrumentation. That is, inadequate instrumentation will be manifest radiographically as inadequate obturation (e.g., a canal that has been instrumented short will also be filled short). In some cases, serial radiographs can be used to troubleshoot if an error occurred during instrumentation or obturation. For example, if a master cone radiograph shows the cone short of working length,

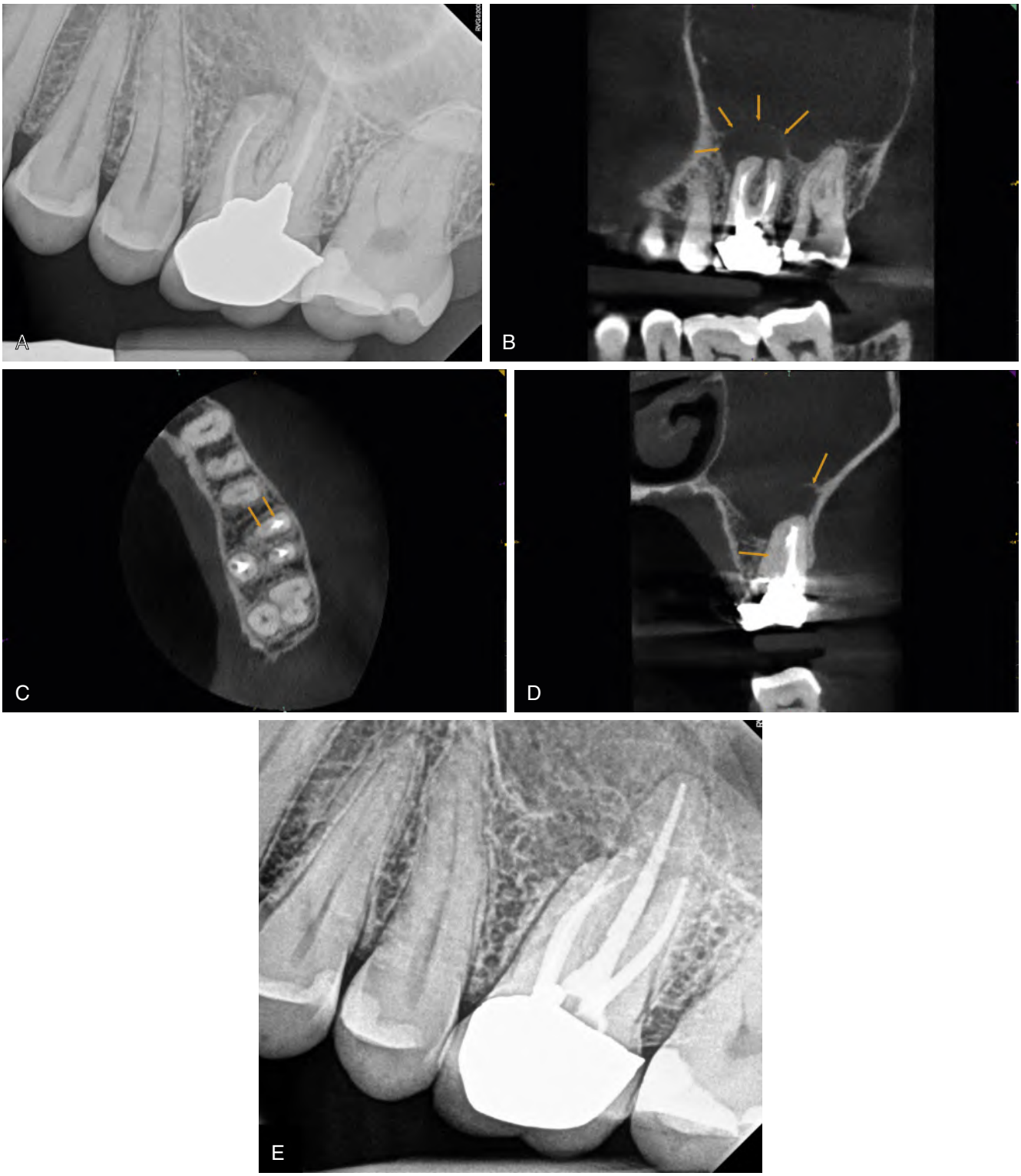
• **Fig. 15.24** Specialized ovens are used to heat obturators, softening the gutta-percha surrounding the core. **(A)** The GuttaCore oven is marketed for use with GuttaCore obturators and has two arms that are pressed down to move the obturator into the heating chamber. (Courtesy Dentsply Sirona.) **(B)** The Soft-Core Heater is marketed for use with Soft-Core obturators and holds up to four obturators at once. (Courtesy Kerr Endodontics.)

but the master apical file radiograph shows the master file to the correct working length, this indicates an obturation error. However, if the master apical file radiograph also shows the file short of working length, this indicates an instrumentation error.

The ideal research design to compare obturation techniques or materials would be a prospective, randomized clinical trial evaluating the outcomes of endodontic treatment after the use of two different techniques or materials. Unfortunately, such outcomes studies do not exist in the endodontic literature and are unlikely to be conducted. The feasibility of such research is poor as a result of the very large sample size needed to have adequate power to detect small differences in outcomes and poor recall rates, especially long-term recall rates needed to obtain valuable data. The outcomes studies available in the literature largely report outcomes of a specific technique, or show no significant difference between contemporary obturation techniques.[69,70,87]

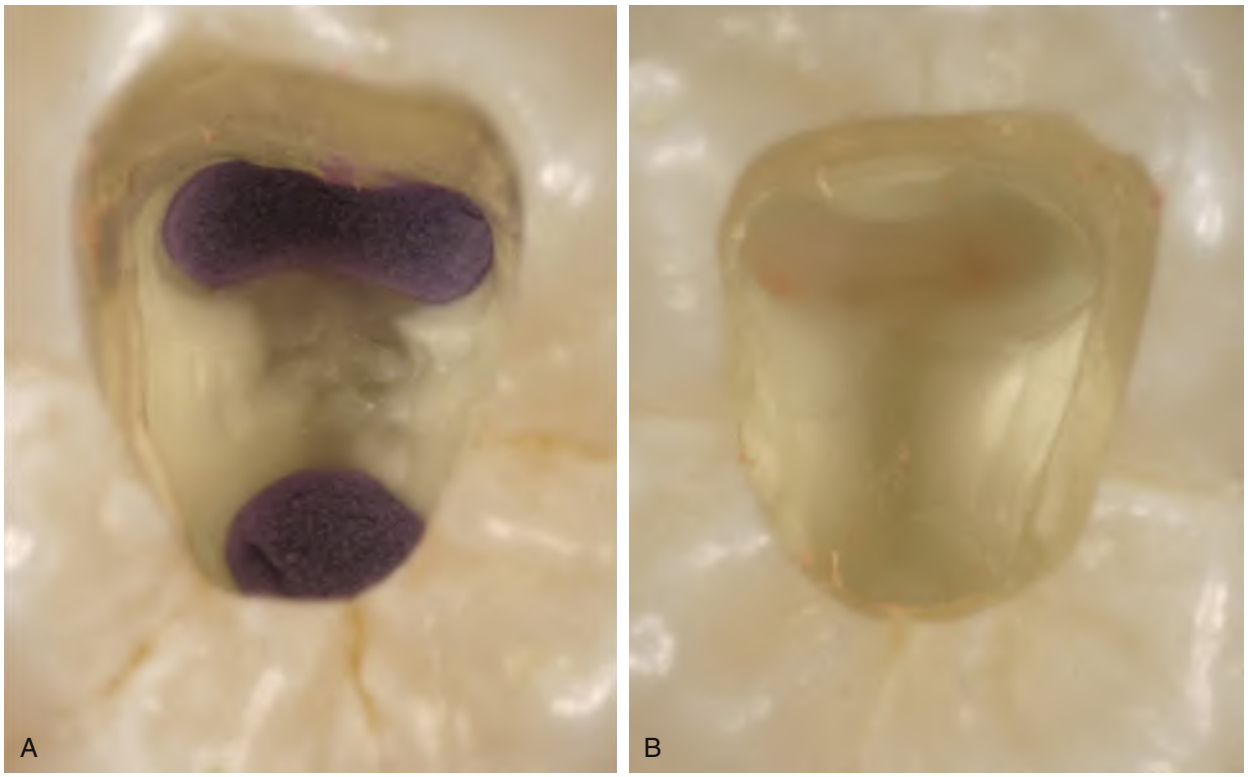
Length of Obturation—Outcomes Studies

The ideal length to which canals should obturated has long been a subject of debate in endodontics.[95] The level of obturation should



• **Fig. 15.25** This patient presented with pain in the maxillary left posterior and percussion sensitivity on tooth #14. **(A)** The preoperative periapical radiograph shows that tooth #14 has been previously endodontically treated, and the obturation of the MB root appears short. **(B)** The sagittal view of the CBCT image shows a large periapical radiolucency. **(C and D)** Both the axial and coronal views show a missed MB2 canal. **(E)** The postoperative radiograph after nonsurgical retreatment shows two canals treated in the MB root. *MB*, Mesiobuccal; *CBCT*, cone beam computed tomography. (Courtesy Dr. Randy Ball.)

be consistent with the level of instrumentation. Clinicians' preferences vary between treating to the radiographic apex or the "foramen" reading on an electronic apex locator, or 0.5 to 1 mm short of one of these levels. The rationale for instrumenting and obturating to a longer length is to ensure that the most apical extent of the canal has been cleaned. The rationale for instrumenting and obturating to a shorter length is to preserve the integrity of the periapical tissues and avoid debris extrusion or overfilling the canal.



• **Fig. 15.26** Intraorifice barrier materials are placed in the coronal 1 to 2 mm of the canal. **(A)** PermaFlo Purple flowable composite orifice barrier. The purple color is easily distinguished from dentin. **(B)** Vitrebond glass ionomer intraorifice barrier. (Courtesy Dr. Scott Starley.)

Several outcomes studies have investigated the influence of the level of obturation on treatment success. Research supports improved outcomes of root canal therapy when the canal is filled 0 to 2 mm from the radiographic apex.[96-98] In a prospective study of the factors affecting outcomes of nonsurgical root canal treatment, the extension of canal cleaning as close as possible to the apical terminus significantly improved periapical healing.[69] In a systematic review, root filling extending to within 2 mm of the radiographic apex significantly improved the outcome of root canal treatment.[99] These studies do not assess obturation level in more detail than the 0 to 2 mm range, and debate still exists as to the ideal instrumentation and obturation length within that range.

Temporization

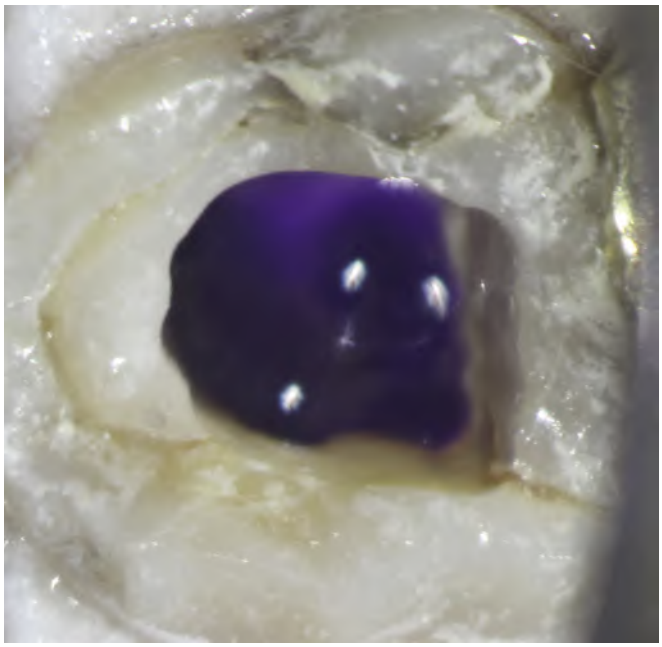
Intraorifice Barriers

The success of endodontic therapy depends on removal of bacteria from the root canal system and preventing recontamination. Coronal leakage occurs when microorganisms enter the root canal from a coronal direction and is a major cause of failure of endodontic treatment.[1] Bacteria and their byproducts may then permeate the root canal system and extend into the periradicular tissues, resulting in sequelae that include symptomatic or asymptomatic apical periodontitis, acute or chronic apical abscess formation, and/or pain. Further treatment is then needed (retreatment, endodontic surgery, or extraction). Recontamination of the root canal system after endodontic therapy may occur if there is a delay in placing the permanent restoration, breakdown of the temporary restoration seal, recurrent caries, leaky margins, and/or fracture or loss of the restoration or tooth structure. Research has shown that leakage can occur through the obturated root canal system in a relatively short amount of time[100-103] (Question 15.10).

To prevent coronal leakage and subsequent failure of the root canal treatment, intraorifice barriers (also referred to as orifice barriers) are often placed coronal to the root canal filling material.[104] Many dental materials have been investigated as intraorifice barriers, but glass ionomer and flowable composite resin are the most widely used in clinical practice. As obturation is completed, the gutta-percha is removed to a level 1 to 2 mm apical to the facial cementoenamel junction or the floor of the chamber in a molar. Any excess sealer and debris is removed from the chamber, typically using alcohol-soaked cotton pellets. The chamber is dried. The intraorifice barrier material is applied in the coronal 1 to 2 mm of the canal using the recommended instructions for the chosen material (Fig. 15.26). In some cases, the chamber floor is also covered (Fig. 15.27).

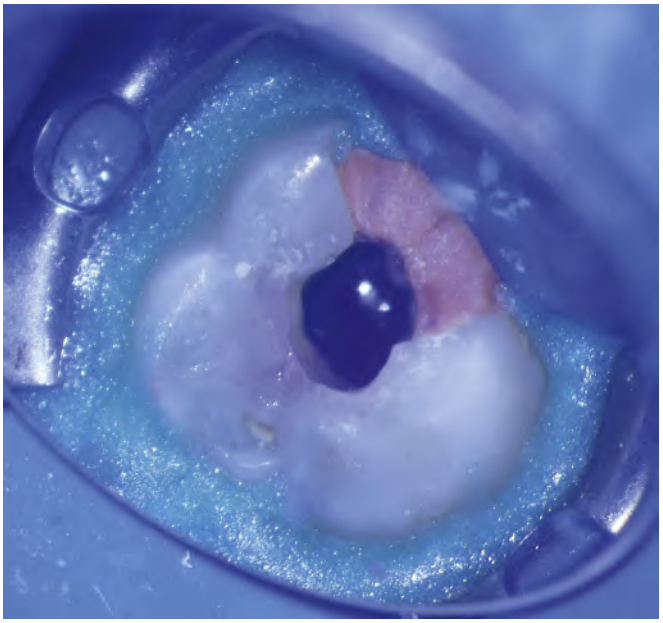
Temporary Filling Materials

As stated previously, prevention of coronal leakage is an important factor in successful endodontic outcomes. The choice of an interim restoration material to seal the access preparation, either between endodontic appointments or between completion of root canal therapy and the definitive restoration, is an integral part of a successful endodontic outcome. Temporization may be relatively straightforward, as in the case of a single-surface occlusal or lingual access preparation. Temporization may also be more challenging and time-consuming, as in the case of a tooth with extensive caries and/or defective restorations that must be removed before endodontic treatment. If one or more proximal surfaces of the tooth are missing after removal of caries and/or



• **Fig. 15.27** Intraorifice barrier that covers the entire pulp chamber floor in a molar. This approach would seal the root canals and any furcation canals against leakage.

• **Fig. 15.28** Occlusal access cavity filled with Cavit as a temporary restoration on a mandibular premolar.



• **Fig. 15.29** Tooth #15 was diagnosed with symptomatic irreversible pulpitis and symptomatic apical periodontitis. The tooth had deep mesial recurrent caries, which needed to be removed before root canal therapy. A temporary buildup was completed using Fuji TRIAGE glass ionomer, to facilitate isolation during root canal therapy. PermaFlo Purple covers the pulp chamber floor as an intraorifice barrier after the completion of obturation. (Courtesy Dr. Kyle Countryman.)

defective restorations, it may be necessary to restore the tooth with a temporary buildup material, either at the start of treatment or at the end of the appointment. If adequate isolation is not achievable after caries removal, then the tooth must be built up before continuing with root canal therapy. This allows for easier isolation of the tooth and prevention of salivary contamination when the caries are deep. It also allows for the ideal access preparation to create a reservoir to contain irrigant during treatment. The decision to wait until the end of the appointment to build up the missing walls has the advantage of saving time at the beginning of the appointment. This approach may also allow more light into the access for better visibility, and in some cases, it may make it easier for the clinician to insert files into the tooth during treatment (e.g., in the case of a missing mesial wall of a maxillary molar).

Cavit (ESPE, Seefeld, Germany) is a very popular temporary filling material that has been found to prevent leakage in numerous studies when used to close endodontic access preparations.[105-112] Cavit is premixed and is easily introduced into the access cavity, as well as easy to remove from the access cavity at the subsequent appointment (Fig. 15.28). Cavit contains zinc oxide, calcium sulfate, zinc sulfate, glycol acetate, polyvinyl acetate resin, polyvinylchloride-acetate, triethanolamine, and red pigment.[105] The calcium sulfate is hydrophilic, causing the hydroscopic expansion of the material. This absorption of moisture and expansion causes the Cavit to seal very well as it sets in a moist environment. A depth of at least 3.5 mm of Cavit is needed to adequately seal an access preparation (Video 15.3).[113]

TERM (Dentsply Sirona, York, PA/L.D. Caulk Division, Milford, DE) is a composite resin interim restorative material for endodontics. It is a visible light cured resin containing urethane dimethacrylate polymers, inorganic radiopaque filler, pigments, and initiators.[105] If 3.5 mm of space does not exist for a temporary filling material, TERM may provide a superior temporary restoration to Cavit. TERM provides an adequate seal at 1, 2, 3, and 4 mm.[114] REVOTEK LC (GC Corporation, Tokyo, Japan), Tempit (Centrix, Milford, CT), and Systemp inlay (Vivadent, Schaan, Liechtenstein) are also temporary filling materials that have been reported to have good antibacterial and sealing qualities[115] (Fig. 15.29).

Study Questions

6. What are the advantages and disadvantages of lateral condensation as an obturation technique?
7. What are the advantages and disadvantages of warm vertical condensation as an obturation technique?
8. In what cases would a custom formed gutta-percha master cone be indicated?
9. What are the advantages and disadvantages of carrier-based obturation?
10. Why must coronal leakage be prevented after root canal therapy?

ANSWERS

Answer Box 15

1 a. The objective of obturation is to create a seal along the length of the root canal system to prevent leakage of microorganisms and their byproducts into the root canal system

2 a. The rationale for completing root canal therapy in two visits is to allow time for an intracanal medicament to aid disinfection of the root canal system between visits.

3 a. The smear layer is removed because it may contain microorganisms and their byproducts and because it may prevent adhesion of filling materials to the dentin walls.

4 a. Advantages of gutta-percha include its biocompatibility, plasticity, handling characteristics, and ability to be removed from the root canal system if needed

5 a. Sealer is used with gutta-percha to help create an adequate seal in the root canal system

6 a. Advantages of lateral condensation are that it is appropriate for use by novice clinicians in a variety of cases. Lateral condensation also is less technique-sensitive than some techniques, has predictable length control, does not require specialized equipment, and has a track record of clinical success. Disadvantages of lateral condensation are that it requires more time than some filling techniques and is difficult to use in some cases with challenging anatomye

7 a. An advantage of warm vertical condensation is that warmed gutta-percha is adapted to the canal walls, which is particularly useful in some irregularly-shaped canals. Disadvantages of warm vertical condensation are that it is more technique-sensitive than some techniques, has less predictable length control, requires additional equipment, and is difficult to visualize within the canal without adequate magnification and lighting

8 a. A formed gutta-percha master cone is useful in cases with a large apical foramen, an irregularly shaped apical preparation, lack of an apical stop, or as a trouble-shooting technique when the master cone is not seating as expected.

9 a. Advantages of carrier-based obturation are time efficiency and the ability of warmed gutta-percha to fill canal irregularities. Disadvantages of carrier-based obturation are length control, stripping gutta-percha off the carrier during seating, and difficult post space preparation and retreatment

10 c. Coronal leakage must be prevented because it allows recontamination of the root canal system with microorganisms and is a major cause of endodontic treatment failure.

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Video 15.1 Obturation
Video 15.2 Obturation with MTA