7

Endodontic Armamentarium

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CHAPTER OUTLINE

LEARNING OBJECTIVES

At the end of this chapter, the student should be able to:

1. Define the basic set of armamentarium appropriate for diagnosis, emergency treatment, canal preparation, obturation, and endodontic surgery.
2. Describe the general characteristics of endodontic armamentarium and show how these characteristics are related to their use.
3. Describe the importance of using magnification for proper endodontic treatment.
4. Present the advantages of three-dimensional (3D) versus two-dimensional (2D) radiographic imaging.
5. Explain the basis for sizing and taper of hand and rotary instruments.
6. Describe the basic design of the more common canal preparation instruments and their mode of use.
7. Describe the various adjunct tools needed to achieve adequate disinfection.
8. Identify the various temporary restorative materials used after endodontic treatment.
9. Describe the various adjunct tools used during endodontic surgery.

Introduction

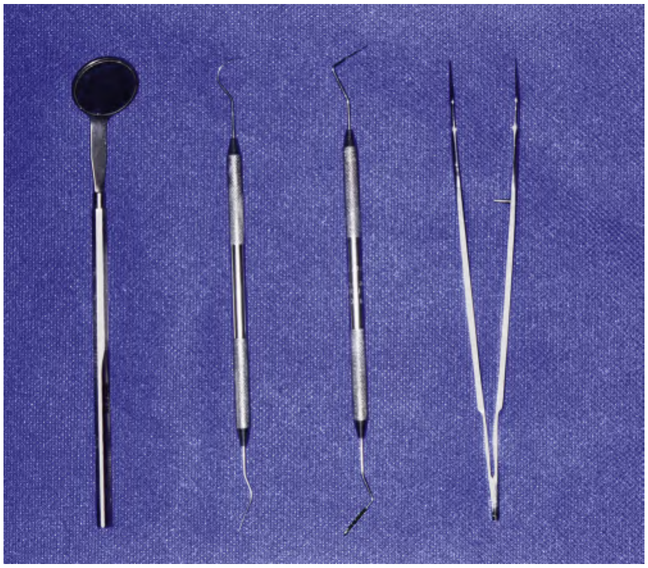
The goals of nonsurgical root canal therapy (RCT) are to chemomechanically débride, disinfect, and shape the root canal spaces, followed by adequately sealing all portals of entry and exit.[1,2] To achieve these goals, multitudes of solutions and dental instruments have been specially designed and used. Historically, varied attempts at endodontic treatments have been documented since ancient times. In 1728 Pierre Fauchard wrote *The Surgeon Dentist*, which described the dental pulp space and the procedure to access this space to relieve abscess formation. Fauchard recommended leaving the access to the pulp space open for months and then filling the opening with lead foil. Advancing on this concept, Robert Woofendale in 1766 was credited with the first endodontic procedure in the United States. He would cauterize the dental pulp with a hot instrument and place cotton in the root canals. From this idea, the concept of pulp extirpation took hold. In 1838 Edwin Maynard fabricated the first endodontic instrument. He ground a watch spring into a broach, which he would then use to extirpate the dental pulp. Over the next several decades, endodontic instruments continued to evolve into the instruments and materials we use today. Over the past two decades, the endodontic armamentarium has undergone major renovations in nonsurgical and surgical treatment that have allowed endodontic treatment to become more successful.

This chapter provides an overview of basic and advanced endodontic armamentarium and describes their use in the clinical setting. Proper knowledge of the various instruments, materials, and equipment, together with their design, composition, and function, is critical to provide patients with proper diagnosis and treatment options. The field of endodontics is constantly evolving with improved armamentarium to assist clinicians with diagnosis and treatment. Clinicians should always consider using newer instruments, materials, and equipment to provide the best possible treatment for their patients. It will not be possible to include all armamentarium used in every endodontic procedure in this chapter. However, the most widely used instruments and materials will be covered in detail.

Examination and Diagnosis

Clinical Examination

The primary aim during endodontic diagnosis is to determine the vitality of the pulp and the status of the supporting periodontal structure. For that, clinicians use a basic examination kit, which is very similar to instruments used for restorative dentistry. It is composed of a mouth mirror, Shepherd's hook explorer, periodontal probe, and cotton pliers (Fig. 7.1). The vitality of the dental pulp is routinely examined using sensibility tests that aim to stimulate the pulp through temperature (cold or hot) or electric stimulation



• **Fig. 7.1** Examination kit containing a mouth mirror, periodontal probe, dental probe, and cotton pliers.

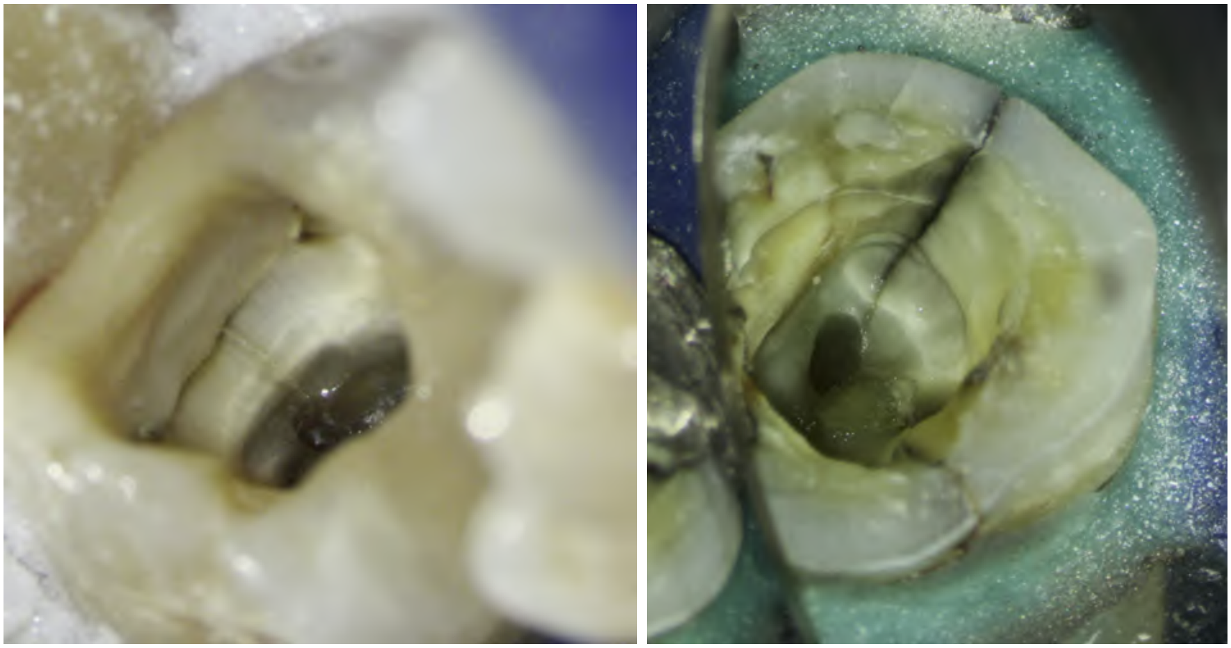
• **Fig. 7.2** EndoIce used for cold testing.

• **Fig. 7.3** Electric pulp testing used to determine pulp vitality.

(Figs. 7.2 and 7.3). The supporting periapical tissues can be examined with the back of the mirror (percussion), the index finger (palpation), and the periodontal probe. Other instruments can be used to determine the presence or absence of a coronal crack or a root fracture, such as a "Tooth Slooth," a transilluminator, methylene blue, or caries detection dye.

Radiographic Examination

Radiographic examination is the key diagnostic tool used to evaluate the periapex. Different types of radiographs can be used for endodontic diagnosis. Two-dimensional (2D) intraoral radiographs, periapical and bitewing, are used to evaluate the teeth, their supporting structures, and any existing restorations. Three-dimensional (3D) radiographs and cone beam computed tomography (CBCT) have become routinely used in endodontic diagnosis due to their ability to provide 3D images of the area of interest. In 2017 a survey sent to members of the American Association of Endodontists (AAE) showed that almost 50% of the endodontists in the United States have a CBCT machine in their offices.[3] CBCT use among endodontists is increasing because it can further assist clinicians in proper diagnosis and treatment planning.[4-8] Rodriguez et al.[7] investigated the influence of CBCT imaging on clinical decision-making choices of different specialists among cases with different levels of difficulty. The results showed that examiners altered their treatment plan after viewing the CBCT scan in 27.3% of the cases and up to 52.9% in high-difficulty-level cases. Although periapical radiographs are still used as the standard radiographic technique for endodontic diagnosis and treatment, there are several clinical situations in which 2D radiographs may not be able to properly assess the clinical condition. Periapical lesions have to reach a certain size and erode the inner cortical plates of the jaws to be visible on a periapical radiograph.[9,10] In addition, 2D radiographs have significant limitations in the detection, assessment, and treatment planning of external cervical root resorption compared with CBCT imaging.[6] In a joint statement by the AAE and the American Association of Oral and Maxillofacial Radiology (AAOMR),[11] they outlined several circumstances in which CBCT can be very useful for better clinical examination (see Chapter 3). These conditions include cases with external and internal resorptive defects, trauma and fracture cases, presurgical treatment planning, and vertical root fracture cases. In addition, they recommend using CBCT to evaluate the nonhealing



• **Fig. 7.4** Illustration of the use of the dental operating microscope to detect cracks within the crown and root. (Courtesy Dr. Hajar Albanian.)

of previous endodontic treatment, in intra-appointment identification and localization of calcified canals, for initial treatments with potential existence of extra canals and suspected complex morphology, and for the diagnosis of patients who present with contradictory or nonspecific clinical signs and symptoms associated with untreated or previously endodontically treated teeth. It should be noted, however, that the accuracy of CBCT relies to a great extent on the specifications and settings of the equipment used (field of view, voxel size, and artifact correction). Additionally, some lesions may not be accurately detected if they are smaller than 1.4 mm in diameter.[5]

Magnification

The dental operating microscope (DOM) is considered standard equipment in the endodontic office. Before the early 1990s, dental loops were used for magnification. The loops were limiting in two ways: first, only low-level magnification was possible; second, because the practitioner had to wear the loops, neck strain and postural problems often resulted. A web-based survey sent to AAE members in 2007[12] showed that 90% of endodontists were using a DOM during treatment in comparison with only 52% in 1999. The clinician can better visualize the root canal anatomy as a result of the magnification and illumination provided by the DOM. Khalighinejad et al. showed that maxillary first molars with nonhealed RCT in which DOM was not used were significantly more likely to have a missed MB2 canal in the affected MB root. This study indirectly shows the value of using the DOM on the outcome of nonsurgical root canal treatment, at least in this situation.[13] Other studies also showed that practitioners were better able to locate and negotiate canals when the DOM was used.[14,15] Although dental loops can be used during endodontic treatment, the DOM offers multiple advantages: a wider field of view, improved illumination, and less physical strain on the practitioner. DOM is also among the instruments and materials that have significantly improved the treatment outcome of endodontic surgery.[16,17] In addition to allowing excellent visualization, it is a great tool for documentation as well. Clinicians can easily take images and videos of the various procedures and use them for better patient communication and education (Fig. 7.4) (Video 7.1).

Isolation

In 1862 Dr. Sanford Barnum developed the rubber dam to allow a saliva-free field in the mouth. Later, Dr. G. A. Bowman improved the rubber dam by inventing the rubber dam clamp, which allowed the stabilization of the rubber dam to a tooth. The rubber dam is intended to isolate the tooth/teeth to be treated from the oral cavity to ensure no microbial contamination. In addition, it offers other kinds of benefits, such as enhancing visualization, providing a clean operative field, and preventing ingestion or aspiration of any instrument, material, or irrigant during treatment. The 2010 AAE Position Statement on Dental Dams indicated that "tooth isolation using the dental dam is ... integral and essential for any nonsurgical endodontic treatment." It is also considered the standard of care in today's practice.

An isolation kit is composed of (1) clamps that clasp the tooth and are available in different shapes and sizes, depending on the tooth to be isolated (Fig. 7.5); (2) rubber dam sheet, a physical barrier to isolate the tooth from the oral cavity; (3) rubber dam hole punch used to create a hole in the rubber dam sheet that allows for placement of the rubber dam clamp; and (4) a rubber dam frame used to hold the rubber dam sheet in place (Fig. 7.6). In some clinical cases, rubber dam placement alone may not sufficiently allow adequate isolation of the tooth before initiating treatment. Supplementary material such as OraSeal or OpalDam (Ultradent Products, Inc., South Jordan, Utah, USA) may be applied around the tooth/clamp junction to enhance tooth isolation (Fig. 7.7). In clinical cases in which an extensive amount of tooth structure is lost, restoration of the tooth to allow for proper isolation is recommended. This restoration can be achieved using glass ionomer or composite restorative materials (Fig. 7.8). If placing a clamp

• **Fig. 7.5** Different types of clamps that can be used for rubber dam isolation, depending on the tooth morphology.

• **Fig. 7.6** Rubber dam kit composed of *(from left to right)* clamp holder, rubber dam punch, rubber dam frame *(white)*, and rubber dam sheet.

on the tooth might result in damage of an existing restoration, a dental dam stabilizing cord, such as Wedjets (Coltene/Whaledent GmbH), can be used to stabilize the rubber dam in place without the use of a clamp (Fig. 7.9).

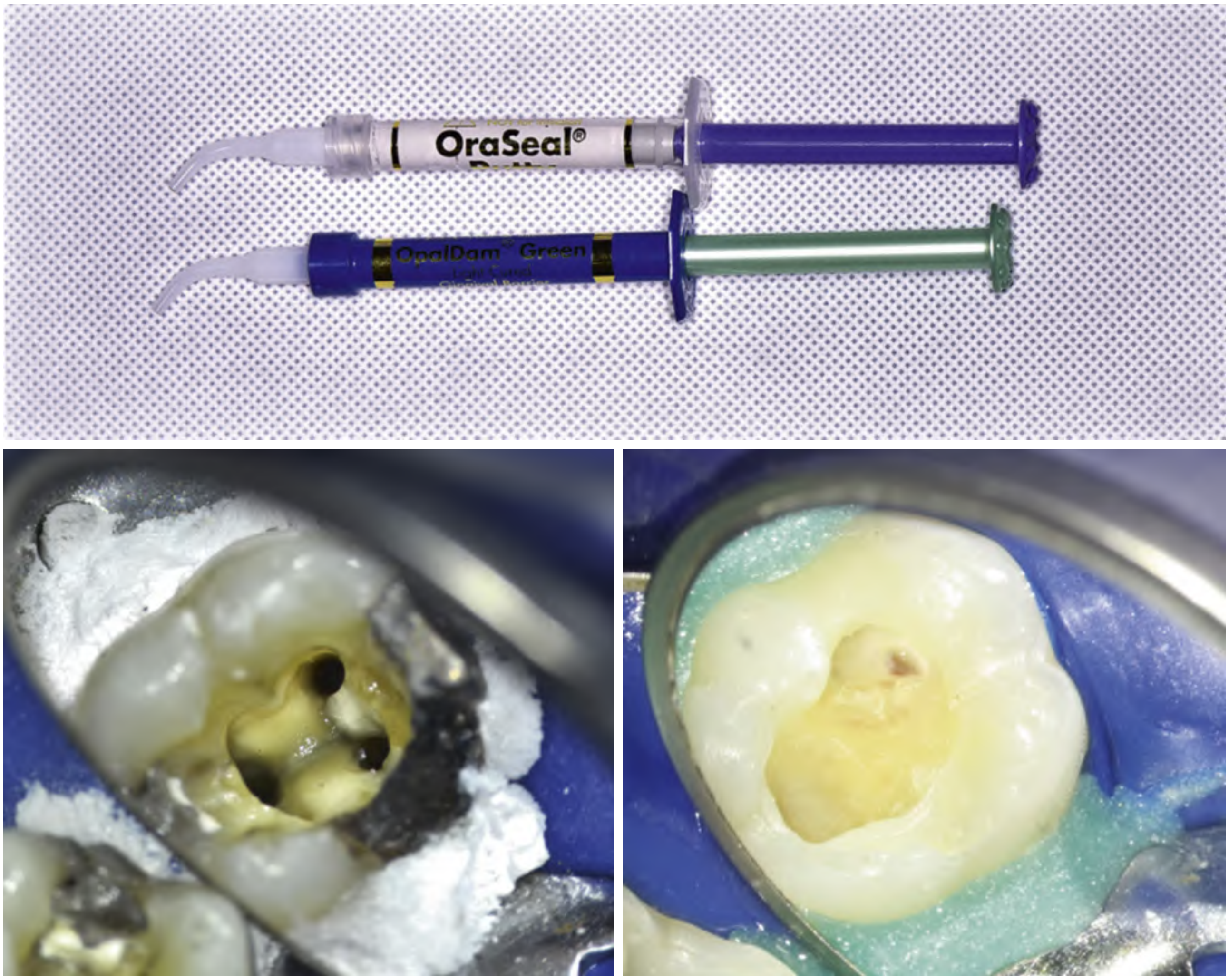
Nonsurgical Root Canal Treatment

Nonsurgical Cassette

The nonsurgical treatment cassette includes all the instruments that are needed during RCT (Fig. 7.10). The cassette contains the instruments used in diagnosis in addition to other procedure-specific instruments, such as (1) local anesthesia syringe; (2) endodontic explorer (DG 16), an instrument that aids in the identification of root canal orifices; (3) a ruler used to measure the instruments for length control during the root canal procedure (Fig. 7.11); (4) endodontic spreaders, used for lateral condensation of gutta-percha; and (5) endodontic pluggers, used for vertical gutta-percha condensation during obturation. Endodontic spreaders and pluggers come in different sizes as well as both finger and handle design (Figs. 7.11 and 7.12). Finally, the cassette includes a metal or plastic instrument that is used to place the temporary filling into the pulp chamber.

Length Determination

To ensure proper length control during root canal treatment, electronic apex locators (EAL) have been used to determine the position of the apical foramen and/or constriction and thus the apical extent for root canal instrumentations. The first EAL was introduced in 1962 by Sunada.[18] Since their development, EAL have evolved to improve their accuracy and reliability in the



• **Fig. 7.7** Images illustrating the use of further isolation after rubber dam placement. Lower left: Isolation using OraSeal putty (Ultradent). Lower right: OpalDam (Ultradent).

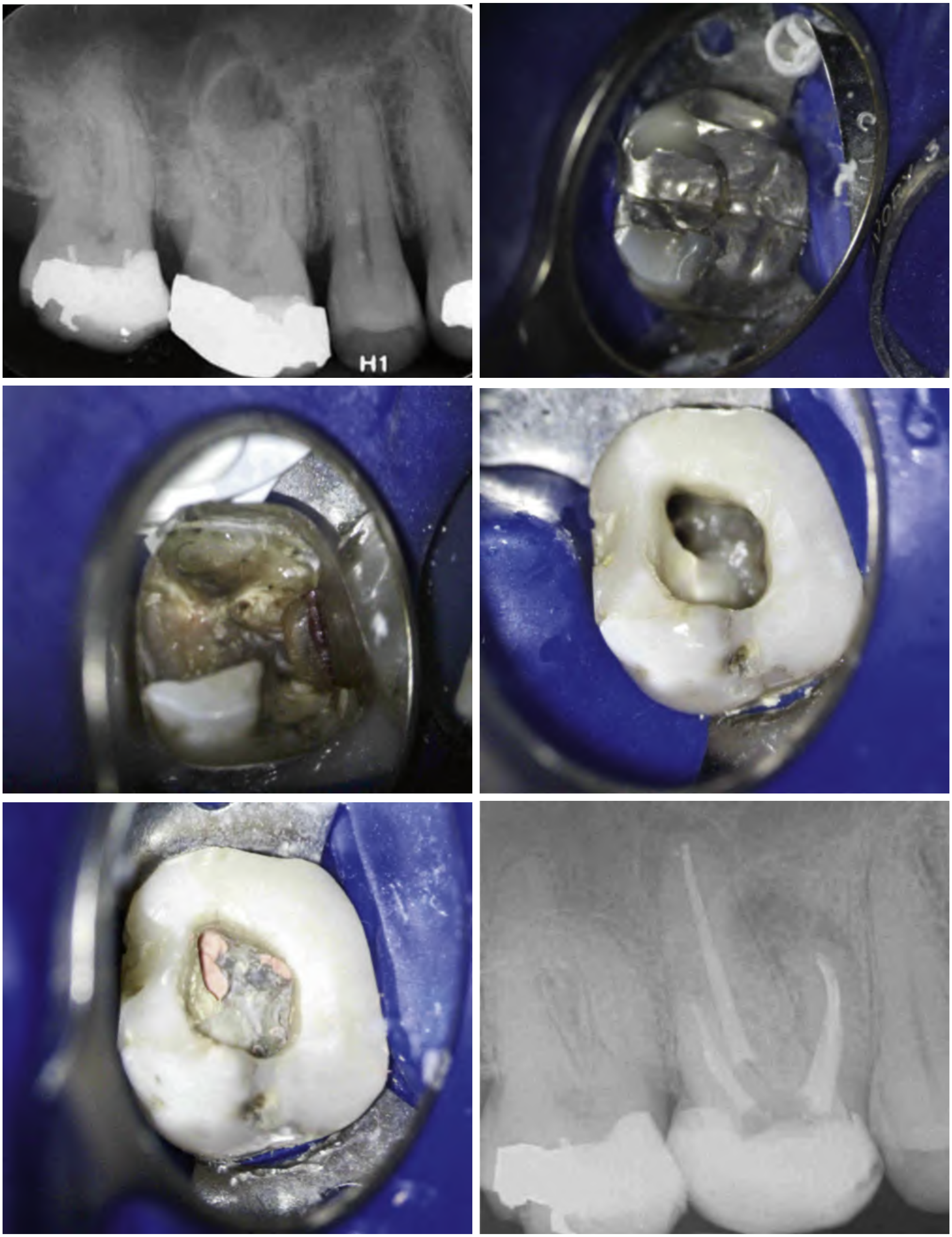
various clinical conditions. Currently, EAL are consistently used by endodontists and widely used by general dentists.[19] EAL have been shown to be more accurate than standard 2D radiographs in working length determination.[20] When use of EAL is combined with a radiograph, clinicians can reduce the risk of over- or underinstrumentation during root canal treatment,[21] and thereby achieve more predictable results.[22,23]

Instrumentation Armamentarium

Endodontic Access

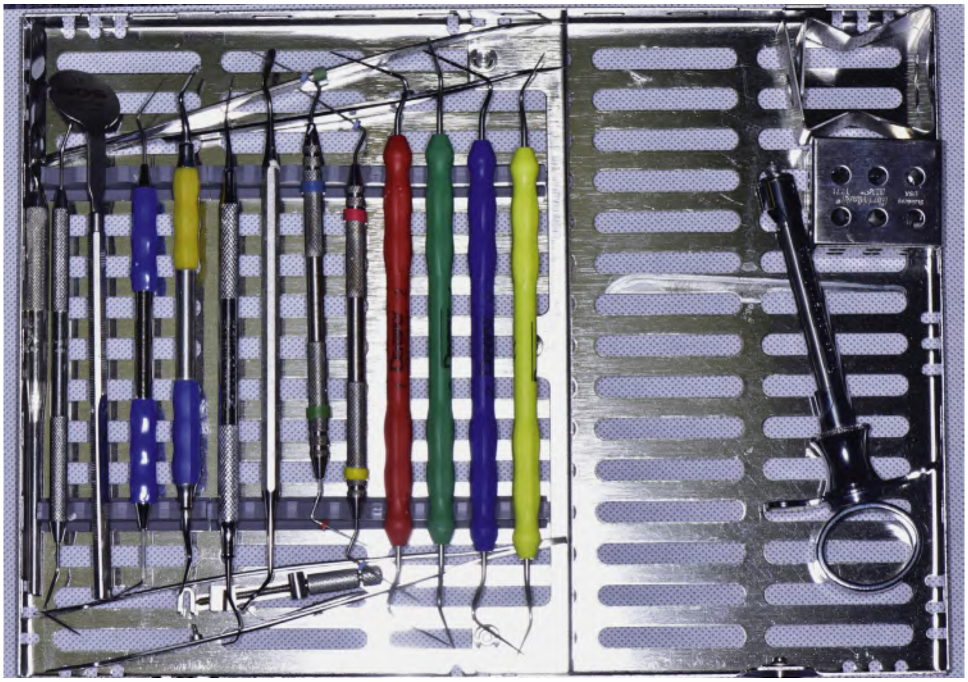
The endodontic access is the opening in the crown of the tooth that allows for localization of the root canal space. Classically, the outline form for the access has been governed by G. V. Black's principles of cavity preparation. However, the access for each tooth should be directed by the anatomy of both the pulp chamber and the curvature of the root. Existing restorations and decay can alter the outline form of the access. Due to the implementation of the DOM, modern endodontic accesses can be smaller and more precise in their location on the crown of the tooth. The access is prepared using a high-speed handpiece and burs with water coolant. The selection of burs for access depends on the material(s) in the crown of the tooth. Ceramic restorations and porcelain are best approached using diamonds burs. Carbide burs are acceptable for metal (amalgam, gold, crown undercasting) and composite restoration.[24] The typical armamentarium consists of sizes 2, 4, and 6 round diamond burs and size 4 round carbide or #1157 carbide burs. After achieving access to the pulp chamber, safe end burs (Endo Z) can be used to avoid any unnecessary damage to the floor of the pulp chamber.

Additional instruments are sometimes required to localize the root canal orifices/canals (Fig. 7.13). Root canal localization can be complicated by calcification in the form of pulp stones and dystrophic calcification of the root canal space. To remove these calcified structures, Munce burs, Mueller burs, or Swiss LN burs can be used. They are long shanked rotary burs that can be used for precise troughing to expose root canal orifices. These burs come in different sizes to facilitate drilling at different levels without the root canal space and are used without water coolant, which can generate a significant amount of debris. Specialized endodontic ultrasonic tips can also be used for root canal localization. The advantages of ultrasonic tips are that they can be used very precisely and, if desired, used with water irrigation. Irrigants, dyes, and light can also help in root canal localization. A drop of sodium hypochlorite (NaOCl) can be placed in the pulp chamber and viewed under the DOM. The solution will often bubble and "light



• **Fig. 7.8** Images illustrating the prebuildup using composite resin after removal of the old restoration and before initiating root canal treatment. (Courtesy Dr. Howard H Wang.)

• **Fig. 7.9** Clampless rubber dam isolation using Wedjet in an upper anterior tooth with an all-ceramic crown. (Courtesy Dr. Elham Shadmehr.)



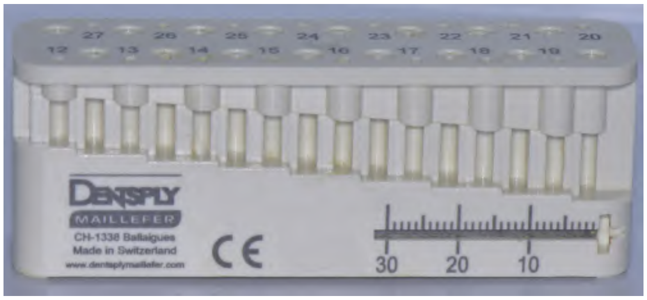
• **Fig. 7.10** Nonsurgical cassette used for endodontic treatment.

up" a canal orifice. Caries detection dye or other stains can also locate hard-to-find root canal orifices. Transillumination of the pulp chamber with a curing light has also been suggested to help locate root canal orifices. In summary, precise endodontic access is essential to a successful root canal treatment.

Cleaning and Shaping Instruments

Once access to the root canal system has been achieved, disinfection of the root canal space can be initiated. The goal of root canal disinfection is removing all pulp tissue and infected debris from the root canal system. Because achieving a sterile environment is currently impossible, the root canal space is then filled with a special filling material to "entomb" any remaining bacteria. Root canal disinfection is achieved through a step called "cleaning and shaping." Although the primary goal is only cleaning, the root canal space needs to be shaped by endodontic instruments to facilitate the cleaning process. It should be noted that the current disinfection process derives from the instruments and materials currently used. With the advancement in technology, noninstrumentation techniques may be used, and the need to further shape the canal to facilities cleaning may be no longer needed. Cleaning and shaping of the root canal space with the current endodontic armamentarium have two primary objectives: (1) the enlargement of the root canal space, and (2) creation of a space amenable to the filling "obturation" method being used. The instruments used for cleaning and shaping are classified by the ISO-Federation Dentaire Internationale. Instruments used by hand only are Group I. Instruments similar to Group I but which are used with a rotary engine or motor are Group II. Rotary engine–driven drills are Group III. All three groups are typically used for an endodontic procedure. Initially, small hand files can be inserted to "scout" the root canal space. After providing a glide path, rotary instrumentation can be commenced. Rotary instrumentation is performed using an endodontic electric motor (Fig. 7.14). The electric motor allows for more precise control of the speed of rotation than that allowed by an air-driven handpiece. Electric motors can also control the allowable torque, which can be set to maximize file performance and minimize file separation (breakage).

Hand and rotary files use standardized systems for sizing and identification. The size of a file is defined by 100 times the tip size. The taper of the file (the increase in diameter from the tip of the file to the handle) is based on 1/100th of a millimeter. The color-coded identification system is based on file size. With the exception of the three smallest file sizes (6, 8, and 10), the color pattern repeats to aid in file size identification (Fig. 7.15). Hand and rotary files come with different cross-sections and accordingly can be used in different motions and at different parts of



• **Fig. 7.11** Endodontic ruler.

the treatment. An illustration of the different hand instrument is shown in Fig. 7.16. The application and use of each of these instruments will be discussed in detail in Chapter 14. The taper for a standardized instrument is constant for the full length of the cutting flutes (typically 16 mm). The taper of the instrument refers to the incremental enlargement of the instrument diameter every 1 mm (Table 7.1). Some rotary endodontic files are variable in their taper, which means that the taper is not constant for the full extent of the cutting flutes and varies for different segments of the file.

After an initial glide path has been created, preparation of the coronal and middle thirds of the canal system can be started. A significant concept in the preparation of the coronal and middle thirds of the canal is called straight-line access. Root canal systems are typically similar to an hourglass in shape.[25] Straight-line access decreases the curvature in the coronal and middle thirds of the root canal, which favorably preserves the apical curvature. The coronal and middle thirds of the canal can be prepared with hand or rotary instrumentation. Traditionally, Hedstrom files were used to enlarge the space. Currently, the coronal and middle thirds are enlarged with Gates Glidden burs, Peeso reamers, specialized access burs, or nickel-titanium orifice openers. All can be effective in the coronal enlargement of the root canal system. Gates Glidden and Peeso reamers can also be used for the preparation of post space after completion of RCT (Fig. 7.17). Their use, however, should be restricted to the coronal and middle third of the canal. Both are available in various sizes (Table 7.2) and lengths. The apical third of the canal can be enlarged with hand or rotary files. The desired final size and taper of the root canal is determined by the width, curvature, and length of the root. Each root canal should be individually evaluated for maximum apical preparation size and taper. The physical attributes of the file (material and design) dictate its optimal use. The clinician should select the instrument type based on its mechanical properties and the desired goal needed to be achieved. Historically, files were made from carbon steel. Carbon steel had strength but was less flexible and degraded by sterilization. Stainless steel is used today and has the benefits of strength, improved flexibility compared with carbon steel, and heat tolerance. More recently, nickel titanium has been used for file fabrication. Nickel titanium allows for strength, flexibility, ability to withstand sterilization, and the ability to

• **Fig. 7.12** Hand pluggers in different sizes.

• **Fig. 7.13** Additional instruments used for canal localization. Long shank round burs in different sizes *(left)*. Ultrasonic tips with a round diamond tip *(right)*.

• **Fig. 7.14** Wireless endodontic motor used for endodontic rotary instruments.

tolerate engine-driven rotation. The combination of these characteristics allows nickel-titanium engine-driven files to produce a more consistent shape. Ultimately, the combined use of hand and engine-driven files is required due to the inherent limitations of each individual file. The ability to produce a consistent shape allows for more efficacious débridement, disinfection, and obturation of the root canal system.

Irrigants, Irrigation Devices, and Intracanal Medicaments

The use of hand and rotary instruments to adequately disinfect the root canal space should always be performed with an irrigant. From a conceptual point of view, the ultimate goal of irrigants is to provide a disinfected, tissue-free, and debris-free root canal space. Currently, there is no irrigant that can ultimately achieve all the required goals. As a result, numerous irrigants are used in modern endodontic treatment. The advantages and disadvantages of each irrigant should be considered during each step of endodontic treatment. Endodontic treatment should then be deconstructed into sections and the appropriate irrigant used for each step.

Numerous irrigants are used during endodontic therapy. NaOCl is the most commonly used irrigant in endodontics because it can dissolve pulp tissue and lubricate the root canals during treatment. In addition, NaOCl is bactericidal and can penetrate deep into the dentinal tubules.[26-30] Although 2% chlorhexidine (CHX) has antibacterial effects and is less caustic than NaOCl, CHX cannot dissolve organic tissue.[31-35] Ethylenediaminetetraacetic acid (EDTA or EDTAC) is used during endodontic treatment due to its ability to chelate inorganic molecules and remove the smear layer[36]; however, it lacks the degree of antibacterial or tissue dissolution properties of other irrigants.[34,37,38] Sterile saline has been used to irrigate root canals as well. Baker determined sterile saline to be an effective irrigant with sufficient volume.[39] However, its lack of disinfection and tissue dissolution are not ideal.[27] Sterile saline can be used as an intermediary solution between certain irrigants, such as NaOCl and CHX, to prevent any undesired chemical interactions.[40,41] Other disinfection solutions that contain a mixture of irrigants, such as MTAD and QMix (Dentsply Sirona, Inc., Tulsa, Oklahoma, USA) have been proposed to be used in endodontic treatment. Further discussion on these irrigants, their advantages, and drawbacks will be further discussed in Chapter 14.

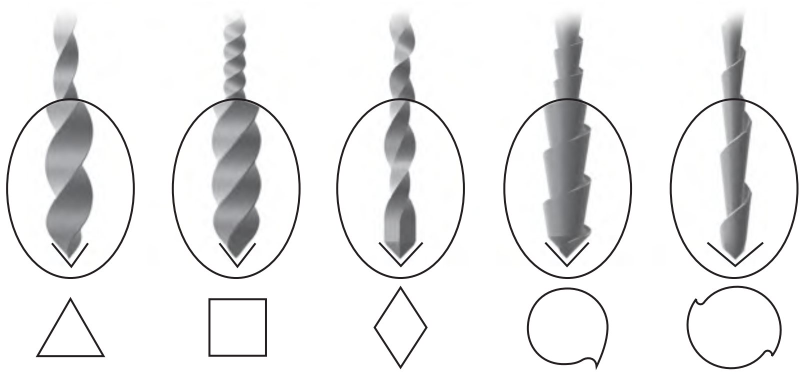
In clinical practice, the practitioner must determine the proper combination of irrigants and the ultimate concentration needed

File #	D0 diameter (in mm)	Handle Color
06	0.06	
08	0.08	
10	0.10	
15	0.15	
20	0.20	
25	0.25	
30	0.30	
35	0.35	
40	0.40	
45	0.45	
50	0.50	
55	0.55	
60	0.60	
70	0.70	
80	0.80	
90	0.90	
100	1.00	
110	1.10	
120	1.20	
130	1.30	
140	1.40	

• **Fig. 7.15** Color-coding specifications for standardization of files and reamers.

for each irrigant on a case-by-case basis. Depending on the status of the pulp and the periapical tissue at the time of treatment, as well as the type of treatment being performed, the combination of different irrigants can improve the quality of canal débridement.[42] Irrigants are commonly delivered in the root canal space using an irrigation syringe and a small-gauge irrigation needle. Endodontic irrigation needles range between 25 to 31 gauge. Smaller-diameter (higher gauge) needles allow greater apical depth and irrigation delivery in the canal, and thus their use should be considered during root canal treatment (Fig. 7.18).[43-45] Endodontic needles have various tip designs. They can be open-ended, close-ended, or side-vented. A side-vented irrigation needle is recommended to minimize pressure buildup caused by an opened-ended needle and thus minimize irrigation extrusion into the periapical tissues.[46,47] Energetically augmenting an irrigant's effectiveness has also been determined to have a positive effect on root canal disinfection. Devices such as an Endoactivator (Fig. 7.19) can allow sonic activation of the irrigants through oscillating patterns of nodes and antinodes.[48,49] The use of a small endodontic file on an ultrasonic handpiece to freely oscillate inside the canal is another form of irrigation activation. The transmittal of acoustic energy generating a rapid movement of fluid in a circular motion (acoustic streaming) and cavitation through the irrigant can improve its effectiveness.[50] Several other methods of irrigation activation will be discussed in Chapter 14.

With the complete preparation and disinfection of the root canal system, the final component to nonsurgical endodontic treatment is obturation of the root canal space. However, in some clinical situations when treatment is not completed due to time constraints or inability to achieve a dry canal, intracanal medicaments can be placed between visits, which can also enhance root canal disinfection. Among the intracanal medicaments used in root canal treatment is calcium hydroxide [$Ca(OH)_2$]. It has antibacterial properties and can assist in dissolving remaining pulp tissue in the root canal space.[51,52] $Ca(OH)_2$ is available in different forms (powder + liquid or paste). Paste forms can be easily injected into the root canal space (Video 7.2) or inserted via lentulo spiral (Fig. 7.20) to allow adequate distribution on to the canal wall. Other medicaments, such as 2% CHX gel, can be also used as an intracanal medicament.

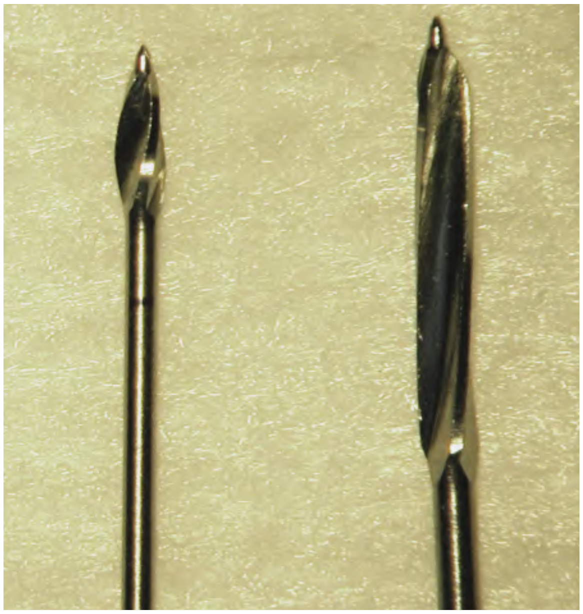


• **Fig. 7.16** Longitudinal and cross-sectional shapes of various hand-operated instruments. Note that small sizes of K-reamers, K-files, and the K-Flex have a different shape than the larger sizes.

TABLE 7.1 Hand Files Tip Size and Diameter Based on Different file Taper

File Size (Color)	Tip Size in mm	Diameter 3 mm from Tip with 02 Taper in mm	Diameter 3 mm from Tip with 04 Taper in mm	Diameter 3 mm from Tip with 06 Taper in mm
6 (Pink)	.06	.12	.18	.24
8 (Gray)	.08	.14	.20	.26
10 (Purple)	.10	.16	.22	.28
15 (White)*	.15	.21	.27	.33
20 (Yellow)*	.20	.26	.32	.38
25 (Red)*	.25	.31	.37	.43
30 (Blue)*	.30	.36	.42	.48
35 (Green)*	.35	.41	.47	.53
40 (Black)*	.40	.46	.52	.58

*Color code repeats starting at size 45 files. After size 60, files increase by 10 and not by 5.



• **Fig. 7.17** *Left*, Gates Glidden drill. Note the noncutting tip and the elliptical shape. *Right*, Peeso reamer. Note the noncutting "safe" tip and parallel sides. These are stiffer and more aggressive than the Gates Glidden drill. Both are used for straight-line access preparation.

TABLE 7.2 Rotary Flaring Instruments

Size	Gates Glidden Drills	Peeso Reamers
No. 1	0.4 mm	0.7 mm
No. 2	0.6 mm	0.9 mm
No. 3	0.8 mm	1.1 mm
No. 4	1.0 mm	1.3 mm
No. 5	1.2 mm	1.5 mm
No. 6	1.4 mm	1.7 mm

Obturation Armamentarium

Obturation of the root canal space is performed to seal the root canal space and prevent reinfection.[1] As mentioned earlier, Dr. Pierre Fauchard recommended obturating root canals with lead foil. During the past three centuries, numerous materials were promoted, including but not limited to, gold, plaster of Paris, rosin-chloroform, silver nitrate, formocresol, cotton, fiberglass, calcium hydroxide, silver cones, Hydron, and polyester. In 1867 Dr. G. A. Bowman introduced gutta-percha as a sole root canal obturation material. In 1925 U. G. Rickert suggested using a sealer in conjunction with gutta-percha to improve the obturation. This concept was later modified to allow for cold lateral condensation (compaction) of the primary gutta-percha cone and the subsequent placement of additional gutta-percha. In 1933 Dr. E. A. Jasper introduced silver cones as an obturation material.[53] The use of silver cones and cold lateral condensation of gutta-percha was the primary obturation methods for root canals until the 1960s. At that time, Dr. Herbert Schilder developed the warm vertical obturation method.[1] This technique included heating a gutta-percha mass and hydraulically compacting the molten material apically to obturate the pulp canal space. This method would create an apical seal, but the coronal and middle thirds of the canal would be devoid of material. The clinician would then continue obturating by inserting small pieces of gutta-percha into the root canal space, heating them, and condensing them, using endodontic pluggers until the entire root canal was obturated. Although silver cones are not used currently, cold lateral and warm vertical gutta-percha obturation techniques are still commonly used today.

The armamentarium needed can vary depending on the obturation technique used and the complexity of each case. The following items are currently the most commonly used:

1. **Gutta-percha cones** are available in different sizes and tapers. Standardized gutta-percha cones correspond to the size and taper of endodontic files used during root canal instrumentation. They are also available in a nonstandardized form (fine,

• **Fig. 7.18** Irrigation syringes containing different irrigation solutions that can be used during endodontic treatment. *From top to bottom*: (1) Sodium hypochlorite (NaOCl), (2) chlorhexidine (CHX), and (3) ethylenediaminetetraacetic acid (EDTA).

• **Fig. 7.19** EndoActivator used for irrigation activation.

fine medium, medium, medium fine, and coarse) that can be customized for every case.

2. **Paper points** are used to dry the root canal space before obturation. The rationale for drying the canal before obturation is that sealers tend to be hydrophobic,[54] preventing the flow of the sealer into the intricacies of the canal space. Moisture can also affect the setting property of sealers.[54] Like gutta-percha, paper points are available in different sizes in standardized and nonstandardized forms. Another method to dry the canal is the use of a surgical suction with a cannula within the canal to remove moisture before obturation.
3. **Sealer** is a cement applied inside the root canal space to adhere the obturation material to the root canal wall. The ideal properties for sealers were defined by Dr. Louis Grossman (Chapter 15). Sealers are available in different compositions. Zinc-oxide eugenol sealers have been traditionally used. However, modern sealers can be composed of epoxy resin or bioceramic materials (see Fig. 7.20). According to the type of sealer and the manufacturer, sealers can be supplied as either a powder and liquid, which are mixed at the time of use, or in a preprepared paste form. The obturation materials are classically placed on a glass slab before use. This placement allows for ease of visualization and a surface to mix the sealer (if required), and it can be used to form custom-made gutta-percha cones (if needed). The placement of the sealer into the canal can be performed by coating a gutta-percha cone or paper point and inserting it into the canal, or via rotary displacement of sealer with a lentulo engine-driven spiral (Fig. 7.21). Currently, several endodontic sealers are provided with an injection tip to facilitate direct application of the sealer in the root canal space.

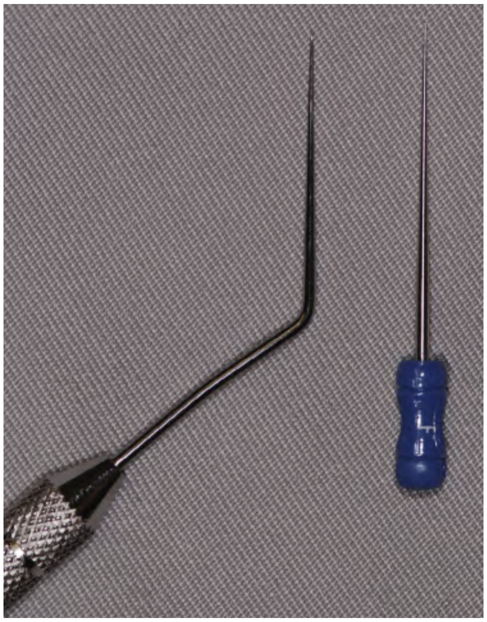
• **Fig. 7.20** The lentulo spiral drill is used to spin calcium hydroxide or sealer into canals.

4. **Spreaders** are used for lateral condensation of gutta-percha in the root canal space. Spreaders come in different shapes and sizes (standardized and nonstandardized). They can also be finger-held or hand-held (Fig. 7.22).
5. **Heat source** (e.g., System B) has the primary purpose of warming the gutta-percha, allowing it to flow under pressure. A heat source can also remove gutta-percha at any level within the root canal space.
6. Thermoplasticized gutta-percha dispensers (e.g., Obtura [Obtura Spartan, Algonquin, IL, USA] and Calamus [Dentsply Sirona, Tulsa, Oklahoma, USA]) are devices that preheat gutta-percha in a chamber, changing its physical properties from a beta phase to an alpha phase, thereby making it softer and easy to pack using endodontic pluggers. The gutta-percha can then be injected in the root canal space and compacted. Once the gutta-percha cools within the root canal space, it changes back to its beta phase, which is more stable. Some devices, such as Dual Calamus (Dentsply Sirona, Tulsa, Oklahoma, USA) can have both, a heat source and a thermoplasticized gutta-percha dispenser, in the same device (Fig. 7.23). Additional details are provided in Chapter 15 regarding the various obturation techniques and armamentarium that can be used to manage various clinical cases.

Study Questions

1. All of the following are normally included in an examination kit EXCEPT:
   a. Mouth mirror
   b. Periodontal probe
   c. Cotton pliers
   d. Periosteal elevator
   e. Dental explorer
2. Which of the following is not found in a typical nonsurgical treatment cassette?
   a. DG16 explorer
   b. Anesthetic syringe
   c. Retro-pluggers
   d. Cotton pliers
   e. Plastic instrument
3. A CBCT scan is recommended for examining all the following conditions EXCEPT:
   a. Dental caries detection
   b. Internal resorption
   c. External resorption
   d. Traumatic injuries
   e. Treatment planning for apical surgery
4. Rubber dam isolation…
   a. Provides a clean operation field
   b. Improves visualization of the tooth to be treated
   c. Prevents aspiration of dental instruments
   d. Limits the visibility to the floor of the mouth
   e. All of the above
5. All of the following irrigants are used for nonsurgical root canal treatment EXCEPT:
   a. NaOCl
   b. EDTA
   c. formocresol
   d. Chlorhexidine
   e. Sterile saline

• **Fig. 7.21** Different types of endodontic sealers. *Top*: Bioceramic sealer (Brassler, Augusta, GA, USA). *Bottom*: AH plus sealer (Dentsply Sirona, Tulsa, OK, USA).

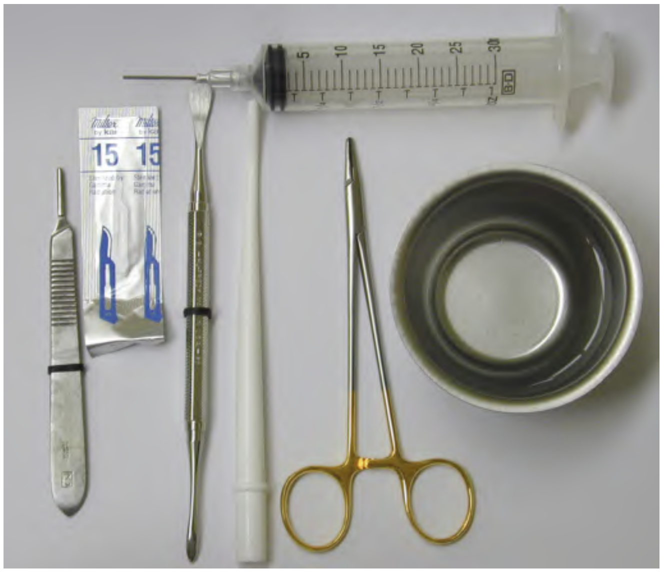


• **Fig. 7.22** D11 handled spreader *(left)* and a fine finger spreader *(right)*. Both are designed for lateral condensation.

• **Fig. 7.23** Dual Calamus obturation device. On the left side is the heat system; on the right side is a thermoplasticized gutta-percha dispenser.

Coronal Seal

After completion of RCT, the access opening in the tooth must be restored. Although some treatments can allow for the placement of a permanent restoration at the time of treatment, the tooth after root canal treatment is often sealed with a temporary material. The pulp chamber is cleaned of all sealer and gutta-percha with a solvent. This process is typically performed using isopropyl alcohol on a cotton pellet or microbrush. Once complete, a piece of sterile cotton or sponge is placed in the pulp chamber. The access is then sealed with a temporary material. Numerous temporary materials have been used historically. Most materials were eugenol-based, such as zinc oxide eugenol (ZOE) or intermediate restorative material (IRM). Noneugenol based materials, such as Cavit or glass ionomer are more commonly used today due to their improved mechanical properties.[55-58] A plastic instrument is then used to adapt the temporary filling material to the access cavity. It should be noted that the success of endodontic treatment is significantly affected by the quality of the final restoration.[59,60] In a systematic review by Gillen et al., researchers showed that the quality of the coronal restoration is as important as the quality of the root canal filling for the success of the endodontic treatment.[59] Thus nonsurgical endodontic treatment is fully completed only with a proper permanent restoration in place.



• **Fig. 7.24** Basic emergency kit for an incision for drainage includes (1) scalpel handle, (2) blade, (3) periosteal elevator, (4) suction tip, (5) needle holder, (6) irrigating syringe with an 18-gauge needle, and (7) sterile saline. A rubber dam drain is a frequent addition.

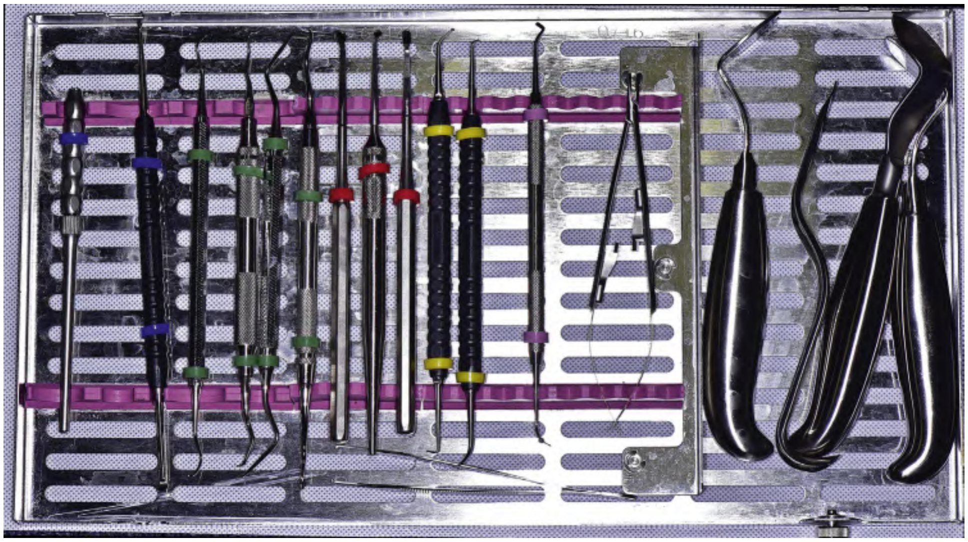
Surgical Armamentarium

Incision and Drainage Armamentarium

Patients can present with swelling before or after endodontic therapy. The swelling can be defined as indurated (cellulitis) or fluctuant (abscess). The swelling can be confined to one fascial space or spread to multiple spaces. The practitioner should always remember that not all swellings are from dental (endodontic) cause. After the swelling has been definitively determined to be of endodontic origin and a thorough review of the patient's past medical history does not contraindicate patient treatment, incision and drainage of the swelling is required. Incision and drainage for endodontic issues is not a solitary treatment. Endodontic therapy in addition to incision and drainage is required to remove the source of the infection and speed resolution of the swelling. The armamentarium used for an incision and drainage is relatively basic and includes (1) scalpel, (2) periosteal elevator, (3) hemostat and (4) sterile saline in a plastic syringe, and (5) drain (Fig. 7.24). Proper anesthesia should be administered before any incision. A scalpel is used to make an incision in the dependent base of the swelling. Number 12 and 15 blades are the most commonly used blades for this procedure. The type of blade used, however, may vary depending on the location and accessibility of the most fluctuant part of the swelling. The incision should not simply cut the gingiva but extend to the cortical bone. Whether the incision should be vertical or horizontal in origin is debatable. Classically, the incision is made in a horizontal direction. Care should be exercised to avoid important anatomic landmarks (e.g., the mental foramen) where transient or permanent injury to the underlying tissues can occur. After making the incision, a periosteal elevator is then placed in the incision to perform blunt dissection. If the swelling is fluctuant, this procedure should provide laudable pus and exudate drainage. In some cases, a curved hemostat may be needed to drain and decompress the swelling. The hemostat is inserted and bluntly forced into the swelling to lyse any loculations. The incision should then be copiously irrigated with sterile saline. After drainage, the clinician must decide whether to place a physical drain. Most swellings of endodontic origin that comprise one fascial space do not require the placement of a physical drain. The incision site will heal and close after treatment. However, the site is still weakened and therefore remains the path of least resistance for future swelling, should it occur. If a physical drain would appear to be beneficial, a piece of rubber dam cut with a dovetail can be inserted into the incision. The dovetail should prevent dislodgement. A suture can also be placed to stabilize the drain if needed. For more extensive swellings, a Penrose drain can be inserted and sutured in place. The steps and techniques of drain placement will be further covered in Chapter 9.

Root End Surgery (Apicoectomy) Armamentarium

Endodontic treatment is usually initiated by cleaning and sealing the root canal space through the crown portion of the tooth. In certain clinical situations or when a previously root canal–treated tooth fails, cleaning and sealing the root canal space may require further treatment using a surgical approach in an attempt to address the canals from the apical end (root end side). For that, a completely different set of instruments and materials are used to allow reflection of the soft tissue and bone, removal of the granulomatous tissue, resection of the apical portion of the root, preparation, and filling of the root end portion from an apical approach. This process can be followed by guided tissue regeneration, if needed, and suturing the soft tissue back to its place. The surgical cassette (Fig. 7.25) consists of (1) scalpel, (2) periosteal elevator, (3) retractors, (4) bone curettes, (5) periodontal curettes, (6) micromirrors, (7) retro pluggers, and (9) needle holders. Also, other instruments and materials are needed in combination with the surgical cassette, such as (1) blades, (2) Impact Air handpiece (see later section), (3) burs, (4) retro-preparation ultrasonic tips, (5) hemostatic agents, (6) dye, (7) retro-filling material, and (8) suture material. The armamentarium used for root end surgery has been modified in the past two decades to allow better management of the soft tissue, bone structure, and root end portion of the tooth. The term used for these instruments in today's practice is "microsurgical armamentarium," and hence the procedure today is termed "microapical surgery," rather than just traditional "apical surgery." The success rate of microsurgery is very high, in the 90% range,[61-64] and has been shown to be superior to traditional endodontic surgery.[17,65] Thus the use of the appropriate armamentarium (and filling material) can play a major role in the success of the treatment provided. The blades used in microsurgery, such as microblades or #15 C, are smaller and more precise to cut soft tissue, compared with traditional surgery that often involved a #15 blade (Fig. 7.26). If microblades are to be used, a microscalpel will be needed. Using the appropriate blade together with proper flap design will result in less recession of the soft tissue after treatment. Periosteal elevators or mold curettes are used to reflect the soft tissue away from the bone. They usually come in different shapes and sizes (Fig. 7.27). Selection of the appropriate size will prevent laceration of the soft tissue during reflection. Unlike nonsurgical treatment, the Impact Air surgical handpiece is designed with a 45-degree angled head to allow for better visibility while cutting the bone (Fig. 7.28). It also does not release any air into the surgical site to avoid the possibility of surgical emphysema. The flap is retracted using the appropriate retractor. A classical retractor often used is the Minnesota retractor. Other retractors have been developed to facilitate easier retraction in the

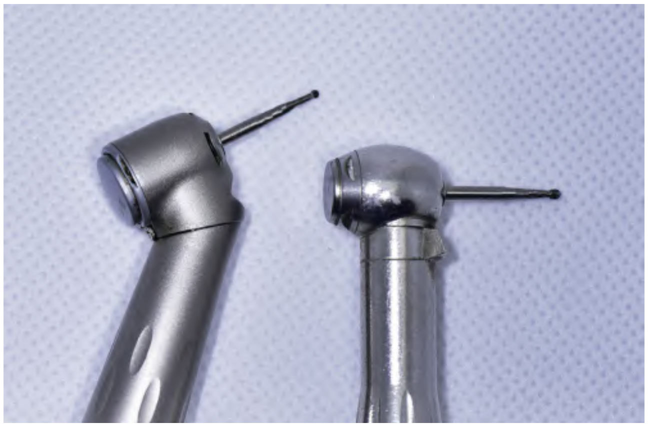


• **Fig. 7.25** Surgical cassette for root end surgery.

• **Fig. 7.26** Different types of blades, *from top to bottom*: (1) standard 15 blade, (2) 15 C blade, and (3) microblade.

• **Fig. 7.27** Mold curettes used to reflect the flap off the bone and elevate the periosteum.

anterior and posterior area (Fig. 7.29). Surgical burs are used to remove bone, create the osteotomy, and cut the root end portion of the tooth. After the osteotomy, bone curettes are needed to remove the granulation tissue from the bony crypt. They also come in different sizes to accommodate for the size of the bony crypt (Fig. 7.30). The granulation tissue is often attached to the root; thus periodontal curettes are used to release the granulation tissue from the root surface (Fig. 7.31). Retro preparation is then initiated using specially designed ultrasonic tips (retropreparation tips), which come in different angulations and sizes to accommodate the different roots (anterior or posterior) (Fig. 7.32). They are also available in different lengths (3 mm, 6 mm, and 9 mm). Although 3 mm retro preparation tips are the most commonly used, 6 mm and 9 mm tips can be often used to allow further cleaning of the root canal space from an apical direction in special clinical cases. Micromirrors are used to visualize the root end portion of the tooth after retro preparation to ensure that no cracks are present (Fig. 7.33). This technique can be combined with the use of dyes to stain the apical end of the root as well



• **Fig. 7.28** Surgical handpiece with a 45-degree angled head *(left)*. Nonsurgical handpiece for standard dental work.

• **Fig. 7.29** Surgical retractors with different tip design for retraction at various locations.

as transillumination to visualize any apical defects[66] (Fig. 7.34). Adequate bleeding control is required for proper visualization and placement of the root end filling. For that, hemostatic agents such as epinephrine pellets, ferric sulfate, or resorbable collagen can be used to control bleeding. The retro-filling material is then placed, using carriers or hand instruments, into the retro cavity. Different categories of retro-filling materials have been used in endodontic surgery. Traditionally, amalgam has been used as a retro-filling material. Due to its moisture sensitivity, it did not provide an adequate seal in the apical area,[67,68] and as a result, the outcome of apical surgery was affected.[17] Over the years, several other retro-filling materials have been introduced, such as IRM, glass ionomer, and resin-based retro-filling material. The most recently introduced and commonly used material in today's microsurgery armamentarium are calcium silicate–based materials such as mineral trioxide aggregate (MTA; Dentsply Sirona, Tulsa, Oklahoma, USA) or Bioceramic putty (Brassler, Augusta, Georgia, USA). These materials have shown superiority in their sealing ability as well as stimulation of hard tissue repair.[68,69] Depending on the crypt size and bone structure, bone substitutes and resorbable membranes can be placed into the bony crypt to enhance and/or restore the integrity of the supporting structure.[70,71] Finally, sutures are used to place the flap back in position. Sutures also come in different sizes, starting 1-0 to 10-0. Usually, 5-0 or 6-0 sutures are used to approximate the flap back to its place. For that process, specially designed needle holders would be used to allow adequate manipulation of the small threads (Fig. 7.35). More details regarding the use of all these instruments are discussed in Chapter 21.

Study Questions

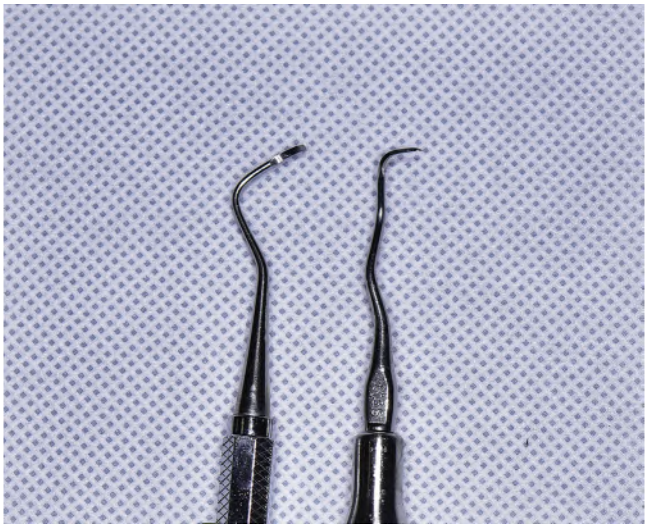
6. Endodontic surgery "apicoectomy" includes:
   a. Resection of an entire root
   b. The placement of a retro-filling material to seal the root canal apically
   c. The use of NaOCl to disinfect the osteotomy site
   d. Stimulation of bleeding to improve visualization and placement of a retro-filling material
7. Dental operating microscopes are beneficial for:
   a. The prevention of carpal tunnel syndrome in the operator
   b. Decreased illumination of the surgical field
   c. Location and negotiation of root canals
   d. Low level magnification
   e. Nonsurgical treatment only
8. Which of the following radiographic methods is not commonly used in endodontic diagnosis?
   a. Periapical radiographs
   b. Bitewings
   c. CBCT
   d. Panoramic x-ray
9. Surgical operating microscopes are superior to dental loops in
   a. Provides higher magnification
   b. Allowing minimal illumination
   c. Minimizing neck strains
   d. All of the above
   e. Only a and c
10. All of the following can be utilized to locate the canal orifices EXCEPT:
    a. DG16 explorer
    b. Mirror
    c. Dental operating microscope
    d. Apex locator
    e. Caries detection dye
11. Which of the following irrigants has the ability to dissolve pulp tissue and disinfect the root canal system?
    a. NaOCl
    b. $Ca(OH)_2$
    c. EDTA
    d. Chlorhexidine
    e. Formocresol

ANSWERS

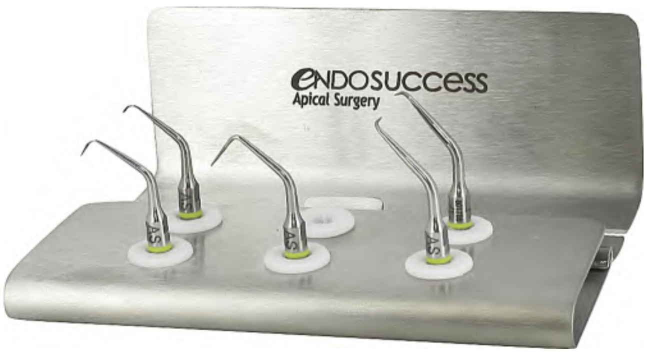
Answer Box 7

1 d. Periosteal elevator
2 c. Retro pluggers
3 a. Dental caries detection
4 e. All of the above
5 c. formocresol
6 b. The placement of a retro-filling material to seal the root canal apically
7 c. Location and negotiation of root canals
8 d. Panoramic x-ray
9 e. Only A & C
10 d. Apex locator

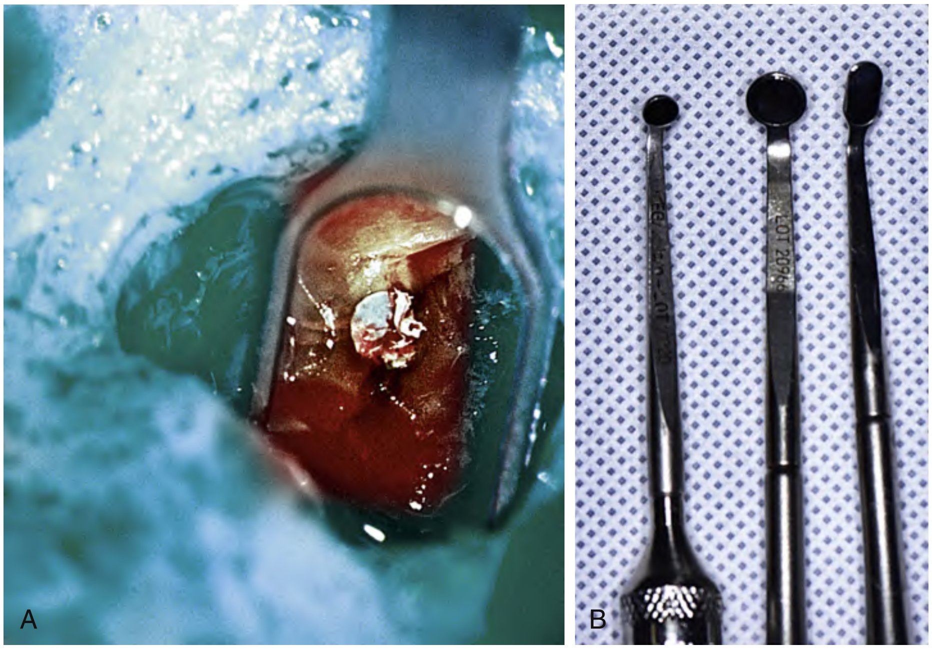
• **Fig. 7.30** Angulated bone curettes to facilitate removal of granulation tissue from the periapical lesion.



• **Fig. 7.31** Periodontal curette to scale the root surface after apical resection and removal of granulation tissue.



• **Fig. 7.32** Ultrasonic set showing the different ultrasonic tip designs that can be used for root end preparation in the anterior and posterior roots.



• **Fig. 7.33** Micromirrors used during endodontic surgery *(right)*. Illustration of the use of a micromirror to visualize an apical crack *(left)*.

• **Fig. 7.34** The product called "To Dye For," used to stain the root surface *(left)*. Illustration of the staining process in root end surgery (*top* and *bottom right*).

• **Fig. 7.35** Standard needle holder *(left)* and Castroviejo needle holder *(right)*.

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