Before the actual operative aspects of root canal therapy are begun, a number of preparatory procedures must first be completed:

1. Radiography is needed, first as an aid to diagnosis, then periodically during treatment. Endoscopy, orascopy, and the surgical microscope are supplemental aids to visual enhancement.
2. Specialized endodontic instruments and equipment must be arranged for ready use.
3. Local anesthesia of the involved tooth or area may be necessary. Special problems of anesthesia also may arise, particularly with mandibular molars and in the case of an inflamed pulp.
4. Rubber dam placement sometimes requires special handling in endodontics.

ENDODONTIC RADIOGRAPHY*

No single scientific development has contributed as greatly to improved dental health as the discovery of the amazing properties of cathode rays by Professor Wilhelm Konrad Roentgen in November 1895. The significant possibilities of their application to dentistry were seized upon 14 days after Roentgen’s announcement, when Dr. Otto Walkoff took the first dental radiograph in his own mouth.¹ In the United States, within 5 months, Dr. William James described Roentgen’s apparatus and displayed several radiographs. Three months later, Dr. C. Edmund Kells gave the first clinic in this country on the use of the x-ray for dental purposes. Three years later (1899), Kells was using the x-ray to determine tooth length during root canal therapy.

“I was attempting to fill the root canal of an upper central incisor,” Kells later said. “It occurred to me to place a lead wire in this root canal and then take a radiogram to see whether it extended to the end of the root or not. The lead wire was shown very plainly in the root canal.”

One year later (1900), Dr. Weston A. Price “called attention to incomplete root canal fillings as evidenced in radiographs.” By 1901, Price was suggesting that radiographs be used to check the adequacy of root canal fillings.² Price is also credited with developing the bisecting angle technique, whereas Kells described what today is called the paralleling technique, made popular some 40 years later by Dr. Gordon Fitzgerald.

Although these early attempts were rarely of diagnostic quality, they were the beginning of a new era for all of dentistry. For the first time, dentists could see the accumulation of past dental treatment—therapy done without knowledge of what lay beneath the gingiva. Needless to say, the calamitous findings must have disheartened the conscientious practitioner. Yet even today, with all of the modern engineering refinements, the sleekness of operation, and the reduction of hazards, a discouraging segment of our profession continues to deprive the public by failing to use radiography to its full potential.

The total application of roentgen rays and the disciplined interpretation of the product are beyond the scope of this textbook. Only the utilization of radiography in endodontics will be discussed here. Suffice it to say that radiography is absolutely essential for root canal therapy.

Application of Radiography to Endodontics

The roentgen ray is used in endodontic therapy to (1) aid in the diagnosis of hard tissue alterations of the
teeth and periradicular structures; (2) determine the number, location, shape, size, and direction of roots and root canals; (3) estimate and confirm the length of root canals before instrumentation; (4) localize hard-to-find, or disclose unsuspected, pulp canals by examining the position of an instrument within the root (Figure 9-1); (5) aid in locating a pulp that is markedly calcified and/or receded (Figure 9-2); (6) determine the relative position of structures in the facial–lingual dimension; (7) confirm the position and adaptation of the primary filling point; (8) aid in the evaluation of the final root canal filling; (9) aid in the examination of lips, cheeks, and tongue for fractured tooth fragments and other foreign bodies (except plastic and wood) following traumatic injuries; (10) aid in localizing a hard-to-find apex during periradicular surgery; (11) confirm, following periradicular surgery and before suturing, that all tooth fragments and excess filling material have been removed from the apical region and the surgical flap; and (12) evaluate, in follow-up films, the outcome of endodontic treatment.

**Limitations of Radiographs**

Radiographs have their limitations! They are suggestive only and should not be considered the singular final evidence in judging any clinical problem. There must be correlation with other subjective and objective findings. The greatest fault with the radiograph relates to its physical state; it is a record of a shadow, and as such only two dimensions are shown on a single film. As with any shadow, these dimensions are easily distorted through improper technique, anatomic limitations, or processing. In addition, the buccal-to-lingual dimension is absent on a single film and is frequently forgotten, although techniques are available to define the third dimension. These techniques are described later in detail.

Radiographs are not infallible. Various states of pulpal pathosis are indistinguishable in the x-ray shadow. Neither healthy nor necrotic pulps cast an unusual image. Correspondingly, the sterile or infected status of hard or soft tissue is not detectable other than by inference. Only bacteriologic evidence can determine this. Furthermore, periradicular soft tissue lesions cannot be accurately diagnosed by radiographs; they require histologic verification. Chronic inflammatory tissue cannot, for example, be differentiated from healed, fibrous, “scar” tissue, nor can a differential diagnosis of periradicular radiolucencies usually be made on the basis of size, shape, and density of the adjacent bone. A common misconception is that an inflammatory lesion is present only when there is at least a perceptible “thickening” of the periodontal ligament space. In fact, investigators have demonstrated that lesions of the medullary bone are likely to go undetected until the resorption has expanded into and eroded a portion of the cortical plate. The difficulties and inherent errors in radiographic interpretation were clearly demonstrated by Goldman et al., who submitted recall radiographs of endodontic treatments, for clinical evaluation, to a group of radiologists and endodontists. They assessed success and failure by observation of radiodensities. There was more disagreement than agreement among the examiners.

Radiographs are an essential aid to diagnosis but must be used with discretion. However, radiographs are the

---

Figure 9-1  Disclosing canals by radiography. A, Right-angle horizontal projection reveals four files in separate canals superimposed. B, Horizontal angulation varied 30 degrees mesially reveals all four canals and file short of working length in mesiobuccal canal (arrow). Reproduced with permission from Walton RE.
only method whereby the dentist can “visualize” that which he cannot see or feel during the process of diagnosis and treatment. He will discover that, as his radiographic techniques and interpretation improve, so will the ease and success of his root canal treatment. The techniques outlined in the following sections have proved to be successful and predictable. If followed, they will greatly simplify difficulties in root canal treatment.

INSTRUMENTATION

Systems
There are two radiographic approaches. The traditional approach is the x-ray exposure of film, which is then chemically processed to produce an image. The newer digital radiography systems rely on an electronic detection of an x-ray-generated image that is then electronically processed to produce an image on a computer screen, an image that is similar in interpretative quality to the traditional radiograph.\(^\text{13-16}\) Advantages of digital radiography include reduced radiation of the patient, speed of obtaining the image, enhancement of the image, computer storage, transmissibility, and a system that does not require chemical processing.\(^\text{17}\) Disadvantages are cost and ease of use, although endodontists are not finding these to be a deterrent to their practice, in which speed and the preceding features are important. As costs decrease and technology improves, use of the digital system will undoubtedly increase by all practitioners. Digital radiography is discussed in full later in the chapter.

Traditional Machines
Two basic types of x-ray machines are commonly used in dental offices. One type has a range of kilovoltage and two milliamperage settings with which the long (16-inch) cone is frequently used. The other type offers only one kilovoltage and milliamperage setting and only the short (8-inch) cone. Either type provides adequate radiographs. However, each has advantages that, under different circumstances, will yield a more satisfactory result. The long-cone system is superior for diagnostic radiographs, whereas the flexible short-cone machine is more appropriate for treatment or “working” films. Any x-ray machine must be properly shielded and collimated by means of a lead diaphragm and filtered by aluminum disks to ensure proper radiation safeguards for the patient and professional personnel. An additional protective measure is the draping of the patient with a lead apron to block scatter radiation.

Long Cone. Because of the clarity of detail and minimum distortion inherent in the long-cone parallel technique,\(^\text{18-21}\) the long-cone machine is preferred for exposing diagnostic, final, and follow-up radiographs.

Short Cone. Because of the number of working radiographs taken in the course of endodontic therapy, the practitioner treating more than the occasional tooth will find that a short-cone machine, with a small, easily manipulated head, saves much time, energy, and frustration (Figure 9-3).

Film. Industrial technological advances have allowed film exposure time to be reduced to fractions of
a second. Recent improvements in emulsion thickness allow rapid processing of the new films, which are used for diagnostic and "working" films alike. A study of Kodak Ektaspeed film ("E" film), which is coated with larger silver bromide crystals and has one half the exposure time of standard Kodak Ultraspeed film, concluded that the "Ektaspeed film had comparable accuracy in measuring root length," even though the new Ektaspeed is somewhat grainier.22 A double-blind study found the slower Ultraspeed film superior "in terms of contrast, image, quality, and rater satisfaction."23 However, a US Army study found both films "adequate for routine endodontic use."24

An even faster film (F speed) has very recently been introduced. This film requires 20% less radiation but appears grainier. There are no published studies to date on the suitability of this new film for endodontic use.

For dentists with a referral endodontic practice, duplicate film packets are recommended for the diagnostic, final treatment, and recall radiographs—one set for the permanent office record, the other for the referring dentist. One must know, however, that the front film in the double pack, the one closest to the x-ray machine, "had significantly superior image quality compared to back films."25

The standard periradicular size film is used for most situations. In addition, every office should have 2 × 3-inch occlusal film available for use when (1) periradicular lesions are so extensive that they cannot be demonstrated in their entirety on one periradicular film; (2) there is interest in or involvement of the nasal cavity, sinuses, or roof or floor of the mouth; (3) trauma or inflammation prohibits normal jaw opening required to place and hold a periradicular film; (4) a handicapped person is unable to hold a periradicular film by the usual means; (5) detection of fractures of the anterior portion of the maxilla or mandible is needed; and (6) very young children are being examined.

**Film Placement.** Film placed parallel to the long axis of the teeth and exposed by cathode rays at a right angle to the surface of the film yields accurate images, free of shortening or elongation26 (Figure 9-4). If this principle is applied, it is unnecessary to memorize fixed cone angulations. In a modern, comfortable operating chair, moreover, with the patient in a semireclined position, she need not be returned to an upright position for each exposure.

Because of the complicating presence of the rubber dam, the methods for placement of working films dif-

![Figure 9-3](image1.png)

*Figure 9-3* Working head of the flexible, compact, short-cone x-ray machine, the GX-770, ideal for exposing endodontic “working” films but of adequate quality for diagnostic, archival, or follow-up purposes. (Courtesy of Gendex Corp., USA.)

![Figure 9-4](image2.png)

*Figure 9-4* Radiographic parallelism. The long axis of the film, the long axis of the tooth, and the leading edge of the cone are parallel and perpendicular to the x-ray central beam. Reproduced with permission from Goerig AC. In: Besner E, et al., editors. Practical endodontics. St. Louis (MO): Mosby; 1993. p. 56.
fer somewhat from the methods for placement of diagnostic, final, and follow-up films.

**Diagnostic Radiographs.** These must be the best radiographs possible. To achieve this goal, there are advantages to parallelism, which permits more accurate visualization of structures as well as reproducibility. This facilitates comparison of follow-up radiographs.

There are a number of devices on the market that ensure film placement and parallelism. The *Rinn XCP* (Dentsply/Rinn Elgin, Ill.) virtually guarantees distortion-free films but cannot be used with the rubber dam in place. The *Rinn Endoray II endodontic film holder* is designed specifically to ensure parallelism yet avoid rubber dam clamps while allowing space for files protruding from the tooth (Figure 9-5). Film holders are preferred to finger retention of the film. A *straight hemostat* is an excellent film holder.

**Working Radiographs.** One great difficulty in root canal therapy is the clumsy, aggravating method of taking treatment radiographs with the rubber dam in place. Some dentists remove the rubber dam frame for access in film placement, and saliva enters to contaminate the operating field. It is therefore imperative that a film-placement technique be used so that the *rubber dam frame need not be removed*. Use of a radiolucent N-O (Nygard–Østby) frame (Coltene/Whaledent/Hygienic; Mahwah, N.J.), *le Cadre Articulé*-type frame (Jored, Ormoy, France, or Trophy, USA) (see Figures 9-57 and 9-58), or the *Star VisiFrame* (Dentaleze/Star, USA) will ensure that apices are not obscured.

With the rubber dam in place, a *hemostat-held film* has significant advantages over the finger-retained film:

1. the film placement is easier when the opening is restricted by the rubber dam and frame;
2. the patient may close with the film in place, a particular advantage in *mandibular posterior areas* where closing relaxes the mylohyoid muscle, permitting the film to be positioned farther apically;
3. the handle of the hemostat is a guide to align the cone in the proper vertical and horizontal angulation (Figure 9-6); and
4. there is less risk of distortion of the radiograph caused by too much finger pressure bending the film; and
5. patients can hold a hemostat handle more securely with less possibility of film displacement. In addition, any movement can be detected by the shift of the handles and corrected before exposure.

In all instances of film placement, the *identifying dimple* should be placed at the incisal or occlusal edge to prevent its obscuring an important apical structure.

**Cone Positioning.** It is a mistake to rely on only one film. There is much to be learned from additional exposures taken from varied horizontal or vertical projections.

**Vertical Angulation.** Ordinarily, it is preferable to align the cone so the beam strikes the film at a right angle. This alignment ensures a fairly accurate vertical image. Elongation of an image, however, may be corrected by increasing the vertical angle of the central beam.

![Figure 9-5](image1) The universal Rinn EndoRay plastic film holder is designed for horizontal posterior films or anterior vertical films, maxilla or mandible, right or left. Here it is set for a maxillary posterior view. The “cupped-out” area accommodates the tooth, clamp, and extruding endodontic files. The parallel sighting rod/handle can be moved from right to left. (Courtesy of Rinn Corp., USA.)

![Figure 9-6](image2) “Working” film properly placed and held under rubber dam with hemostat. Cone is aligned at right angle to handle. (Courtesy of Dr. Richard E. Walton.)
ray. Conversely, foreshortening is corrected by decreasing the vertical angle of the central ray. To remember this, one should think of the sun: it casts a shortened shadow at noon when it is at its zenith, or increased vertical angle.

Frequently, an impinging palatal vault prevents parallel alignment of the film and the teeth. However, if the film angle is no greater than 20 degrees in relation to the long axis of the teeth, and the beam is directed at a right angle to the film, no distortion occurs, although there is a less effective orientation of structures. The resulting radiograph is still adequate.

**Horizontal Angulation.** Walton introduced an important refinement in dental radiography that has materially improved the endodontic interpretive film. He demonstrated a simple technique whereby the third dimension may be readily visualized. Specifically, the anatomy of superimposed structures, the roots and pulp canals, may be better defined.

The basic technique is to vary the horizontal angulation of the central ray of the x-ray beam. By this method, overlying canals may be separated, and by applying Clark's rule, the separate canals may then be identified. Clark's rule states that “the most distant object from the cone (lingual) moves toward the direction of the cone.” Stated in another way, using a helpful mnemonic, Clark's rule has been referred to as the SLOB rule (Same Lingual, Opposite Buccal): the object that moves in the same direction as the cone is located toward the Lingual. The object that moves in the opposite direction from the cone is located toward the Buccal. The SLOB rule, simply stated, is “The lingual object will always follow the tube head.” Goerig and Neaverth cleverly applied the SLOB rule to determine, from a single film, from which direction a radiograph was taken: mesial, straight on, or distal. Knowing the direction, one is then able to determine lingual from buccal. The SLOB rule, simply stated, is “The lingual object will always follow the tube head.” Goerig and Neaverth cleverly applied the SLOB rule to determine, from a single film, from which direction a radiograph was taken: mesial, straight on, or distal. Knowing the direction, one is then able to determine lingual from buccal. (Figure 9-7). Stated more simply, Ingle's rule is MBD: Always “shoot” from the Mesial and the Buccal root will be to the Distal.

**Horizontal Angulation Variations.** Mandibular Molars. As previously emphasized, the film must be positioned parallel to the lower arch. The standard horizontal x-ray projection then is at a right angle to the film (perpendicular), as shown in Figure 9-8. The two mesial canals are superimposed one upon the other and appear as a single line.

Through the Walton projection, however, the canals can be made to “open up.” This is done by directing the central beam 20 to 30 degrees from the mesial (Figure 9-9, A). In Figure 9-9, B (black arrows), the two canals in each root can now be readily discerned.

The contrast gained by varying the horizontal projection can best be seen in a clinical case with four canals. Figure 9-10, A, taken at a right angle, clearly shows the four instruments superimposed on one another. Figure 9-10, B, on the other hand, taken from a 30-degree variance in horizontal projection, emphasizes the third dimension: the separation of the instruments in the canals. By applying Ingle's rule (MBD: shoot from the mesial), one also determines that the buccal canals are toward the distal.

Another point should be made at this time concerning a frequent mistake in “reading” periradicular radiographs. It can best be illustrated by a cross-sectional drawing of molar root structure. Roots containing two canals are often hourglass-shaped, as Figure 9-11, A, indicates. When an x-ray beam passes directly through this structure, the buccal and lingual portions of the root are in the same path (arrows). Because a double thickness of tooth structure is penetrated by the x-rays, it is seen in the film as a radiopaque root outline in close contact with the lamina dura. This is readily apparent on the radiograph (Figure 9-11, B).

By aiming the cone 20 degrees from the mesial, however, the central beam passes through the hourglass-shaped root at an angle (Figure 9-12, A). In this case, the two thicknesses of the root are projected separately onto the film. Since less tooth structure is penetrated by the x-ray, the image on the film is less dense. A radiolucent line is clearly seen in Figure 9-12, B (open arrow). This radiolucent line can be erroneously “read” as a root canal. One should take care to follow up the length of the line. Instead of entering the pulp chamber, it can be traced to emerge at the gingival surface of the root. This simple interpretive error can easily lead to gross mistakes in endodontic cavity preparation.

**Mandibular Premolars.** The importance of varying the horizontal angulation when radiographing mandibular premolars is demonstrated in Figure 9-13, A, wherein the central ray is directed at a right angle to the film. What appears to be a single straight canal is discernible in each premolar (Figure 9-13, B). There is an indication, however, in the image of the first premolar that the canal might bifurcate at the point of the abrupt change in density (arrow).

Directing the central ray 20 degrees from the mesial in the first premolar (Figure 9-14, A) causes the bifurcation to separate into two canals (Figure 9-14, B). The tapering outline of the tooth, seen in both projections, would indicate, on the other hand, that the two canals undoubtedly rejoin to form a common canal at the apex. In both the right-angle and 20-degree variance projections, the second premolar appears as a single canal.
Maxillary Molars. Maxillary molars are consistently the most difficult to radiograph because of (1) their more complicated root and pulp anatomy, (2) the frequent superimposition of portions of the roots on each other, (3) the superimposition of bony structures (sinus floor, zygomatic process) on root structures, and (4) the shape and depth of the palate, which can be a major impediment.

As is true of the mandible, the complex root anatomy and superimpositions may be dealt with by varying the horizontal angulations. Film placement must again be parallel to the posterior maxillary arch, not to the palate.

The standard right-angle projection for a maxillary first molar that is illustrated in Figure 9-15, A, produces the image seen in Figure 9-15, B, wherein the zygomatic process is superimposed on the apex of the palatal root (arrow) and the distobuccal root appears to overlie the palatal root. The sinus floor is also superimposed on the apices of both the first and second molars.

When the horizontal angulation is varied by 20 degrees to the mesial (Figure 9-16, A), the zygomatic process is moved far to the distal of the first molar and the distobuccal root is cleared of the palatal root (Figure 9-16, B, arrows).
Figure 9-8  Mandibular molars. A, Central ray directed at right angle to film positioned parallel to arch. B, Limited information is gleaned from radiograph because of superimposition of structures and canals. Reproduced with permission from Walton RE. 27

Figure 9-9  Mandibular molars. A, Central ray directed at 20 degrees mesially to film positioned parallel to arch. B, Two canals are now visible in both roots of the first molar (black arrows). Open arrow indicates confusing root outlines. Reproduced with permission from Walton RE. 27

Figure 9-10  Mandibular molars. A, Right-angle horizontal projection superimposes four files, one on the other. B, Horizontal variance of 30 degrees separates four canals. SLOB rule proves lingual canals are to the mesial. Reproduced with permission from Walton RE. 27
The opposite projection also can be used to isolate the mesiobuccal root of the first molar, that is, the central ray may be projected from 20 degrees distal to the right angle (Figure 9-17, A). Although this projection distorts the shape of the mesiobuccal root, it also isolates it (Figure 9-17, B), so that the canal is readily discernible (arrow). Also note that the zygomatic process is moved completely away from any root structure, including the second molar.

The same technique illustrated here for the maxillary first molar can be applied to the second or third molars by directing the central beam at a horizontal variance through those teeth.

Maxillary Premolars. Variance in the horizontal projection has great value in maxillary premolar radiography, particularly for the first premolar, which generally has two canals, but sometimes three. The clinical efficacy of the Walton technique is well illustrated in Figure 9-18. The right-angle horizontal projection produces the single canal image seen in Figure 9-18, A. By varying the angulation by 20 degrees, however, the two canals are separated (Figure 9-18, B), giving an unobstructed view of the quality of the fillings in both canals.

Mandibular Anterior Teeth. Aberrations in canal anatomy in the mandibular anterior teeth are infamous. Variance of the horizontal x-ray projections in this region will bring out the differences. Figure 9-19, A, illustrates the standard x-ray projection bisecting the film held parallel to the arch. The incisor teeth appear
to have single canals. But a broad single canal is seen in
the distorted canine image (Figure 9-19, B).

By varying the film placement and projecting directly
through the canine, as seen in Figure 9-20, A (which is
about 30 degrees variance for the incisors), separate canals
appear in the incisors (Figure 9-20, B, arrow) and are then
seen to coalesce at the apex. This would be expected, how-
ever, when one views the tapered incisor roots seen in
both horizontal projections, roots far too narrow to sup-
port two separate canals and foramina. Once again, the
abrupt change in canal radiodensity in the premolars
(arrow) should make one suspicious of canal bifurcation,
a fact that has already been confirmed in Figure 9-14, B.

Maxillary Anterior Teeth. Although canal or root
aberrations appear less frequently in the maxillary
anterior teeth, root curvature in the maxillary lateral
incisors is a particularly vexing problem. Grady and
Clausen have shown, for example, how difficult it is to
determine when foramina exit to the labial or lingual.30
Their radiographs of extracted teeth matched with
photographs of instrument perforation short of the
apex are a warning to all (Figure 9-21).

Processing. Another deterrent to full endodontic
utilization of radiography has been the length of time
required in most offices to process films. Old, weakened
solutions greatly increase the time required for process-
ing. Moreover, adherence to the manufacturer’s recom-
ended temperature and time (68°F for 5 to 7 minutes)
for developing and clearing has retarded “on-the-spot”
processing and viewing in most busy practices.

Ingle, Beveridge, and Olson demonstrated, in a
well-controlled blind study, the effects of varied pro-
cessing temperatures. A processing temperature of 92°F
yielded, in less than 1 minute, the most acceptable
Figure 9-15  Maxillary molars. A, Central ray is directed through maxillary molar at right angle to inferior border of film. Arrow and dotted line passing through malar process indicate it will superimpose over first molar. B, Superimposition of first molar roots, sinus floor, and malar process (white arrow) confuse the diagnosis. Reproduced with permission from Walton RE. 27

Figure 9-16  Maxillary molars. A, Central ray directed at 20 degrees mesially skirts malar process, projecting it distally. B, Distobuccal root is cleared of palatal root and malar process is projected far to distal (white arrow). Between right-angle and 20 degrees projection, all three roots are clearly seen. Reproduced with permission from Walton RE. 27

Figure 9-17  Maxillary molars. A, Central beam projected 20 degrees from the distal. B, Mesiobuccal root of the first molar is isolated (black arrow) and second and third molars are cleared of malar process, which is projected forward (white arrow). Sinus floor may be “lowered” or “raised” by changing vertical angulation. Reproduced with permission from Walton RE. 27
radiographs. A group of 37 physicians and dentists selected as “best” the films developed at 92°F from a coded selection of films processed at 4°F intervals in the range of 68 to 100°F. At 92°F, using Kodak developer and fixer mixed to company specifications, development required only 30 seconds and fixation required 25 to 35 seconds, with no loss of quality.

By comparison, the 70°F temperature, recommended at that time by the manufacturer, required 5 minutes developing time and 10 minutes fixing time for Ultraspeed film. Ektaspeed is slightly better: 72 to 80°F for 2½ to 4 minutes developing and 2 to 4 minutes fixing time. Finally, all films need to be final washed for at least 30 minutes.

In a practice limited to endodontics only, small quart-size tanks are adequate and economical. Frequent change of solutions is recommended.

Rapid Processing. Concentrated rapid-processing chemicals, such as Kodak’s Rapid Access solution, have become very popular in endodontic practice. Although they are more expensive ounce for ounce, they save measurable time, requiring only 15 seconds developing and 15 seconds clearing time in the fixer at room temperature.
A Tel Aviv/UCLA study tested four rapid-developing solutions, processing both Ultraspeed and Ektaspeed films. Film fog became a problem as the solutions deteriorated with time. Kodak Rapid Access had to be changed every day, whereas the other solutions, Colitts (Buffalo Dental; Syosset, N.Y.), IFP (M & D International), and Instaneg (Neo-Flo, Inc., USA), would deteriorate over 60 days. They also found that precise developing time and 3 to 5 seconds rinse time between developing and fixing are absolutely essential.32

Figure 9-20 Mandibular anterior teeth. A, Film is positioned for canine radiograph using bisecting-angle technique. Horizontally, central beam is projected at right angle to film. B, Canine image is single straight canal, but incisor image reveals bifurcated canals that reunite in narrow tapered root (arrows). Note “bonus” image of bifurcated canals, first premolar. Reproduced with permission from Walton RE.27

Figure 9-21 A, Labiolingual projection through canine shows instrument apparently at apex with slight distal curvature. B, Mesiodistal projection reveals instrument actually emerging from labial short of apex. C, Instrument perforating foramen to labial well short of radiographic root end. (Courtesy of Dr. John R. Grady and Dr. Howard Clausen.)
Warning: These rapidly processed films will fade or discolor with time.\textsuperscript{33,34} This change can be prevented, after viewing, by returning the wet film for a few minutes of fixation, followed by washing for 30 minutes, and then drying. The films will then retain their quality indefinitely.

Table-Top Developing. For really rapid response and ease of processing, combining rapid-speed solutions with a table-top processing hood (Figure 9-22) greatly improves radiographic reporting, particularly working films. These hoods are often used right in the operatory. The operator places his hands through light-proof cuffs and observes hand movement inside the hood through the red Plexiglas cover. The rapid solutions and rinse water can be in small cups no deeper than a periradicular film (see Figure 9-22).

Direct Digital Radiography

As dentistry parallels photography, in the move from silver halide film to digital photography and computer processing, the profession will undergo continued growth toward digital radiographic systems. Digital radiography used in dentistry is available in three variations: direct digital, storage phosphor, and indirect digital.

The direct digital systems use a solid-state sensor such as a charge coupled device (CCD) similar to the chips in home camcorders. These systems have a cable that connects the sensor to the computer and in turn to the screen monitor (Figure 9-23).

The storage phosphor systems use a photo-stimulable phosphor plate that stores the latent image in the phosphor for subsequent readout by an extraoral laser scanner (Figure 9-24).

Indirect digital systems use a scanning device connected to a computer for digitizing traditional silver halide dental films.

In clinical endodontics, the most applicable technology is the direct digital (wired) type of digital radiographic system. In a general practice, however, it can be advantageous to have the film-scanning capability.

Direct digital radiography (DDR) makes use of a rigid solid-state sensor, typically a CCD, a complementary metal oxide silicon, or a charge injection device, connected by a cable to a computer, a monitor, and a printer. The typical DDR sensor is packaged in a hard aluminum or plastic shell that encases several components (Figure 9-25). X-radiation (light), generated from any modern x-ray head, is converted by a screen to green light that is transmitted through an optical fiber to the CCD sensor. The CCD...
then converts the green light to electrons that are deposited in electron wells for subsequent readout, line by line by the electronics.35–37

The most significant advantage to the DDR-style devices is the near instantaneous (a few seconds) availability of the images after exposure without removing the sensor from the mouth.

This allows multiple angles to be taken to help in location of canals, identification of root curvatures, verification of working lengths, and verification of intermediate obturation results. Treatment delays caused by missed apices, cone cuts, and poor exposure are reduced from several minutes to seconds. This can be accomplished with one half to one-eighth of the radiation normally used in exposing a single silver halide dental film.

**Tangible Benefits.** There are several immediate benefits to using DDR for endodontic procedures. No darkroom or processing equipment is needed. Infection control procedures are reduced, and duplicates are instantly made with absolutely no loss in image quality. Additionally, the sensitivity of the receptors and the digital nature of the image permit reduction of the patient’s x-ray exposure. Computers can be used to store and enhance the image or to transmit it over a telephone line to an insurance company or to a colleague for instant consultation. Most important is the trust and credibility gained by displaying a huge image that the patient can see and understand, using a familiar delivery medium—a “TV” picture (Figure 9-26). The radiographic picture on the computer screen helps the clinician explain needed treatment. This is particularly important for specialists as they may have only one or two visits to gain the patient’s trust, explain the need for treatment, obtain informed consent, and complete their care.

**Time Savings.** Time saved by not waiting for film processing is certifiable with digital radiography. Automatic chemical processing takes 4 to 6 minutes, whereas the slowest digital system takes only 7 seconds. Yet this does not tell the whole story. The real time for a radiographic “event” is measured from the time the clinician first prescribes the radiograph until the time the image is ready for viewing. The assistant must drape the patient with the lead apron and position the sensor or film, which takes a few minutes. Then the film is removed from the mouth, chemically processed, rinsed, and dried. Thus the real time for film radiography is about 6 minutes, whereas digital radiography is closer to
3 minutes, including the draping. With DDR, however, there is no “dead time” during the radiographic event and no need to mentally “re-enter” the case.

Retakes. Ease of retakes is often overlooked when discussing time savings. Ease of retakes is the real time saver. With film, a retake requires another 6 minutes or more, whereas with digital, a retake takes an instant. An even greater benefit is that the x-ray head, patient, and sensor are all still in place. This simplifies interpretation and adjustment to different angles. There is no need to “remember” the case or wonder at what angle the last radiograph was taken.

Dose Reduction. Lower x-ray dosage is another quantifiable benefit of all digital radiography systems. Almost all of the digital systems are capable of reducing exposure to 50% of conventional E-speed film. Exposure can be further decreased to less than 20% if image quality is slightly compromised. This is accomplished by underexposing the sensor and then using the computer-processing functions to visually improve the image quality.

With the growing concern of patients regarding radiation exposure, digital systems help defuse their concerns about radiography.

Computer Processing. Although the software programs provided with the different digital radiography systems have a dazzling array of image-processing algorithms, only a few are of primary importance in endodontics. The most important image-processing tool is the brightness/contrast tool. Images that are washed out or underexposed can often be computer processed to increase their contrast and decrease the brightness (Figure 9-27). However, as useful as this tool is, it cannot correct a badly overexposed image because the pixels have been saturated, and no recovery can be made other than re-exposing the sensor.

From a patient education perspective, another computer enhancement that is quite useful is the Pseudo-3D feature shown in the Trophy software (Figure 9-28). The radiograph is converted to a contour map while maintaining the relative gray levels. The radiolucency at the periapex of the tooth is dark, relative to the surrounding structures, and thus appears as a “hole in the bone” in the Pseudo-3D view. This allows the clinician to communicate, in a more understandable manner, the loss of periapical bone.

Digital Radiographic Technique for Endodontics

The assistant enters the patient’s demographics into the computer and selects the “exam type” from the menu that appears on the screen. The sensor is then sheathed in a latex “finger cot” (for sanitary reasons) (Figure 9-29) and correctly positioned intraorally. The x-ray head is then positioned, the computer software is activated, and x-ray exposure is made. The computer has captured and stored the image as it appears on the monitor screen (Figure 9-30). If adjustments are needed, the sensor and/or the x-ray beam (head) may be repositioned while the sensor is still in place. Again, the corrected image appears on the screen to guide the dentist and/or instruct the patient. All of the images will be “stored” and may later be recalled to complete the patient’s record. The “before and after” images can then be transported by “hard copy” or electronic mail to the referring dentist.

Tooth Length Measurement. The ability to accurately measure preoperative working length is another useful tool. Since the pixel sizes making up the digital

Figure 9-27 Computer processing to enhance image. Left, Slightly underexposed, unprocessed image. Right, Computer-processed image highlights resorptive defect over the distal root. (Courtesy of John A. Kahdemi.)
image are known, it is easy for the computer to calculate a preoperative length, even around curvatures. (Figure 9-31). Most digital radiography programs allow the clinician to start at either the coronal or apical reference point and enter (by clicking a mouse) several points along the anticipated canal path. These preoperative lengths are within 0.5 mm more than 95% of the time.

Sensor Sizes. Endodontic imaging needs can be met by a single sensor size. Generally, the smaller sensor size (size 1 equivalent) is the most useful in an endodontic setting (see Figure 9-25). The smaller size is more comfortable for the patient and easier for the assistant to place. The larger sensors can be more difficult to place because of their rigidity. An extra sensor should be available in the event of sensor failure.

Holders. Properly designed “paddle”-style holders greatly facilitate infection control procedures. Correct sensor positioning and angulation lead to better images. These holders can be easily bent to manage tipped and rotated upper and lower molars. Snap-A-Ray and Rinn Endoray II-style holders can also be

Figure 9-28  Computer enhancement using Pseudo-3D feature of Trophy software that converts a traditional two-dimensional radiograph into a “third-dimensional” contour map that is better understood by the patient. Note the periapical lesion as a "dark hole." (Courtesy of John A. Khademi.)

Figure 9-29  For sanitary reasons, the sensor is sheathed in a latex "finger-cot." (Courtesy of John A. Khademi.)
used, but they are bulkier and harder to sheath. Occasionally, the aiming guides are in the way during angled radiography or interfere with the rubber dam.

**Exposure.** There is considerably less latitude with regard to correct exposure with digital systems than with film. Although this may seem counterintuitive, given that the digital images can be reprocessed, overexposure results in permanent loss, on the screen, of anatomic structures. With digital images, one should err on the side of underexposure—the opposite of film images. Additionally, some x-ray heads do not have a low enough setting; to further decrease exposure, the x-ray head is moved away from the patient by 6 to 12 inches.

**Buyer’s Guide**

The prime technical factors to consider in the purchase of a digital radiography system for use in endodontics are the ease of use of the software and the availability of appropriately sized sensors, a sensor replacement warranty, and efficient holders. Multiple image processing and enhancement tools, although appealing, contribute little to the day-to-day use of the system and can often be in the way. The differences in image quality between the present systems are relatively narrow.

**Computer Systems.** This new technology to replace film requires a Windows NT or Windows 2000 server with Fault-Tolerant hard drives (RAID). Uninterruptible power supplies should be installed on the server and all clinical workstations. Images should be automatically backed up and stored off-site.

**Monitors.** Large, high-quality computer monitors allow maximum resolution of the image to be displayed as well as the ability to display multiple images. Larger monitors are often brighter, which allows for easier interpretation in the well-lit dental operatory. Flat panels or liquid crystal displays are becoming increasingly popular as the dental operatory becomes starved for space. One would be well advised, however, that some flat panels have very limited viewing angles, and the image is almost invisible when viewed off-angle.

**FUTURE TRENDS**

**Digital Subtraction Radiology**

Digital Subtraction Radiology (DSR) uses a computer to assess, in two or more radiographs, pathologic changes that have taken place over a period of time. With conventional radiography, detection of a change, such as an increase or decrease in lesion size, is done by viewing two films, side by side, on a view box. Unfortunately, this is a very insensitive technique for detecting small bony changes. With conventional radiography, a 30 to 50% radiodensity difference is needed for reliable detection of change, and cancellous bone changes may not be visible at all. DSR can significantly improve one’s diagnostic accuracy of periapical lesions, allowing for earlier intervention and more accurate detection of active disease.
To use the DSR technique, the two digital images to be compared are brought into the computer software. Since they are digital images, they are stored in a numeric format in the computer memory and can be compared mathematically. Typically, the background images that have not changed—crowns, fillings, and so forth—are subtracted, which in turn highlights areas that have changed—lesion size and/or density, for instance.43

Tomography
Another exciting development is the generation of dental tomographic images44 (E Hebranson and P Brown, personal communication, 1999). Tomography is a radiographic technique that essentially “slices” the teeth into thin sections. Computers then reassemble the sections to generate a three-dimensional image. When these techniques are refined, pulp spaces and roots will be visualized in the third dimension. Buccolingual curvatures will be evident, as well as the shape of the canal space and the location of the apical foramen (Figure 9-32). An additional advantage would be the elimination of specialized angled radiography; all angled views will be simultaneously captured in one exposure.

RADIOGRAPHIC INTERPRETATION
Since properly positioned, exposed, and processed radiographic or digital images (Figure 9-33) are of value only if they are properly interpreted, every advantage must be taken to obtain the most information from the image. For the student and seasoned practitioner alike, a good magnifying glass has often brought to light an extra root, root canal, or hard-to-find apex.

A superlative method for examining radiographs is the Brynolf magnifier-viewer.45 This device enhances the viewing of individual films in two ways: the image is magnified several times, and all peripheral light is effectively blocked out. Masking the light source around a radiograph greatly increases the ability of the viewer to distinguish grades of density.46 A film that has been slightly overexposed, if magnified and inspected over a strong light, yields a remarkable amount of unsuspected information. In a re-treated case, endodontic success had been denied for 9 years until inspection under magnification of the original radiograph disclosed a previously overlooked third root on a maxillary first premolar.

Many departures from classic radiographic procedures have been strongly advocated for endodontic

Figure 9-32  Tomographic images of a maxillary molar reconstructed by computer. Tomography essentially “slices” the image into thin sections and then “reassembles” them into a three-dimensional image. A, Buccal view. B, Mesial view. (Courtesy of John A. Khademi.)
therapy. Any variation that makes the exposure and processing of radiographs easier, faster, and better, and the interpretation more thorough, increases the value of these "eyes beneath the surface." It is when we do not see what we are doing that failures increase.

**VISUAL ENHANCEMENT**

**Endoscopy**

Light and magnification are key factors in endodontics because what cannot be seen cannot be properly treated. The *Endoscope* (Karl Storz, Germany/USA) and the *Orascope* (Sitca, Inc., USA) provide both light and magnification for better access and location of canal orifices, fractures, failing silver points, separated instruments, and posts. They are also extremely useful in endodontic surgery, including apicoectomy, retrofillings of the root end, location and repair of perforations, and internal and external resorptive defects.

Endoscopy is the inspection of body cavities and organs using an endoscope. This device consists of a tube and an optical system with a high-intensity light. The image captured by the endoscopic camera is projected onto a video monitor for viewing (Figure 9-34). In endodontics, one can visualize access openings, canal orifices (Figure 9-35), the canal interior, fractures, resorptive defects, and surgical sites, all highly magnified.

Endoscopy dates back to the time of Hippocrates II (460–375 BC) when physicians of the time used tubes inserted into body openings to view interior structures. Abulkasim, in AD 1012, used a mirror to reflect light through the hollow tube. Aranzi, in 1585, used reflected solar rays to peer into nasal cavities. Bonzzani (1804) used a candle as a light source, and Segalas in 1826 added a cannula for ease of insertion. Desormeaux (1835) is considered the father of endoscopy, using kerosene lamplight reflected through a mirror system. He used this system as a cystoscope and a urethroscope. Panteleone (1869) refined the Desormeaux scope for looking into the uterus. In 1877, Nitze added an optical lens system to the tube. Dittel (1887) added a small incandescent bulb at the end of a cystoscope as a light source. (Thomas Edison invented the incandescent lamp in 1880.) By the end of the nineteenth century, there existed cystoscopy, proctoscopy, laryngoscopy, and esophagoscopy. In 1901, Ott was the first to make a small incision into the abdomen and use a mirror head to reflect light. Also in 1901, Kelling injected air through a separate needle during a cystoscopic procedure in a dog as the first closed endoscopic procedure. Takagi (Tokyo 1918) was the first to examine the knee joint. In 1952, Hopkins used quartz rods in the tube of the scope to project light into the operating field, and in 1968 fiber optics were added, and the system that is used today came into being.

The first use of the endoscope in endodontics was to observe fractures in teeth. Held et al. and Shulman and Leung in 1996 reported the use of the endoscope for both conventional and surgical endodontics. Bahcall et al. recently described using the endoscope...
Preparation for Endodontic Treatment

There are many advantages to using the endoscope in endodontics: direct illumination of the field, brightness with no loss of resolution, and the ability to view inaccessible areas by seeing around corners and beneath areas. The endoscope may be easily positioned 0.5 to 10 mm from the working field, where it will remain in focus. There is also a short learning curve of 2 weeks to 3 months, no eyestrain, freedom of body movement, and no need for the use of a mirror to reflect the image as is needed with the surgical microscope.

Magnification can be from 10 to 50 times the original, depending on the equipment. The endoscope is also cost effective compared with the microscope. It is easily transportable on a cart (see Figure 9-34) and can also be used as an intraoral camera. Both the dentist and assistant have full view of the operating field on the television monitor. Either the dentist or the assistant can hold the scope in place while the procedure is being performed.

There are few disadvantages to the endoscope. The operating field is not seen in three dimensions; however, this has not been shown to be an important limiting factor in either medical or dental endoscopy. Inadvertent damage to the quartz rods inside the scope can occur. A nonbendable sheath covering the scope is used to create rigidity and protect the rods from damage. The scope can be scratched by burs or various instruments if the tip of the scope is held in very close proximity to the operating field. However, these are unusual occurrences because the endoscope can be easily positioned so that it is not in direct proximity to the field of operation.

The equipment that makes up the endoscope system is the endoscope itself, a camera coupler/lens, a video camera, fiber-optic cables to carry light from a halogen or xenon light source, a camera control unit, a video recorder and/or a video color printer, and a video monitor to view the procedure (Figure 9-36). Although the video recorder and printer are not necessary for operation of the endoscope, they are useful for documentation and patient education. Furthermore, an endodontist may send a referring dentist a color print of a completed surgical procedure instead of, or along with, a radiograph.
Endoscopes for endodontics can be obtained in 4- and 8-inch lengths. The tube of the working end of the endoscope contains quartz rods, some of which bring light into the field of operation and some of which return the image to the camera that projects the image onto the video monitor. The working end of the scope can be obtained in a wide variety of angulations: 0, 30, 45, 90, and 135 degrees. The most useful endoscope for endodontics is the one having a 30-degree angle.

The endoscope comes in a variety of widths, from 0.7 to 10 mm. The most useful width for endodontic surgical procedures is 4 mm, and for conventional endodontic treatment, a 0.7 to 4 mm scope is best.

The source of light is delivered to the scope by fiber-optic cables. Hundreds of glass fibers are bundled together to carry light to the quartz rods inside the scope. Light can come from either a halogen or a xenon source. A halogen light will provide from 150 to 300 watts of illumination with a slightly yellow hue. A xenon light source at 300 watts will provide with a white hue that will have greater consistency and brightness. The xenon light is also more penetrating than is the halogen.

The camera coupler/lens attaches to the end of the scope. The coupler can be equipped with a zoom control that allows a closer view in the form of a zoomed picture that will usually fill the entire monitor screen. Cameras are produced in one- and three-chip models. A one-chip camera will deliver 450 lines per second of image to a video monitor. A three-chip camera delivers 800 lines per second. For comparison, a standard television delivers 265 lines per second. For endodontic procedures, at this time, a one-chip camera will provide sufficient definition and clarity.

The camera control unit controls color density and shutter control. Automatic gain control ensures clarity of the picture. The signal degenerates with a longer cable and the devices (video recorder and printer) through which the signal has to travel before it reaches the monitor where it can be viewed. Any size monitor can be used; however, as the screen increases in size, the sharpness of the image decreases.

A video recorder can be used to capture an endodontic procedure. The best quality image for analog video is the Hi 8 system. The highest quality image, however, is recorded by using a digital video recorder, wherein the images can be edited and copied multiple times, with no loss of resolution, as will occur with an analog system.

Stability of the scope itself is important. A variety of sheaths inserted over the tube of the scope are used to provide rigidity, support, and stability. They also protect the tip from potential damage from instruments. Shulman has described a stabilization technique for endodontic surgical procedures. He suggests placement of the end of the rigid sheath on the surface of the bone, adjacent to the surgical site, thus producing a stable video image.

The sheaths come with a variety of working ends. Canal orifices, calcified canals, perforations, and resorptive defects can be viewed using a forked-ended sheath that can rest on access openings, a marginal ridge, or the buccal or lingual surface of the tooth being treated or an adjacent tooth (Figure 9-37, A). Sheaths with retractors that have serrated ends that are a similar shape to that of a handheld retractor can be anchored in bone to provide support and flap and cheek retraction during surgery (Figure 9-37 B). A sheath shaped like a tongue retractor is used to move the patient’s tongue aside while viewing the lingual aspect of a tooth. The scope can be anchored in position by the sheath and the lens/camera coupler can then be rotated 360 degrees to completely view all aspects being treated.

During procedures involving rotary instruments, the tip of the endoscope can become covered with debris and the video picture can become blurred. Saline in a syringe or sterile water from a triplex or Stropko syringe (see chapter 12, “Endodontic Surgery”) can be used to rinse away the debris and clear the viewing field on the monitor. A cotton swab saturated with saline solution can also be used to accomplish debris removal.

![Figure 9-36 The Endoscope System. The Scope, surveying tooth, contains quartz rods that convey the image. They, in turn, are surrounded by a fiber-optic light source. The Scope is attached to the camera by a camera coupler, which in turn connects to the computer and printer as well as to the monitor. Images appear on the monitor and are stored in the computer for later printing if desired. (Courtesy of F. H. Kahn and B. B. Shulman.)](image-url)
Preparation for Endodontic Treatment

After use, the sheaths should be placed in an ultrasonic cleaner to remove debris and sterilized in an autoclave with ethylene oxide or glutaraldehyde. The scope cannot be placed in an ultrasonic cleaner but can be easily cleaned by soaking in an enzymatic cleaner or washed gently with soap and distilled water and then sterilized in glutaraldehyde for 12 hours. Autoclavable scopes are also available. The lens head/camera coupler can be cleaned with a mild soap and distilled water and sterilized by soaking in glutaraldehyde. It is best protected with a disposable plastic tube—wrap during use to keep it sterile and free of debris.

The Orascope (Sitca, Inc., USA) is an evolutionary extension of dental endoscopy: Orascopy. Currently, there are two diameter sizes of flexible fiber-optic probes: the 1.8 mm and the 0.7 mm (Figure 9-38). The 1.8 mm probe has 30,000 fibers and the 0.7 has 10,000. A ring of light transmitting fibers surrounds the visual fibers (Figure 9-39). Both probes have a large depth of field and do not need to be refocused after the initial focus. The 1.8 mm probe is used to visualize conventional and surgical sites. The 0.7 mm probe is used for that and for intracanal visualization as well (Figure 9-40). Canal cleanliness, location of accessory canals, perforations, broken instruments, and resorptive defects are easily examined. The 0.7 mm probe must be used in a dry canal. It will not penetrate blood, exudate, or irrigant. The coronal two-thirds of the canal should be flared to at least a size 70 instrument. Jedmed is planning to release an endoscopic system called Endodontic Endoscopic Systems (E.E.S.).

Future Possibilities

Many advances being made in medical endoscopy can easily be adapted to endodontic endoscopic procedures. Software can piece two-dimensional images together to create a virtual three-dimensional fly-through. Virtual reality technique training will enhance and speed the learning curve for difficult endodontic procedures. Video and audio conferencing using a webcam, which is an endoscope to project video images, digital radiographs, and patient files, can be sent over the Internet so that dentists anywhere in the world are able to confer and obtain the best diagnosis and treatment planning for their patients. Future possibilities are unlimited.

SPECIALIZED ENDODONTIC INSTRUMENTS AND EQUIPMENT

“The lack of proper equipment” is a reason often given by dentists who do not practice root canal therapy, and it well might be. Not only are special instruments imperative for endodontic treatment, but a special arrangement of these instruments is necessary.
Impractical, inefficient scurrying around the office to gather together a collection of unsterile, ill-adapted equipment completely discourages the practitioner from endodontic therapy. These problems may be solved by procuring the correct equipment and supplies; by packaging the hand equipment into sterilized towel kits, into canisters, or on prearranged trays; and finally, by storing the small endodontic instruments in an organized, compartmentalized instrument case.

Sterilized Towel Kit
Standard dental instruments, along with a few special instruments necessary for root canal therapy, are wrapped into a pack in two layers of towel and fastened with a banker’s pin or autoclave tape. This rolled kit can then be sterilized and stored, ready for use (Figure 9-41).

When treatment is to begin, the towel kit is unrolled on the working surface and the instruments arranged on the sterile surface according to their frequency of use. The following instruments are contained in the towel kit:

Three dappen dishes
One Luer syringe, 3 mL (disposable)
One Luer type 27-gauge ProRinse needle
One mouth mirror, “Front Surface”
Two cotton pliers
One DE spoon excavator, Starlite #31
One plastic instrument, Glick #1, Star Dental
One measuring gauge or millimeter ruler (metal)
One pair of scissors, embroidery, 3¼-inch overall length
One D-G explorer, Star Dental

Three gauze sponges, 2 inch
Three cotton rolls #3, 1-inch long

In any number of receptacles, ranging from a simple banker’s sponge soaked in germicide to sophisticated stainless and plastic holders, the assistant may arrange the root canal instruments in numerical order and properly measured to length. It is impractical, if not impossible, to pass the short-handled instruments to the operator: hence the orderly arrangement for easy acquisition. For dentists working alone, the Endoring (Jordco/Almore International Inc., USA) is recommended (Figure 9-42).

Handpieces
The only regular dental equipment needed, other than anesthetic syringes and rubber dam equipment, are the two contra-angle handpieces: one high speed, the other conventional speed. All handpieces must be sterilized. The assistant should then place the correct burs in the contra angles, sized according to the tooth to be treated.

The burs, stored in the sterile instrument case, are removed from the case with the sterile cotton pliers and placed in the contra angle with the pliers (Figure 9-43). While the shaft of the bur is held with the pliers, the foot control of the conventional handpiece is just tapped. As the bur spins, it will drop down into place, and the latch may be closed.

For the high-speed handpiece, the burs can be dropped down into the chuck, which is then tightened. The handpiece must be absolutely concentric. Whipping of the end of the bur, experienced with a worn chuck, will fracture teeth and is particularly dan-
Preparation for Endodontic Treatment

Gross when an extra long bur is being used to amputate an entire root.

Endodontic Instrument Case

The collection of tiny endodontic instruments must be kept in an organized arrangement yet lend itself readily to sterilization. The metal endodontic instrument case meets these requirements. Storage cases have long been available but never as refined as the modern cases (Figure 9-44). All of the reamers, files, broaches, burs, and filling equipment, as well as paper points and cotton pellets, are stored and sterilized in the case. The dentist or assistant removes these with sterile pliers only as needed.

The instrument case may be placed beside the dentist on a Mayo stand, or the assistant may obtain material from the case kept on the cabinet top. Supplies are transferred from the case to the open towel kit, which is the working surface. The case needs to be resterilized only when one of the instrument sizes is depleted. New instruments should replace sizes 10 through 25, which should be used only once. The larger instruments may be thoroughly cleaned and reused when the case is replenished before sterilization. A thorough discussion of endodontic instruments is found in chapter 10.

A selection of instruments is available from the various distributors of endodontic supplies. These selections have been developed for the clinician who treats all types of endodontic problems in a general practice of dentistry. The case and its contents are sterilized according to the directions given under “Asepsis in Endodontic Practice,” chapter 3. The surgical armamentarium is dealt with in “Endodontic Surgery,” chapter 12. Table 9-1 lists the contents of the endodontic instrument case.

PAIN CONTROL IN ENDODONTICS

In no other area of dentistry is the management of pain of greater importance than in endodontics. All too often the patient in need of endodontic therapy has endured a prolonged period of ever-increasing discomfort before seeking dental care. The reasons for this discomfort are manifold; however, there is one simple explanation in the overwhelming majority of these patients: They are scared! They are afraid of dentistry, which might be the reason for their dental problems in the first place; they are frightened of “root canal work” because of the common perception that “it hurts”; and they are often terrified at the thought of receiving local anesthetics, or “shots,” in patient parlance.

It is possible to achieve clinically effective pulpal anesthesia on all teeth, infected or not, in any area of the oral cavity, with a very high degree of success and without inflicting any additional pain on the patient in the process.
Figure 9-44  Five examples of instrument kits. A, ENDO-BLOC. B, University Case. C, ENDEX Endodontic System. D, Guldener SPLIT-KIT. E, TEXAS Case. (A, Courtesy of Endobloc, Inc., Cincinnati, OH; B, Courtesy of Union Broach, New York; C, Courtesy of Whaledent International, New York; D, Courtesy of Dentsply/Maillefer; E, Courtesy of University of Texas, San Antonio, TX.)
In the following section, common (and some uncommon) local anesthesia techniques that are used to provide effective pain control during dental treatment are presented.

Although it is possible (and probable) that the administration of local anesthesia will be both atraumatic to the patient and clinically effective, many endodontic patients (and, unfortunately, some professional colleagues) do not share that feeling. Given that a significant percentage of these patients are dental phobics, and that one of the greatest fears they harbor is the fear of pain, it is not unusual for these patients to experience “pain” at any and all times during treatment, warranted or not. There are the patients who jump when air is blown into the mouth; who exhibit an overactive gag reflex when anything is placed on the tongue or palate; who are “moving targets” during administration of the local anesthetic; who complain of “pain” constantly during treatment, even when the treatment being performed is truly incapable of provoking a true pain response (eg, cutting enamel or removal of an existing restoration).

The pain reaction threshold (PRT), defined as that point at which a person will interpret a stimulus as being painful, can be altered significantly in a given patient. These alterations can be to the patient’s benefit (elevation of the PRT) or disadvantage (lowering of the PRT). Given that there is significant variation in individual response to stimulation (as described by the normal distribution curve), approximately 70% of a given population will respond appropriately to a given stimulus (eg, may say “ow” when receiving a mild painful stimulus). An additional 15% will under-react to the same stimulus. Their interpretation of this mildly painful stimulus will be that it did not hurt at all. This 15% of the population is called “hypo-responders.” Thus, approximately 85% of a normal population will respond as expected to mildly painful stimuli. It is the remaining 15% of patients who are the “hyper-responders.” Hyper-responding persons will interpret as painful what are usually nonpainful stimuli. And then there are the truly remarkable persons—the Indian fakir who is capable of walking across hot coals or lying on a bed of nails without experiencing any pain, or the stoic dental patient who withstands excruciating pain during every aspect of treatment.

With endodontic therapy, the number of patients who will hyper-respond to stimulation is significantly increased. Factors that lower the pain reaction include (1) the presence of pain at the start of treatment, (2) fatigue, and (3) fear and anxiety. To varying degrees, all may be present in endodontic patients.

Table 9-1 Contents of the Endodontic Instrument Case

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Style “B” Hand Instruments .02–.04 Tapers*</td>
<td></td>
</tr>
<tr>
<td>1 × 6 file, B, #08</td>
<td>1 × 6 file, B, #50</td>
</tr>
<tr>
<td>1 × 6 file, B, #10</td>
<td>1 × 6 file, B, #55</td>
</tr>
<tr>
<td>1 × 6 file, B, #15</td>
<td>1 × 6 file, B, #60</td>
</tr>
<tr>
<td>1 × 6 file, B, #20</td>
<td>1 × 6 file, B, #70</td>
</tr>
<tr>
<td>1 × 6 file, B, #25</td>
<td>1 × 6 file, B, #80</td>
</tr>
<tr>
<td>1 × 6 file, B, #30</td>
<td>1 × 6 file, B, #90</td>
</tr>
<tr>
<td>1 × 6 file, B, #35</td>
<td>1 × 6 file, B, #100</td>
</tr>
<tr>
<td>1 × 6 file, B, #40</td>
<td>1 × 6 file, B, #120</td>
</tr>
<tr>
<td>1 × 6 file, B, #45</td>
<td>1 × 6 file, B, #140</td>
</tr>
<tr>
<td>1 × 6 file, B, Golden Mediums, #12–37</td>
<td></td>
</tr>
<tr>
<td>1 × 12 files Hedstrom, assorted # 25–110</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burs</td>
<td></td>
</tr>
<tr>
<td>1 × 3 bur, carbide #701U, RA</td>
<td></td>
</tr>
<tr>
<td>1 × 6 bur, #2 (3 surgical, 3 standard, RA)</td>
<td></td>
</tr>
<tr>
<td>1 × 6 bur, #4 (3 surgical, 3 standard, RA)</td>
<td></td>
</tr>
<tr>
<td>1 × 6 bur, #6 (3 surgical, 3 standard, RA)</td>
<td></td>
</tr>
<tr>
<td>Broaches</td>
<td></td>
</tr>
<tr>
<td>1 × 6 barbed broaches, fine</td>
<td></td>
</tr>
<tr>
<td>1 × 6 barbed broaches, medium</td>
<td></td>
</tr>
<tr>
<td>1 × 6 barbed broaches, coarse</td>
<td></td>
</tr>
<tr>
<td>1 × 6 barbed broaches, extra coarse</td>
<td></td>
</tr>
<tr>
<td>Obturation Instruments</td>
<td></td>
</tr>
<tr>
<td>2 only cement spatula, #3</td>
<td></td>
</tr>
<tr>
<td>2 only glass mixing slab, opal</td>
<td></td>
</tr>
<tr>
<td>Paper points: fine, medium, and coarse</td>
<td></td>
</tr>
<tr>
<td>Cotton pellets: large and small</td>
<td></td>
</tr>
<tr>
<td>Special Towel Kits</td>
<td></td>
</tr>
<tr>
<td>6 only: double-ended, hand style, M-spreader/pluggers</td>
<td></td>
</tr>
<tr>
<td>8 only: Schilder pluggers,</td>
<td></td>
</tr>
<tr>
<td>8–12 Cold sterilized or presterilized gutta-percha points and cones</td>
<td></td>
</tr>
<tr>
<td>Cotton files: large and small</td>
<td></td>
</tr>
<tr>
<td>Cotton files: large and small</td>
<td></td>
</tr>
</tbody>
</table>

*The same selection can be made for engine-driven nickel-titanium (NITI) instruments, sizes 15–80. Both stainless and NITI files have color-coded handles.

To increase the likelihood of pain-free endodontic treatment and to ensure the patient a “comfortable” experience, every dentist should make an effort to modify any of the factors acting to lower the PRT.

Chapter 18 covers a subject of great importance to the endodontist (analgesics), but also of importance to the endodontic patient is the matter of sedation. Fear and pain are a potent combination, capable of provoking some of the most catastrophic situations in the dental office, such as cardiac arrest. In surveying the inci-
The administration of local anesthetic can be almost entirely prevented if consideration is given by the doctor to the patient’s “feelings” about receiving “shots.” Most persons do not relish the thought of receiving intraoral local anesthetic injections, demonstrated by the high incidence of adverse reactions occurring at this time. Interestingly, 53.9% of all emergencies reported by Malamed were “fainting,” and over 54% of all emergencies occurred during the administration of the local anesthetic. Syncope during injection can be prevented virtually 100% of the time by following a few simple steps to make all local anesthetic injections as comfortable (atraumatic) as is possible (Table 9-2). Although all of the steps are important, three stand out: (1) placement of the patient who is to receive an intraoral local anesthetic into the supine position before the injection, (2) the slow administration of the local anesthetic solution, and (3) the use of conscious sedation before the administration of the local anesthetic.

The very simple concept behind the successful use of conscious sedation is that fearful patients are overly focused on everything that happens to them in the dental chair. Simply by administering a drug (central nervous system depressant) that takes the patient’s awareness away from the dental milieu, the patient no longer over-reacts to stimulation, does not care about the procedure, and in effect becomes a “normal” patient.

The administration of inhalation sedation with nitrous oxide and oxygen (N₂O–O₂), carefully titrated, alleviates any fears of injections in the majority of needle-phobic dental patients. Continued administration of N₂O–O₂ during the endodontic procedure is entirely appropriate if the patient is at all apprehensive. In addition to relieving patients’ anxieties, N₂O acts to elevate the PRT, providing a beneficial effect throughout the endodontic procedure. N₂O–O₂ is the safest of all conscious sedation techniques and, when properly used, is also one of the most effective.

When inhalation sedation is contraindicated (eg, patient is a mouth breather, patient has a “cold” or upper respiratory infection, or sedation has proved ineffective in the past in eliminating the patient’s fears), other techniques of conscious sedation should be considered. These include the administration of central nervous system-depressant drugs (eg, benzodiazepines) orally, intramuscularly, intravenously, or intranasally. The safest and most effective, when used properly, is intravenous conscious sedation. With the availability of two benzodiazepines, diazepam (Valium) and midazolam (Versed), administered via titration, it is possible to eliminate the dental fears of virtually all patients. Additionally, these drugs provide varying degrees of

Table 9-2 Atraumatic Local Anesthesia Technique

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Use a sterilized, sharp needle.</td>
</tr>
<tr>
<td>2.</td>
<td>Check the flow of local anesthetic solution before insertion of needle into tissues.</td>
</tr>
<tr>
<td>3.</td>
<td>Determine whether to warm the anesthetic cartridge and/or syringe.</td>
</tr>
<tr>
<td>4.</td>
<td>Position the patient (supine recommended).</td>
</tr>
<tr>
<td>5.</td>
<td>Dry the tissue.</td>
</tr>
<tr>
<td>6.</td>
<td>Apply topical antiseptic (optional).</td>
</tr>
<tr>
<td>7a.</td>
<td>Apply topical anesthetic (minimum 1–2 minutes).</td>
</tr>
<tr>
<td>7b.</td>
<td>Communicate with the patient.</td>
</tr>
<tr>
<td>8.</td>
<td>Establish a firm hand rest.</td>
</tr>
<tr>
<td>9.</td>
<td>Make the tissue taut.</td>
</tr>
<tr>
<td>10.</td>
<td>Keep syringe out of the patient’s line of sight.</td>
</tr>
<tr>
<td>11a.</td>
<td>Insert needle into the mucosa.</td>
</tr>
<tr>
<td>11b.</td>
<td>Watch and communicate with the patient.</td>
</tr>
<tr>
<td>12.</td>
<td>Slowly advance the needle toward target.</td>
</tr>
<tr>
<td>13.</td>
<td>Deposit several drops of local anesthetic before touching periosteum.</td>
</tr>
<tr>
<td>15a.</td>
<td>Slowly deposit local anesthetic solution.</td>
</tr>
<tr>
<td>15b.</td>
<td>Communicate with the patient.</td>
</tr>
<tr>
<td>17.</td>
<td>Observe patient after injection.</td>
</tr>
<tr>
<td>18.</td>
<td>Record injection on the patient’s chart.</td>
</tr>
</tbody>
</table>

Adapted from Malamed SF.57
amnesia, the patient having no recall of events occurring during their treatment (“it didn’t happen”).

Because of the prevalence of fear in endodontic patients, the use of conscious sedation should become increasingly more popular. Unfortunately, the use of conscious sedation by endodontists is extremely rare. The benefits to be gained from the proper use of conscious sedation greatly outweigh the very slight risks involved with their use.

**Local Anesthetic Techniques**

Problems arising in achieving profound pulpal anesthesia invariably develop in the mandible (Table 9-3). A survey by Walton and Abbott of 120 missed local anesthetic injections demonstrated that maxillary teeth were the problem 32% of the time. On the other hand, on two of three occasions when anesthesia was ineffective, mandibular teeth were involved. Mandibular molars were the culprit 47% of the time. Repeating the same survey, Malamed found significantly different results. When inadequate local anesthesia developed, maxillary teeth were the problem only 9% of the time, whereas 91% of the offending teeth were in the mandible. Of even greater significance is the fact that mandibular teeth, other than molars, were never the problem (0%).

Why the relative lack of anesthesia problems in the maxilla compared with the mandible? The very different composition of the cortical plate of bone on the buccal aspect of maxillary and mandibular teeth is one factor. In the adult mandible, the buccal cortical plate of bone is significantly thicker than that found overlying maxillary teeth. This added thickness makes the use of supraperiosteal anesthesia ineffective in the mandible, obviating the use of the easiest and most effective injection—infiltration.

**Mandibular Anesthesia**

To provide effective pulpal anesthesia in the mandible, one must administer the local anesthetic drug at a site where the nerve is still accessible (eg, before the nerve enters the mandibular foramen and into the mandibular canal). Thus, one is limited to two injection sites. One site is the lingual aspect of the mandibular ramus, where three techniques may be used: the inferior alveolar (IA) nerve block (the traditional “mandibular block”); the Gow-Gates mandibular nerve block (GGMNB), and the Akinosi-Vazirani closed-mouth mandibular nerve block. A second site of access to the mandibular nerve is available on the mandible, the mental foramen, located (usually) between the two premolars. Local anesthetic administered at this site will provide profound pulpal anesthesia of the premolar, canine and incisor teeth virtually 100% of the time, even when infection is present.

On those occasions when these three mandibular nerve block injections fail to provide successful pulpal anesthesia, one of several supplemental techniques may be considered. These include the periodontal ligament (PDL) injection, intraosseous (IO) anesthesia, and intrapulpal injection. The IO technique has proved to be of tremendous benefit in endodontics, particularly as a means of providing anesthesia to the “hot” mandibular molar.

**Maxillary Anesthesia**

Although profound anesthesia of maxillary teeth is normally easier to obtain, problems, if they occur, usually do so following the administration of an infiltration injection to a central incisor, canine, or molar. The apex of the central incisor may lie under the cartilage of the nose, making infiltration less effective (as well as more uncomfortable). Canines that have longer than usual roots may not be anesthetized when the anesthetic is deposited below the apex (needle is not inserted far enough). Infiltration anesthesia of maxillary molars will fail in situations where the palatal root flares greatly toward the midline of the palate. Most local anesthetics infiltrated into the buccal fold will not diffuse far enough toward the midline to provide adequate pulpal anesthesia in this situation. Additionally, where periapical infection is present, the success rate of injected local anesthetics is diminished, sometimes considerably.

Fortunately, maxillary anesthesia can readily be achieved through the administration of nerve blocks. Three nerve blocks, the posterior superior alveolar (PSA), middle superior alveolar (MSA), and anterior superior alveolar (ASA, “infraorbital”), successfully provide pulpal anesthesia to maxillary teeth, even in the presence of infection.

**Mandibular Techniques**

The techniques are described briefly and their advantages and disadvantages highlighted. For a more in-

---

**Table 9-3 Teeth Requiring Supplemental Injections**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteriors</td>
<td>2%</td>
<td>2%</td>
<td>9%</td>
<td>0%</td>
</tr>
<tr>
<td>Premolars</td>
<td>18%</td>
<td>2%</td>
<td>12%</td>
<td>0%</td>
</tr>
<tr>
<td>Molars</td>
<td>12%</td>
<td>5%</td>
<td>47%</td>
<td>91%</td>
</tr>
</tbody>
</table>

Adapted from Walton RE and Abbott BJ; Malamed SF.
For an in-depth description of these techniques, the reader is referred to local anesthesia textbooks by Malamed and Jastak and Yagiela.

**Inferior Alveolar Nerve Block (IANB) (Table 9-4).** This traditional mandibular nerve block provides, when successful, pulpal anesthesia of all mandibular teeth in the quadrant, along with buccal soft tissues and bone anterior to the mental foramen and the lingual soft tissues and anterior two-thirds of the tongue.

Many approaches exist to this technique, all of which are acceptable, with two provisos: (1) the success rate for pulpal anesthesia should be at least 85% (with one injection depositing approximately 1.5 mL of anesthetic), and (2) the technique should not increase risk of harm to the patient.

The aim in the classic Halsted approach to the IANB is to deposit local anesthetic at the mandibular foramen, the site where the IA nerve enters the mandibular canal. Although still taught as the primary mandibular technique in most dental schools, the 85% success rate for pulpal anesthesia encountered with this technique is the lowest of any injection administered in dentistry. The most common reason the IANB is missed is caused by depositing the anesthetic solution below the mandibular foramen. As the IA nerve has already entered into the thick bony canal, pulpal anesthesia is not produced. The experienced doctor will re-administer additional local anesthetic at the site slightly (5 mm) higher than the initial site. The patient should be in a supine position during the IANB, but it is recommended that they be returned to a more upright (comfortable) position following drug administration and while awaiting the onset of anesthesia.

**Gow-Gates Mandibular Nerve Block**

The GGMNB is a true third division (V$_3$) nerve block, providing pulpal anesthesia to all mandibular teeth in the quadrant, as well as the same soft tissue distribution as the IANB. Additionally, the GGMNB provides sensory anesthesia of the buccal nerve as well as the mylohyoid nerve, eliminating one cause of partial anesthesia seen in mandibular first molars in approximately 1% of patients.

Local anesthetic is deposited on the lateral aspect of the neck of the mandibular condyle (Figure 9-45). V$_3$ has just exited the foramen ovale and, with the patient’s mouth maintained in a wide-open position, the nerve lies near the condylar neck. First discussed in 1973, the GGMNB has slowly become more and more popular. Once learned, the GGMNB will provide a greater success rate for mandibular pulpal anesthesia. Unfortunately, a learning curve does exist, and some doctors, frustrated by early failures, abandon this excellent technique. The major problem encountered in learning the GGMNB is the inability to contact bone at the neck of the mandibular condyle. The primary reason for this failure is closure (even slight closure) of the patient’s mouth while the needle is being advanced (Figure 9-46).

### Table 9-4 Inferior Alveolar Nerve Block

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic</th>
<th>+ Aspiration</th>
<th>VAS*</th>
</tr>
</thead>
<tbody>
<tr>
<td>All mandibular teeth in quadrant</td>
<td>25 gauge: long</td>
<td>1.5 mL</td>
<td>10–15%</td>
<td>1–4</td>
</tr>
</tbody>
</table>

*VAS = visual analog scale, a rating of pain sensation. A score of "0": felt nothing; "1": minor, no problem; "3": some discomfort; "10": worst pain ever experienced.

### Table 9-5 Gow-Gates Mandibular Nerve Block

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic</th>
<th>+ Aspiration</th>
<th>VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>All mandibular teeth in quadrant</td>
<td>25 gauge: long</td>
<td>1.8–3.0 mL</td>
<td>1–2%</td>
<td>1–3</td>
</tr>
</tbody>
</table>

VAS = visual analog scale.
As with the IANB, patients receiving the GGMNB should be supine during the injection, but returned to a more upright, comfortable position at the conclusion of the injection and while awaiting the onset of anesthesia. It is important that the mouth be maintained in a wide-open position throughout the injection and for 2 minutes following its completion.

Akinosi-Vazirani Mandibular Nerve Block (Closed-Mouth Technique)\(^62,63\) (Table 9-6). Described in 1977, this mandibular block technique is of benefit in situations in which unilateral trismus is present, secondary to repeated mandibular injections at a previous dental visit. The patient is unable to open the mouth more than a few millimeters, preventing the administration of intraoral local anesthesia, as well as the performance of dental treatment. Since V\(^3\) is both a sensory and motor nerve (to the muscles of mastication), blockade of V\(^3\) provides relief of the muscle spasm, permitting the patient’s mouth to open and the planned dental care to proceed.

The teeth are kept lightly in contact throughout the injection and the cheek is retracted. A long needle, either a 25- or a 27-gauge is placed, with its bevel facing the midline, into the buccal fold on the side of injection at the height of the mucogingival junction of the last maxillary molar (this injection is intermediate in height between the GGMNB and IANB). Soft tissue on the lingual aspect of the mandible is penetrated at a site immediately adjacent to the maxillary tuberosity and the needle is advanced 25 mm, where the local anesthetic is deposited. Motor paralysis usually develops before soft tissue and pulpal anesthesia. The patient, supine during the injection, should be repositioned more upright (comfortable) following injection and while awaiting onset of anesthesia.

Incisive Nerve Block (INB) (Mental NB) (Table 9-7). The INB is an underused technique, but one that provides pulpal anesthesia to the five mandibular anterior teeth on a very reliable basis, even in the presence of infection. Soft tissue anesthesia of the lower lip, skin of the chin, and buccal soft tissues anterior to the mental foramen is achieved 100% of the time. Local anesthesia is infiltrated outside the mental foramen and then, with the use of finger pressure, forced into the foramen and mandibular canal where the incisive nerve (a terminal

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic (Adult)</th>
<th>+ Aspiration</th>
<th>VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>All mandibular teeth in quadrant</td>
<td>25 or 27 gauge: long</td>
<td>1.8 mL</td>
<td>&lt; 10%</td>
<td>0–2</td>
</tr>
</tbody>
</table>

VAS = visual analog scale.
branch of the IA nerve) is located. Pressure should be applied to the area for at least 1 minute, preferably 2 minutes, following deposition of the anesthetic. Lingual soft tissues, including the tongue, are not anesthetized in the incisive nerve block. Should lingual soft tissue anesthesia be required for placement of a rubber dam clamp, it can be achieved painlessly by advancing the needle through the already anesthetized buccal papilla toward the lingual while depositing small volumes of local anesthetic en route. With proper technique (eg, finger pressure for 2 minutes), the INB is virtually 100% successful, painless (there is no need for the needle to contact bone), and can be used successfully from the outset (there is no learning curve for this injection).

Maxillary Techniques

Posterior Superior Alveolar Nerve Block (PSANB) ("Zygomatic" NB) (Table 9-8). When successful pulpal anesthesia of maxillary teeth is not achieved through supraperiosteal injection, nerve block anesthesia usually succeeds. PSANB provides consistently reliable pulpal anesthesia to the three maxillary molars, even in the presence of infection or widely flared palatal roots. Buccal soft tissues and bone overlying this area are also anesthetized. As no bone is contacted in PSANB, the injection is extremely comfortable; however, the absence of bony contact increases the risk of developing a hematoma following the injection. This usually develops when the needle is advanced too far into the tissues. From the needle penetration site in the buccal fold by the second maxillary molar, the short needle is advanced to a depth of 16 mm in an inward, upward, and backward direction. This places the needle tip into the pterygomaxillary space, where the PSA nerves are located. In some patients, the mesiobuccal (MB) root of the first molar may not be anesthetized with the PSANB but may be anesthetized by an MSA nerve block, described in the following paragraph.64

Middle Superior Alveolar Nerve Block (MSANB) (Table 9-9). When present, the MSA nerve provides pulpal anesthesia to the two premolars and the MB root of the first molar (as well as the buccal soft tissues and bone overlying this area). Advancing the tip of the needle well above the apex of the second premolar and administering 0.9 mL of anesthetic will provide successful anesthesia almost 100% of the time.

Anterior Superior Alveolar Nerve Block (ASANB) ("Infraorbital" NB) (Table 9-10). In a technique technically similar to the incisive nerve block ("mental") in the mandible, the ASANB provides pulpal anesthesia to the incisors, canine, and both premolars on the side of injection, as well as their overlying soft tissues. The ASA is highly successful in the presence of infection (unless the infection is present in the region of the infraorbital foramen). The needle is inserted into the buccal fold by the first premolar and aimed for the infraorbital foramen, which is located by palpation. A volume of 0.9 mL of local anesthetic is deposited outside the infraorbital foramen and then forced into the foramen by the application of finger pressure for 2 minutes (1 minute minimally).

Supplemental Injection Techniques

Periodontal Ligament (PDL) Injection and Intraligamentary Injection (ILI) (Table 9-11). When pulpal anesthesia of a single tooth is required, the PDL injection should be considered. This is of special importance in the mandible, where nerve block anesthesia is the

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic</th>
<th>Aspiration</th>
<th>VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandibular incisors and canine and premolars</td>
<td>27 gauge: long</td>
<td>0.6 mL</td>
<td>5.7%</td>
<td>0–2</td>
</tr>
</tbody>
</table>

VAS = visual analog scale.

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic</th>
<th>Aspiration</th>
<th>VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary molars</td>
<td>25 or 27 gauge: short</td>
<td>0.9 mL</td>
<td>3.1%</td>
<td>0–2</td>
</tr>
</tbody>
</table>

VAS = visual analog scale.
Preparation for Endodontic Treatment

In the maxilla, supraperiosteal injection infiltrated above the apex of any tooth will provide successful pulpal anesthesia with a success rate of > 95%. Because of the thickness of the mandibular cortical plate of bone (in adults), infiltration techniques are doomed to failure. Therefore, although the PDL may be successfully administered to any tooth, its use is most often reserved for mandibular teeth, specifically mandibular molars.

Although special syringes have been developed to assist in delivery of the local anesthetic in the PDL injection, a regular syringe may be used quite effectively. A volume of 0.2 mL of local anesthetic solution must be deposited interproximally on each root of the tooth to be treated. The bevel of the needle should be placed against the root of the tooth while it is advanced down into the PDL space until resistance prevents any further penetration (Figure 9-47 and Figure 9-48). As the anesthetic is slowly deposited, it should be noted that there is significant resistance to the administration of the solution and that the soft tissues in the area become ischemic. Presence of these two signs usually connotes successful anesthesia. Onset of clinical action is immediate; however, the duration of pulpal anesthesia is quite variable, although it is most often long enough to permit access to the pulp chamber of a previously sensitive tooth.

Two contraindications exist to administration of the PDL injection: primary teeth and the presence of periodontal infection. The presence of pocket infection in the site of needle insertion increases the risk of osteomyelitis developing subsequent to the injection (Figure 9-49).

Intraosseous (IO) Anesthesia (Table 9-12). In true IO anesthesia, local anesthetic is injected directly into the bone surrounding the root of a tooth. Conceptually the IO injection is quite simple: the impediment to local anesthetic diffusion through bone in the adult mandible is the thickness of the cortical plate. Where a foramen is present, such as the mental foramen, the drug can gain access to the nerve and produce conduction blockade. Unfortunately, no such foramen is found on the buccal aspect of the mandible distal to the mental foramen, making it more difficult to obtain consistently reliable pulpal anesthesia on mandibular molars (see Table 9-3).

In the IO technique, a small perforation or foramen is made through the cortical plate of bone with a tiny dental bur, into which a needle is inserted and local

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic (Adult)</th>
<th>+ Aspiration</th>
<th>VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary premolars + MB root first molar</td>
<td>27 gauge: short</td>
<td>0.9 mL</td>
<td>&lt; 3%</td>
<td>0–2</td>
</tr>
</tbody>
</table>

MB = mesiobuccal; VAS = visual analog scale.

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic (Adult)</th>
<th>+ Aspiration</th>
<th>VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary incisors, canine premolars + MB root first molar</td>
<td>25 gauge: long</td>
<td>0.9 mL</td>
<td>0.7%</td>
<td>0–2</td>
</tr>
</tbody>
</table>

MB = mesiobuccal; VAS = visual analog scale.

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic (Adult)</th>
<th>+ Aspiration</th>
<th>VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 tooth</td>
<td>27 gauge: short</td>
<td>0.2 mL per root</td>
<td>0%</td>
<td>0–10</td>
</tr>
</tbody>
</table>

VAS = visual analog scale.
Figure 9-47  Needle penetrating distal periodontal ligament space of mandibular molar. (Courtesy of Drs. Colin and Gwenet Lambert.)

Figure 9-48  Insertion of needle for periodontal ligament injection. a, Correct insertion, bevel faces cribiform plate. b, Incorrect insertion directing stream toward tooth. (Courtesy of Drs. Colin and Gwenet Lambert.)

Figure 9-49  Damage and repair to periodontal structures from intraligamental injection. A, Needle tract from lower right into gouged cementum, top left. Chips of cementum (C), erythrocytes (E), and debris (D) carried in by needle indicate severity at time of injury. B, Tissue repair 25 days after intraligamental injection. New bone (arrows) has replaced bone resorbed following injection. Reproduced with permission from Walton RE, Garnick JJ. JOE 1982;8:22.
Preparation for Endodontic Treatment

anesthetic is administered. Intraosseous injections can provide anesthesia of but a single tooth or of multiple teeth in a quadrant, depending on the site of injection and the volume of anesthetic administered. When treating one or two teeth, 0.45 to 0.6 mL is usually used. IO anesthesia has proved to be of great benefit in endodontics when traditional injection techniques fail. Nusstein et al. found that 81% of mandibular and 12% of maxillary teeth in 51 patients diagnosed with irreversible pulpitis required IO anesthesia because of failure to gain pulpal anesthesia with infiltration or IA nerve block. IO anesthesia “was found to be 88% successful in gaining total pulpal anesthesia for endodontic therapy.”

Parente et al. administered IO anesthesia to 37 patients with irreversible pulpitis. Thirty-four were mandibular molars, 2 were maxillary molars, and 1 was a maxillary anterior tooth. Maxillary teeth received infiltration anesthesia, whereas mandibular teeth received the IA injection with a minimum of 3.6 mL of local anesthetic. IO anesthesia successfully provided pulpal anesthesia in 91% of mandibular molars (31/34) and for two of three maxillary teeth.

There are two concerns regarding the IO injection. First, the local anesthetic is administered into a highly vascular site, where absorption into the cardiovascular system is quite rapid. Administration of an overly large volume of local anesthetic could lead to elevated blood levels of the anesthetic and signs and symptoms of overdose. The second concern regards the inclusion of vasopressors (eg, epinephrine) in the local anesthetic solution. This can lead to a rapid absorption into the cardiovascular system leading to an “epinephrine reaction” in which patients experience mild tremors of the extremities, palpitations, and diaphoresis after receiving the IO injection. Use of a vasopressor-containing local anesthetic in a patient with significant cardiovascular disease could provoke potentially life-threatening complications. It is recommended that a “plain” non-epinephrine local anesthetic solution be used in the IO technique.

Intrapulpal Anesthesia (Table 9-13). When the pulp chamber has been exposed and, because of exquisite sensitivity, treatment cannot proceed, intrapulpal anesthesia should be considered. With the increased interest in the very successful IO technique, however, the need for intrapulpal anesthesia should diminish.

A small needle is inserted into the pulp chamber until resistance is encountered (Figure 9-50). The local anesthetic must be injected under pressure. There will be a brief moment of intense discomfort as the injection is started, but anesthesia usually supervenes almost immediately, and instrumentation can proceed painlessly. Because of the discomfort involved in intrapulpal anesthesia, the patient must be advised of this before the injection is begun. The concurrent administration of inhalation sedation (N₂O–O₂) or intravenous Versed will minimize patient response by alleviating the PRT.

Summary
Clinically effective pain control can be achieved in the vast majority of patients requiring endodontic therapy. When problems achieving pain control occur, it is usually at the initial visit, when a frightened patient, who has been hurting for some period of time, finally seeks relief from pain yet oftentimes is unable to manage the fears of dentistry. Through a combination of thoughtful caring for the patient, the use of conscious sedation, when indicated, and the effective administration of local anesthesia, endodontic treatment can proceed in

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic (Adult)</th>
<th>+ Aspiration</th>
<th>VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 tooth</td>
<td>27 gauge: short</td>
<td>0.2 to 0.3 mL</td>
<td>0%</td>
<td>5–10</td>
</tr>
</tbody>
</table>

VAS = visual analog scale.

Table 9-12 Intraosseous Anesthesia

<table>
<thead>
<tr>
<th>Teeth Anesthetized</th>
<th>Recommended Needle</th>
<th>Volume of Anesthetic (Adult)</th>
<th>+ Aspiration</th>
<th>VAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 or 2 teeth</td>
<td>27 gauge: short</td>
<td>0.45 to 0.6 mL</td>
<td>0%</td>
<td>0–2</td>
</tr>
</tbody>
</table>

VAS = visual analog scale.
a more relaxed and pleasant environment for both the patient and dental staff.

**ENDODONTIC PRETREATMENT**

Root canal therapy does not necessarily begin with the placement of the rubber dam but with the **restorative or periodontic procedures necessary to simplify its placement**. These procedures determine the restorability of the tooth and establish a healthy periodontal relationship between tooth, gingiva, and bone. Pretreatment encompasses all procedures that ensure the ease of root canal treatment directed toward restoring and maintaining the involved tooth. The type of pretreatment varies with each case, but certain fundamental objectives must be considered:

1. Prevention of postoperative discomfort and the inopportune fracture of teeth. **Gross occlusal reduction** should be performed on any decayed or filled posterior tooth undergoing root canal therapy. All such teeth will be required to have capped cusp restorations or full crowns on completion of treatment. This reduction should be done **before** rubber dam placement to check occlusal clearance in all excursive movements. It should also be done **before** the first endodontic treatment, rather than after, in order **not to disturb** cuspal reference points used to establish proper **length of the tooth**. Exempt from this pretreatment are posterior teeth that have been adequately restored and anterior teeth.

2. Prevention of bacterial contamination from salivary leakage and prevention of percolation of intracanal medication. All **faulty restorations** and carious defects must be removed and replaced with temporary filling material (**TERM**) (L. D. Caulk; Milford, Dela.) or with alloy in the case of two or three surface fillings.

   To restore a minimal defect on the proximal, TERM can be placed after the endodontic appointment is completed and before the removal of the rubber dam. On subsequent appointments, normal access can be made through the TERM temporary, but if such access weakens the filling, the entire temporary should be replaced at each visit.

   The use of Cavit (Premier-Espe; Norristown, Pa.) is limited by its slow-setting property, requiring 1 hour in a wet environment to reach a complete set. It is also inadequate in large two- and three-surface temporary restorations and will never last beyond a week in any case.

3. **Provision of a sound margin of tooth structure for rubber dam placement**. The sound margin may be exposed by periodontal procedures or the crown may be restored with a temporary band.

**Periodontal Therapy**

Gingival hyperplasia or hypertrophy can be easily removed by gingivectomy or by the use of electrosurgery or laser. Both techniques are expedient but have the disadvantage in some cases of producing large surface wounds that may hemorrhage and must heal by secondary intention.

In such situations, and in cases in which the crown has been fractured or destroyed to the gingival level, a more refined mucogingival technique is indicated. The inflamed gingival margin is removed by means of an internally beveled horizontal incision. This measure eliminates an external wound and permits a rubber dam application immediately on completion of the procedure without the problem of hemorrhage control. Two vertical relaxing incisions, extended from the gingival margin **into the alveolar mucosa**, create a mucogingival flap and permit the free movement of this flap to be **repositioned apically** and sutured to

---

**Figure 9-50** Intrapulpal pressure anesthesia with lidocaine. A, Coronal injection through pinhole opening in dentin. B, Pulp canal injection for each individual canal. Needle is inserted tightly and one drop of solution is deposited. (Courtesy of Drs. Colin and Gwenet Lambert.)
Preparation for Endodontic Treatment

This technique permits the exposure of additional root surface for the placement of the rubber dam clamp and final restoration. In some cases, corrective osseous recontouring may be necessary (Figure 9-51).

Copper Bands
The preceding periodontal procedures are expedient and can usually be limited to the endodontically involved tooth. However, there are some problems that cannot be easily corrected by periodontal therapy. Gross subgingival caries may be better treated by the cementation of a copper band custom fitted to the particular carious defect (Figure 9-52). The extraction of a partially erupted third molar may leave a bony defect and a deep carious lesion on the distal root of the second molar (Figure 9-53). A copper band may be readily adapted to extend subgingivally in this area, where anatomic considerations preclude definitive periodon-

Figure 9-51  A, Preoperative view of maxillary canine whose crown is totally destroyed by caries under defective bridge abutment. Level of gingival tissue (arrow) in relation to remaining root is apparent. B, View following root canal therapy and apical repositioning of attached gingiva. Elongation of clinical crown is seen (arrow) in comparison with view in A. C, View of final restoration. Important canine abutment (arrow) is salvaged by combined endodontic–periodontic procedures. (Restoration by Dr. James Haberman.) D, Retrofilling of pulpless canine abutment was done during mucogingival surgery. Previous endodontic filling was incomplete. (Endodontic–periodontic therapy by Dr. Edward E. Beveridge.)
tal therapy. In severe cases, the periodontal or carious defect may be beyond repair, requiring **hemisection** of the distal root of the lower second molar. Banding may then be helpful to seal off the bisected pulp chamber.

**Orthodontic Bands**

Whereas the copper band is custom-fitted to adapt to a carious defect extending **well below** the gingival margin, the orthodontic band is prefabricated to fit the tooth supragingivally. Thus, it is not used to replace the copper band but to help retain a large temporary filling or support a tooth with undermined enamel walls. It is an essential step in the treatment of a tooth that is thought to be cracking or split (Figure 9-54). It serves as an excellent temporary restoration to prevent splitting during extended treatment, or after treatment, when final restoration has to be postponed. All bands are cemented with zinc oxyphosphate cement.

**Temporary Crowns and Restorations**

Aluminum shell crowns and plastic crowns or bridges cemented with zinc oxide–eugenol cement are not acceptable as proper pretreatment temporization. The placement of the rubber dam clamp and the tension of the rubber dam displace these temporary crowns, as does repeated rubber dam application and endodontic manipulation. In addition, access attempted through the temporary crown and cement may easily be misdirected against one of the axial walls of the preparation instead of directly into the pulp chamber.

**RUBBER DAM APPLICATION**

Rubber dam application is an essential prerequisite for providing nonsurgical endodontic treatment. For root canal treatment, rapid, simple, and effective methods of dam applications have been developed. In all but the most unusual circumstances, the rubber dam can be placed in less than 1 minute.

Although the modern endodontic approach to the use of the dam has changed, the importance and purposes of the dam remain the same:

1. It provides a dry, clean, and disinfected field.
2. It protects the patient from the possible aspiration or swallowing of tooth and filling debris, bacteria, necrotic pulp remnants, and instruments or operating materials (Figure 9-55).
3. It protects the patient from rotary and hand instruments, drugs, irrigating solutions, and the trauma of repeated manual manipulation of the oral soft tissues.

**Figure 9-52**  
A, Badly broken-down pulpless molar with root resorption. Before endodontic treatment, cavity must be sealed off. B, Custom-fitted copper band allows for full treatment. (Courtesy of Dr. James D. Zidell.)

**Figure 9-53**  
Destruction caused by partially erupted third molar and caries. Extended copper band will isolate crown for endodontic treatment. (Courtesy of Dr. James D. Zidell.)
4. It is faster, more convenient, and less frustrating than the repeated changing of cotton rolls and/or saliva ejectors.

The rubber dam also provides a fluid seal from saliva from the working field. It has been recently shown in vivo that intraoral and extraoral microorganisms contaminating the root canal system will lead to eventual failure.79

Equipment
Time-and-motion studies have stressed the efficacy of kit or tray preparations that pool instruments and materials to be used in a given procedure. Applied to rubber dam application, this system encourages its more routine use.

Dam Material. Rubber dam is available in a variety of thicknesses, colors, sizes, methods of packaging, and material. The medium-weight thickness is recommended for general all-around use. It has the advantage of cupping around the cervical of teeth, providing a fluid seal without the use of floss ligature ties around each tooth. Also, it does not tear or rip easily and provides an unusual degree of protection from injury for the underlying soft tissues. It exerts a greater retracting force on the lips and cheeks than does the thinner material, thus affording greater access and improved vision.

There are advantages, however, in using the thin weight dam on mandibular anterior teeth and partially erupted posterior teeth. The problem of retaining a clamp on these tapered teeth, with little or no cervical undercut, is solved by applying the thinner dam, which exerts less dislodging force on the clamp. The disadvantage is that it is easily torn.

Dam materials may be purchased in 5- or 6-inch-wide rolls to be cut to size; precut sheets, either 5 inches × 5 inches, 5 inches × 6 inches, or 6 inches × 6 inches unsterilized and boxed; or precut and individually sterilized and packaged. A sheet 6 inches × 6 inches will fill all needs of various applications and is large enough to fit any size frame.

The choice of light or dark-colored material is largely up to the individual. However, dark material provides a contrasting color as a background for the light-colored tooth.

Rubber dam is available in latex and nonlatex material. The prevalence of allergies to latex has been increasing; it is important to recognize patients who may have an allergy to latex.80 Latex-free dams, such as silicone rubber (Coltene/Whaledent/Hygenic Corporation, USA), are currently available. Additionally, the digits can be cut from a vinyl glove, and the remainder can be adapted to act as a rubber dam in patients who exhibit hypersensitivity to latex.

Punch. Any rubber dam punch that is convenient for the operator and creates a sharp clean hole in the dam material is satisfactory. All too often the punch has not been correctly centered over a hole, and a “nick” on the cutting margin results, producing an incomplete jagged cut in the dam material. This is easily corrected by “sharpening” the cutting edge of the hole with carborundum stone. Failure to correct this punching error will result in salivary leakage and contamination of the field at the site of the ragged hole in the dam.

Figure 9-54 Prefabricated orthodontic band for supragingival containment of large temporary proximal filling or to support weakened enamel walls. (Courtesy of Dr. James D. Zidell.)

Figure 9-55 Swallowed endodontic file ended up in appendix and led to acute appendicitis and appendectomy. Rubber dam would have prevented this tragedy. Reproduced with permission from Thomsen LC, et al. Gen Dent 1989;37:50.
greater the chance of contamination. Stretching the dam while taking radiographs and capillary forces also contributed. Leakage was significantly reduced by application of a wound dressing, Nobecutane (Astra Pharmaceutical, Sweden) and silicone medical adhesives (Dow Corning Medical Products, USA) to seal the dam and the tooth.\(^8\)

Others have sealed this interface with cyanoacrylate,\(^8\) rubber base adhesive,\(^8\) Super Poli-Grip Denture Adhesive (Dentico, Inc., USA), and Oraseal (Ultradent Products, USA), made specifically to seal the rubber dam, including tears in the dam (Figure 9-56).

**Frames.** In addition to supporting the dam, frames should be **radiolucent** to prevent obliteration of an important area on the endodontic working radiograph. There are a variety of rubber dam frames that meet these requirements. The U-shaped **Young’s frame** is made of either metal for use in restorative dentistry or of radiolucent plastic for endodontic applications. It is easily manipulated and is widely used. This frame holds the dam against the patient’s face, and an absorbent napkin under the dam can be used for patient comfort.

The **Nygaaard-Østby (N-Ø)** rubber dam frame (Coltene/Whaledent/Hygenic Corp.; Mahwah, N.J.) is shield shaped, made of radiolucent nylon, and may be in place while a tooth is subjected to x-ray without interfering with the radiographic image (Figure 9-57). It tends to hold the dam away from the patient’s face and is thus cooler, drier, more comfortable, and requires no absorbent napkin. Because of its shape, it also directs the breath from the nostrils away from the operative field, thus minimizing possible root canal contamination by nasal staphylococci* (see Figure 9-57).

Another U-shaped frame, the **Starlite VisiFrame** (Interdent Inc.; Culver City, Calif.), is also made in radiolucent plastic. Because of its shape, it exerts less tension on the dam and is easier to use than the N-Ø frame when taking radiographs of molars. Like the N-Ø frame, it requires no absorbent napkin, and stands away from the face.

An innovative, articulated frame developed to facilitate endodontic radiography is **le Cadre Articulé** (the articulated frame) (Jored, Ormoy, France, and Trophy, USA). Developed in France by Dr. G. Sauveur, it is curved to fit the face (Figure 9-58, A) and is hinged in the middle to fold back, allowing easier access for radiographic film placement (Figure 9-58, B).

**Clamps.** Although a basic selection of five to seven clamps will permit most dentists to place a clamp and dam on a majority of teeth encountered, the more experienced operator builds up a larger collection over the years. Teeth that are rotated, partially erupted, malaligned, fractured, anomalous in crown form, or with severe carious involvement all present problems requiring special clamps or clamping techniques.

Table 9-14 lists a suggested assortment of metal clamps for the various teeth. Incisor and premolar clamps that are losing their tension should be retained as they often make excellent clamps for unusual molar applications.

---

*This most important point bears emphasis. All of the dental office personnel should have nose cultures, and if staphylococci are present, should apply Neosporin or Mycitracin to their nostrils each day.
Plastic clamps (Moyco/Union Broach, USA) are also available in two sizes, large and small, and are used in selected cases. When metal clamp obstruction is a problem in radiography, **radiolucent plastic clamps** allow for an unobstructed view of the tooth. Plastic clamps can also be used to isolate teeth during vital tooth bleaching, using a heat lamp to avoid excessive heat buildup that occurs with conventional metal clamps.

Metal rubber dam clamps may damage tooth structure, restorations, and the **porcelain surface** of crowns or veneers. Conflicting reports have recently been published on the effect of rubber dam retainers on the surface of porcelain. One study reported that damage to the porcelain surface resulted when metal rubber dam retainers were in contact with porcelain-fused-to-metal (PFM) restorations. Another study demonstrated that neither the broad contact of a plastic retainer beak nor the point contact under a metal retainer beak damaged the contact area of porcelain surface of a PFM cylinder. However, repeated applications of rubber dam clamps, in multiple appointments necessary to complete endodontic procedures, is likely to increase the risk of damage.

For endodontic treatment particularly, the use of clamps with wings allows a more rapid, efficient means of applying the rubber dam. A well-trained assistant is able to perform much of the usual technical procedure of application described later in this section. The wings allow the dentist to place the clamp, dam, and frame in one operation (Figure 9-59). In addition, the wings cause a broader buccal-lingual deflection of the dam from the involved tooth, allowing increased access.

Rubber dam clamps undergo stress with repeated use and sterilization. Additionally, clamps that are used during endodontic procedures may be chemically stressed and subject to fracture if in contact with the irrigant sodium hypochlorite. It is a good safety measure to place dental floss ligatures around both ends of the clamp bows so that if the clamp fractures, both portions can be retrieved.

**Forceps.** Either the Ash- or Ivory-style clamp forceps is satisfactory. One advantage of the **Ivory forceps**,
however, is the projections from the engaging beaks. These allow the operator the opportunity to exert a gingivally directed force, which is often necessary to direct the clamp beyond the height of contour and into proximal undercuts. The projections on the beaks also allow positive control, enabling the jaws of clamps to be tipped to depress either the “toe” or “heel” of the clamp. The Ash-style forceps beaks, on the other hand, afford a fulcrum point for posterior or anterior rotation of the clamp.

Tucking Instrument. A plastic or cement instrument is used to shed the rubber dam off the wings of the clamp once the clamp has been positioned. It is also used, along with a stream of air, to invert or “tuck” the edges of the dam into the gingival sulci, thus ensuring a moisture-proof seal. This is particularly necessary in multiple-tooth applications.

Dental Floss. At one time it was recommended that dental floss be routinely used as a ligature placed around the cervix of each tooth to invert or “tuck” the dam and provide a seal. Through the use of medium or heavy dam material, this is no longer necessary. Floss is still essential, however, for the testing of contacts before dam application and for passing the dam material through the contacts. In both instances, the operator should release his lingual grasp of the floss and pull it out to the buccal, rather than back through the contact point.

Saliva Ejector. Any disposable/radiolucent saliva ejector is acceptable. It should always be placed underneath the dam for endodontic use, in contrast to the procedure of cutting a hole through the dam. This will prevent possible salivary contamination of the field and be less of a hindrance while taking radiographs with the dam in place.

Technique of Application

Three methods of applying a rubber dam, two for a single-bowed clamp and one for a double-bowed clamp, are described in the following sections.

Preparation of Rubber Dam Application

Using a Single-Bowed Clamp

Dentist.
1. Remove supra- and subgingival calculus and dental plaque. Mark the tooth to be treated with a marker pen.
2. Select the clamp to be used.
3. Test contacts with floss to ensure passability and to test for sharp edges that might tear the dam.

Assistant.
1. Punch one appropriate-sized hole just off center of a 6 inch × 6 inch piece of dam material. Rotate the dam to match the tooth to be treated: upper or lower, right or left. Traditionally, only the teeth receiving therapy should be included in the dam application.
2a. Stretch the dam over the frame and place the wings of the selected clamp in the punched hole with the bow of the clamp to the distal (Figure 9-60), or
2b. Place only the bow of the clamp through the punched hole of the rubber dam.
3. Place the forceps in the clamp holes with tension and hold in readiness for the dentist (see Figure 9-60).

Application by the Team Dentist.
4. Place an index finger in the vestibule to retract the lip and cheek. The patient is instructed to place the tongue on the opposite side.
5. Sight the tooth to be clamped between the jaws of the clamp (Figure 9-61, A). Direct vision is essential.
6. Place the clamp into the cervical proximal undercuts on the tooth as the index finger is removed from the vestibule (Figure 9-61, B). Finger pressure is sometimes used to ensure seating of the clamp
7a. For 2a above, shed the dam off the clamp wings with the tucking instrument (Figure 9-61, C). Care is taken not to rip the dam, or
7b. For 2b above, loosely apply the rubber dam frame to the corners of the rubber dam with the aid of the assistant. Then stretch the dam under the wings of the clamp with the tucking instrument and tighten the rubber dam over the entire frame.
Figure 9-60  Assistant has mounted rubber dam on frame and has positioned wings of clamp in dam. She presents assembled unit with forceps to dentist, ready for placement. Notice that hole is punched just off center of 6 x 6-inch rubber dam. Position of hole is identical for each tooth and dam is rotated for either right or left side, upper or lower.

Figure 9-61  A. Dentist retracts lip and cheek with thumb and index finger of left hand and sites tooth to be clamped (here a maxillary premolar) between bows of the clamp. Care must be taken not to clamp wrong tooth. B. Clamp is carried into gingival undercuts. If undercuts are slight, clamp may be rotated on tooth to take advantage of undercuts along labial and lingual-proximal long axis. C. Dam is shed from clamp wings with tucking instrument, which is also used to carry lip of dam under gingival sulcus after tooth is air-dried. D. Dental floss is used to carry dam past interproximal contacts. Floss should then be pulled to buccal rather than removed back past contact.
8. Use floss to aid in passing the dam through contacts. Pull the floss through the labial or buccal rather than pulling back through the contacts (Figure 9-61, D).
9. In multiple-tooth applications, tuck the dam into the gingival sulci of the unclamped teeth, using the tucking instrument.

**Assistant.**

10. Use compressed air to dry the teeth; this aids in tucking.
11. Aid in tightening the rubber dam over the frame once the clamp is on the tooth and after the rubber dam is stretched under the wings of the clamp.
12. Place the saliva ejector under the dam. On a maxillary dam application, many patients do not need the saliva ejector.

**Preparation of Rubber Dam Application Using a Double-Bowed Clamp**

**Dentist.**

Same as for a single-bowed clamp.

**Assistant.**

1. Punch one large hole just off center of a 6 inch × 6-inch piece of dam material.
2. Stretch the dam over the frame

**Application by the Team Dentist.**

1. After the assistant has positioned the dam over the involved and marked tooth (Figure 9-62, A), place the clamp into the cervical proximal undercuts on the tooth.
2. Use floss to aid in passing the dam through the contacts (Figure 9-62, B).

Completed dam application should take less than 30 seconds of the dentist’s time in all but the unusual cases. In applying the dam to a single tooth, however, the dentist must take great care that the correct tooth is clamped. After placement, the record is checked and the teeth are counted under the dam, first by the dentist and then independently by the assistant.

The team that is hesitant about clamping the wrong tooth must be cautioned about using the time-honored system of first placing the clamp, then the dam, then the frame. This sequence of rubber dam application may lead to accidental swallowing of a rubber dam clamp. There are several reports in the literature on the ingestion of rubber dam clamps. This further emphasizes the importance of using floss ligatures around rubber dam clamps so that dislodged clamps and broken clamps can be retrieved quickly.

**Removal of Dam**

1. For single-tooth applications, simply remove the clamp with the forceps and remove the dam.
2. In multiple-tooth applications, first remove the clamp, then place a finger under the dam in the vestibule, and stretch the dam to the facial, away from the teeth. Cut the stretched interproximal dam with scissors and then remove the dam. After removal, it is essential that the dam be inspected to

---

Figure 9-62  A, Rubber dam in place, exposing involved tooth previously marked with a marking pen. B, Clamp placement in gingival undercuts. Dental floss carries dam past interproximal contacts and is removed by pulling to buccal rather than back through contacts. (Courtesy of Jeffrey M Coil.)
ensure that no interproximal dam septum has been left between the teeth.

Circumstances Requiring Variations from the Usual Application

A number of circumstances require a variation from the standard dam application.

First Circumstance. A well-done gingival gold filling or PFM veneer crown on the involved tooth that could be damaged by clamps.

Variation. Clamp one tooth posterior to, and extend the rubber dam one tooth anterior to, the involved tooth.

Second Circumstance. Multiple adjacent teeth requiring treatment.

Variation. The posterior tooth is clamped normally while the clamp is reversed (with the bow pointing mesially) on the more anterior tooth. By another approach, the most posterior tooth is clamped normally, while the anterior portion of the dam is retained and retracted without a clamp. Neaverth has suggested that a \( \frac{1}{4} \)-inch-wide strip of dam can be stretched thin to simulate dental floss (personal communication, Feb. 2000). It is then passed through the contact and, when released, acts as a wedge holding the dam in place (Figure 9-63).

Third Circumstance. Bridge abutments, splints, and orthodontic bands with wires.

Variation. Punch a larger-than-usual hole in the dam. Smear Oraseal around the hole on the underside of the dam. This mucilaginous material prevents leakage. Clamp the tooth in the normal manner. In addition, place a round toothpick through the gingival embrasure next to the pontic. If leakage is still a problem, add more Oraseal around the abutment at the site of the leakage.

Fourth Circumstance. Partially erupted tooth.

Variation. An Ivory #14A or Ash #A clamp forced subgingivally into the cervical undercut will often hold. On occasion, an Ash #C clamp, placed on the oblique, will suffice. For supragingival retention, when no undercut is present, Japanese researchers have recommended placing a small amount of self-curing composite resin on the labial and lingual unetched enamel surfaces. The clamp is set in this scaffold of the cured resin. After use, the resin can be lifted off with an excavator.

Fifth Circumstance. Caries, resulting in a subgingival restorative margin of the involved tooth (Figure 9-64, A).

Variation. Clamp one tooth posterior to, and extend rubber dam one or two teeth anterior to, the involved tooth. The furthest anterior tooth isolated may receive a rubber dam clamp with its bow pointing mesially. If floss sheds through, or the rubber dam rips between the contacts, Oraseal may be necessary to develop a fluid seal (Figure 9-64, B). This multiple-tooth isolation facilitates easy placement of an interproximal...
matrix used during final restoration, without interference from a rubber dam clamp on the involved tooth.

Sixth Circumstance. Hemisected maxillary or mandibular molars.

Variation. Hemisected mandibular molars are treated as a premolar. Those that are wide buccolingually are best clamped with a fatigued Hu-Friedy or Ivory #2 or #2A.

A hemisected maxillary molar with the lingual root remaining is also best treated as a large premolar. A Hu-Friedy #27 clamp frequently adapts well. When the two buccal roots of a maxillary molar remain, it is then best treated as a small molar, and an Ash #A frequently suffices. Often the hemisected maxillary molar can be clamped only by placing the clamp obliquely.

Seventh Circumstance. Full-crown preparation without a cervical undercut to retain the clamp.

Variations. A proper full-crown preparation will shed toward the occlusal, and the clamp may not provide adequate resistance to the tension of the rubber dam. It may be necessary to place parallel horizontal grooves on the buccal and lingual axial walls of the preparation near the gingival margin to permit the clamp to grasp onto the preparation. The Ivory #2 or #2A clamp will fit into these grooves for retention. It has also been suggested that applying composite resin on the buccal and lingual unetched surfaces might be superior to cutting grooves.91

 Eighth Circumstance. Posterior teeth with minimal tooth structure for clamp retention.

Variation. The tension of the rubber dam as it is stretched taut over the frame exerts pressure, or a force of displacement, on the bow of the clamp. The clamp may be reversed on the working tooth; a second clamp is placed over the rubber dam on the next tooth posterior to absorb the pressure of the rubber dam.

Periodontal crown lengthening to “elongate” the crown of a fractured or badly decayed tooth was discussed in the section “Endodontic Pretreatment.”

Ninth Circumstance. Extensive caries resulting in subgingival buccal and/or lingual margin(s).

Variation. The involved tooth can undergo periodontal crown lengthening, addition of restorative material to allow for supragingival clamp placement, or gingival surgery to expose more tooth structure to allow for clamp placement (see Figure 9-51).

Tenth Circumstance. Fractured cusp with subgingival margin on buccal or lingual surface.

Variation. Use three-tooth rubber dam isolation as in second circumstance. By placing a short cotton roll under the wing of the rubber dam clamp, additional reflection of the rubber dam can be achieved (Figure 9-65). Note that the clamp would otherwise be unstable if placed on the involved tooth in the traditional single-tooth isolation.

Eleventh Circumstance. Tooth with calcified pulp chamber and canal(s).

Variation. Use three-tooth rubber dam isolation as in second circumstance. Involved tooth is without a clamp, allowing the operator to better visualize the CEJ region of the tooth. There are no clamp wings to obstruct one’s view. A periodontal probe can be traced along the root surface to orientate oneself to the crown–root angulations during difficult-access cavity preparations. Additionally, the image in working films is unlikely to be obstructed by the clamp (Figure 9-66).
SUMMARY

Students, recent graduates, and veteran practitioners alike will find restorative and endodontic practice more rewarding and less frustrating as their mastery of rubber dam applications increases. The use of simplified techniques, improved materials, and organized procedures, as well as patience, practice, and perseverance, will hasten this mastery. Remember, it is imperative that a rubber dam be used for all endodontic procedures!

REFERENCES


