canal-filling materials were similarly loosely identified, this condition in enlarging instruments was devastating to the clinician.

In Ingle's system, which was endorsed and further developed by the International Standards Organization (ISO), the position where the cutting blades began on an instrument was called D_1, and the flutes extended up the shaft for 16 mm to stop at position D_2. The rest of the handle had no flutes, and its length was the difference between 16 mm and the total length from tip to handle. This length of cutting edges (length between D_1 and D_2) was to be 16 mm, regardless of the length or style of instrument (Figure 5-7, *top*).

Furthermore, the name of the instrument was to be its width at D_1 in hundredths of millimeters, instead of the antiquated 1 through 12 nomenclature. In addition, these standardized instruments all were given the same taper because D_1 plus .30 mm was established to be the width at D_2. This development of common taper made the placement of instruments in small or curved canals much easier.

Therefore, the name of each instrument gave considerable information about it. The operator knew how wide the instrument was at its working tip, how wide it was 16 mm up the shaft, and by dividing .30 by 16, it was calculated that each 1 mm of instrument length equaled 0.01875 mm (approximately 0.02 mm) of instrument width. To make this calculation easier and more useful, a slight accommodation was made several years later whereby the width between D_1 and D_2 was widened to .32 mm, or 0.02 mm of width per millimeter of length (see Table 5-1). The standard ISO taper, therefore, was set at .02.

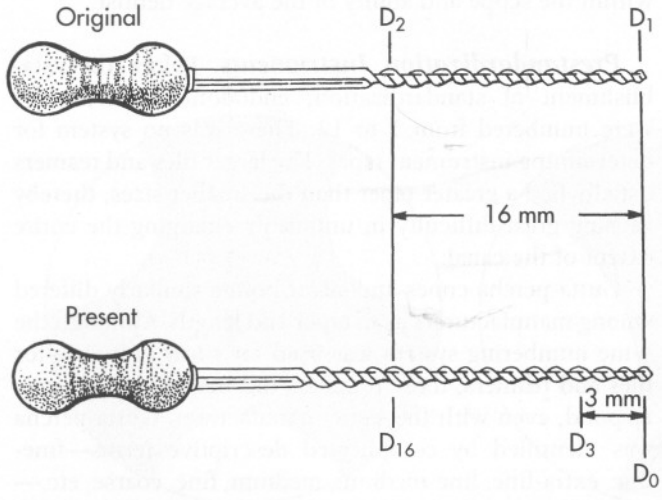


FIGURE 5-7 Original and present (new) standardized instruments. The original standardized instrument (*top*) had the designation of D_1 at the beginning of the flutes and D_2 at the end of the flutes, 16 mm farther up the shaft. Originally the width at these sites was calculated to be D_1 + .30 mm = D_2, making the taper 0.01875 mm of width per millimeter of length, but this was soon altered to D_1 + .32 mm = D_2, or 0.02 mm of width per millimeter of length as the taper. In recent changes, the new standardized instrument (*bottom*) was designed so that D_1 was changed to D_0 and 16 mm up the shaft was changed from D_2 to D_{16}, regardless if the flutes ended there or continued for several more millimeters farther. The standard taper remained as 0.02 mm of width per millimeter of length, but the new formula became D_0 + .32 mm = D_{16}.

After many years of disagreement, several years ago an ISO committee made another change in standardization nomenclature. This change altered the name of the original site D_1 (where the cutting flutes begin) to become D_0, and 16 mm farther up the shaft was changed to D_{16} (Figure 5-7, *bottom*). Several companies had begun to lengthen the cutting edges up the shaft to 18 mm or more, and the original designation of D_2 was not consistent enough (see Figure 5-7, *bottom*). The K-Flex file, for example, has cutting edges 19 mm up the shaft, which I consider to be beneficial.

Table 5-1 lists the widths of the instruments at the start of the cutting edges and at the 16 mm level (D_0 and D_{16}). It also indicates the widths of the non-ISO standard taper of .04, which is used for reverse flaring instruments and will be discussed later in this chapter.

In the prestandardized instruments, it had been thought that there was often too great a difference in instrument width from one size to the next larger size. Therefore canal preparation became tedious and time consuming because frequently it took great effort to reach the correct working length when using the next-sized-wider instrument. To rectify this problem, instrument widths were established so that only the differences of 0.05 mm would separate one size from the next in instruments smaller than size 60, with 0.10 mm between consecutively larger sizes. With experience in canal enlargement, the operator could anticipate the degree of looseness that must be felt with one instrument in the canal before the next-wider size could be placed. Silver points and gutta-percha cones were similarly identified, sized, and shaped to conform more closely to the canals prepared with the standardized instruments.

Quality Control. Materials and instruments manufactured under the specifications of the standardized system are certainly far superior to those previously available. However, it is difficult for companies to exert perfect quality control on their products, and discrepancies often are found. At present an instrument is still considered acceptable if it is within 0.02 mm of the standard. Therefore a size 30 file may be as small as 0.28 mm at D_0 or as wide as 0.32 mm.

Efforts are being made to tighten the degree of accuracy gained by the manufacturers to follow more exactly the originally suggested standardization methods. Until greater quality control is established, however, the operator should be aware of the possible inconsistencies and be

able to anticipate the possibilities of a discrepancy and compensate correctly when one occurs. Customization of a master gutta-percha cone (see Chapter 7) is often useful. Filling materials must be tried into prepared canals and the correctness of apical fit verified by radiograph before final cementation.

RULES FOR CANAL PREPARATION

For the best results in canal preparation, certain basic rules must be followed.

1. *Preparation must enlarge the canal while retaining the general form of the preoperative shape, but it also must develop the most desirable shape to fill.* One of the most common faults occurring during canal preparation is an attempt by the operator to alter the canal's original shape. Overuse of reaming action, failure to precurve instruments, excessive use of chelating agents, and disregarding the path of the initial exploring instruments produce a preparation that does not include the original canal within its boundaries (Figure 5-8).

The significance of retaining original canal shape may seem to be unimportant at first glance. So what if some variance occurs? How serious can that be? The entire problem may be seen in better perspective when one realizes that the original canal shape includes the apical foramen, the sealing of which is a prime objective of endodontic therapy. Because this site is at the tip of the root, a mild

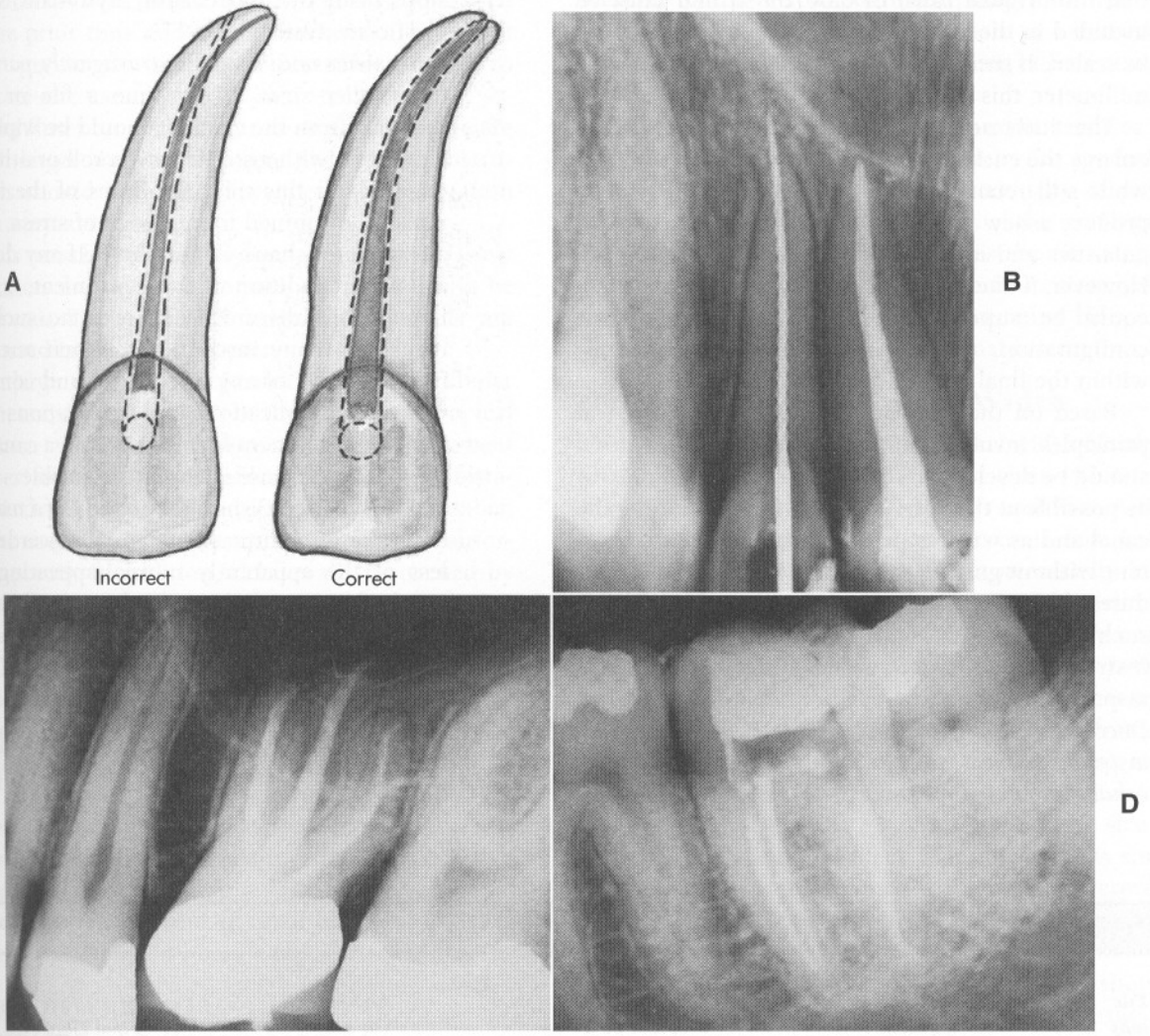


FIGURE 5-8 **Canal preparation must always retain original canal shape but allow for keeping the apex as narrow as possible consistent with cleaning the canal and the orifice as wide as possible consistent with not gutting the crown. A** *(left),* Incorrect preparation *(dotted line)* does not include original canal *(shaded area);* correct preparation *(right)* enlarges original canal in all dimensions while retaining general original canal shape. **B,** Canal in lateral incisor has not been prepared correctly, and a false canal (perforation) was produced. **C** and **D,** There are no straight canals in molar teeth, but rather canals with gradual gentle curves. Final filling radiographs must show that these curves have been enlarged along their entire lengths but that the general original shape has been retained.

variance in the center portions of the root may lead to severe alteration at the tip, particularly if the canal is curved.

You may wonder how much alteration is permissible so the apical foramen remains within the final canal shape. Because of the minuscule dimensions with which we are dealing, there is not much room for error. Small canals may be negotiated initially with a size 10 file, which fits quite tightly at the apex. In other words, the narrowest diameter of the canal at that site is only 0.1 mm, and the total area of the file at that cross-sectional position is merely 0.00785 sq mm (Table 5-2). If the canal is enlarged apically to size 30, which is an average recommended size for such a small canal, the cross-sectional area there is 0.0707 sq mm. This means that the original canal of 0.00785 sq mm must be included in the final 0.0707 sq mm if the apex is to be sealed. If the canal deviates only a few tenths of a millimeter, this may cause serious problems.

The intracanal instruments must be used to enlarge the entire canal length to the apical foramen while still retaining the preoperative shape, not to produce a new or false canal. Obviously canal irregularities and large curvatures must be eliminated. However, if after preparation is completed the tooth could be superimposed over the preoperative configuration, the original canal shape must lie within the final preparation.

Based on these considerations and the physical principles involved, an ideal shape of preparation should be developed. This shape could be **as narrow as possible at the apex consistent with cleaning the canal and as wide as possible at the orifice consistent without gutting the crown.** Many of the procedures that are strongly encouraged in this chapter, such as flaring, reverse flaring with non-ISO tapered instruments, circumferential filing, and use of rasping action, enhance obtaining this desired shape.

2. *Once the working length of a tooth is determined, all instruments must be kept within the confines of the canal.* Overinstrumentation, or the continued passage of an intracanal instrument through the apical foramen, is a frequent cause of intratreatment pain. If the apical constriction is consistently broken during instrumentation, there will be no firm dentin against which to pack or place the canal filling material.

   Therefore, as soon as the canal working length is determined, that measurement is recorded and adhered to during instrumentation. The only possible way to ensure that the canal length is observed during the preparation is to use a measurement indicator or stop. It is impossible to tell by the eye alone the length that the instrument has penetrated beyond the tooth. The use of the measurement control handle has already been described. For those who prefer metal or plastic-handled instruments, stops made of rubber band, Styrofoam, silicone, or plastic are available.

3. *Instruments must be used extravagantly, particularly in the smaller sizes.* Every time a file or reamer is removed from the canal, it should be wiped clean of any debris with a sterile cotton roll or other suitable material. At this time the flutes of the instrument must be examined for any sign of stress, fatigue, or alteration of shape (Figure 5-9). If any doubt exists as to the condition of the instrument, it should be immediately discarded. There is no such thing as using too many instruments. When one considers the small cost of any instrument and compares this with the complications and aggravations that result from an instrument breaking within a canal, the plea for extravagant use is clearly defensible.

   Sizes 8 and 10 should be used for a maximum of only one appointment and then discarded, regardless of the apparently normal-appearing flutes. If canals are very sclerotic and these small instruments are used for long periods, they should be replaced frequently at the same appointment.

   Sizes 15 through 25 should be discarded after two appointments. To indicate when these instruments have been used once, so they may be discarded after the next appointment, a bur nick can be placed on



TABLE 5-2 Correlation Between Files

Initial File That Binds	*Area at D1 (sq mm)*	*Probable MAF*	*Area at D1 (sq mm)*	*Final Flare Size*
10	0.00785	25 or 30	0.0491 or 0.0707	40 or 45
15	0.01766	30	0.0707	45
20	0.0314	35	0.0962	50
25	0.0491	40	0.1256	55
30	0.0707	45	0.1590	60
35	0.0962	50	0.1963	70
40	0.1256	55	0.2375	80

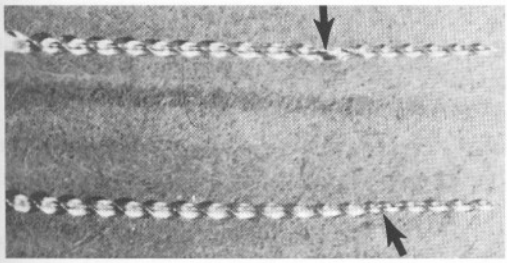


FIGURE 5-9 Flutes with signs of fatigue or stress *(arrows)* must not be used in canal preparation. Instruments must be examined closely every time they are removed from canal for such telltale signs of danger. Should either of these changes be noted, the instrument must be discarded immediately.

the handle. When the tray is next cleaned, any instruments with nicks are known to have been used at one prior time and are thrown away. Those that were previously unmarred are then scored to indicate one use.

The flutes on instruments of size 30 or above are much larger and easier to see. These larger instruments should be replaced whenever any alteration from normal is noted.

4. *Canals must be prepared in a wet environment.* Heavy irrigation during canal preparation must always be observed. The preferred irrigating solutions are discussed later in this chapter.

Enlarging a dry canal, particularly for mandibular teeth, may lead to packing of the area near the apical foramen with dentin chips that would prevent proper sealing. The use of an irrigant floats intracanal debris and dentin filings to the chamber, where they may be removed by aspiration or absorbent points. In addition, canal walls moistened by irrigants are much less likely to bind instruments, thereby reducing fatigue of the flutes and potential breakage.

DETERMINATION OF CORRECT WIDTH FOR CANAL PREPARATION

In addition to determining the correct length for canal preparation, a method for calculating the correct degree of enlargement must be clarified, both at individual appointments and by the time of canal filling.

Minimal Instrumentation at Any Appointment—to Reach Size 25

The minimum degree of canal enlargement that will allow for the use of a broach to remove tissue bulk is that achieved by a size 20 instrument. Therefore this is the minimum degree of enlargement to obtain at the initial appointment for preparing any canal. The smaller-sized instruments begin to increase the canal diameter by removing hard tissue but merely shred vital pulp tissue, causing any remaining tissue to become inflamed. Tissue tags, debris, and other potential irritants are packed toward the apical portion of the canal during the initial phases of instrumentation. If these materials are not removed by broaching and irrigation before the end of the appointment, a chronic inflammation may occur, complicating subsequent procedures.

For these reasons, if it does not appear that enlarging to at least size 20 is obtainable for a canal at any given appointment, it is best not to perform any enlargement on that canal. This means that in the treatment of mandibular molars with vital pulps, the first appointment might allow only for access preparation, pulpotomy, and enlargement of the large canal. The smaller, mesial canals are better untouched at this appointment, with even the taking of a radiograph for calculation of working length being avoided. At the next appointment, sufficient time will be available to enlarge the smaller canals to a minimum of size 20 and then allow for the broaching of the entire canal length.

This plan is possible in asymptomatic teeth or those where the inflammation is confined in the coronal pulp tissue. The medicament, usually some type of phenolic derivative, is placed over the orifices of the smaller canals and fixes the tissue and/or cauterizes the nerve endings. For symptomatic teeth with inflammation already spread to the smaller canals, sufficient time must be spent for proper debridement of the entire canal system.

Determination of Apical Width

The classic test for determining correct width of any canal preparation has been the finding of clean, white dentin shavings on the flutes of the reamers and files. Although this is a seemingly objective and accurate test, I do not believe that it is correct. It does not necessarily indicate that there is a thorough removal of tissue, debris, and affected dentin; furthermore, it does not verify one very important requirement—that the canal is ready to fill.

Many canals are oval or ribbon shaped in cross section. Clean, white dentin shavings are attainable from walls close to each other, but the far walls (poles) may be completely untouched while this sign is obtained.

Bringing every canal to a similar size (e.g., size 40 in posterior teeth and size 80 in anterior teeth) is similarly incorrect because some canals will be vastly overprepared and weakened, whereas others will not be sufficiently cleansed.

The optimal enlargement of each canal should be calculated separately; there is no hard and fast rule that is universally acceptable. However, I have used for many years a calculation based on the initial size of file that binds at the apical portion of the canal. In other words, if a size 10 file is put into a relatively small canal but is loose and does not remove dentin, it does not bind. In the same canal a size 20 or 25 files does work against the canal walls but does not reach the apical portion of the canal. A size 15 does reach the apical portion and does file the walls;

thus it is the initial size of file that binds at the full working length. The first size that binds at the working length is called the *initial apical file* (IAF). I then enlarge such a canal three full sizes larger than this initial file, or to size 30, using a circumferential filing technique. Obviously this calculation must be made for every case and will vary from canal to canal. The enlargement of the canal three full sizes larger than this is very standard, and the file thus used is a very important file to the remainder of the preparation. The file three sizes larger than the first file that binds is called the *master apical file* (MAF).

If the IAF is a size 10, a cross section of the canal near the apex conforming to D_0 of the file will have an area of about 0.00785 sq mm. The correct MAF will be size 25, and the cross-sectional area conforming to D_0 will be approximately 0.04909 sq mm or $6\frac{1}{4}$ times as large. This is a minimum degree of enlargement in even the tightest cases, yet going to this size of three files larger gives an increase near the apex of $6\frac{1}{4}$ times. Further up the canal, the enlargement will be much greater. Table 5-2 lists IAF size, MAF size, and the respective diameters conforming to D_0 on the file.

Gaining Sufficient Enlargement for Using Gutta-Percha—the Flared Preparation

For many years the canal was enlarged at the apex, and no further thought was given to the shape of the rest of the canal. Whatever shape it attained during the apical enlargement was not altered. The first article in the endodontic literature generally is attributed to Coffae and Brilliant (1975), however a segment on flaring was included in the first edition of this textbook (1972). Many additional studies, particularly those by Walton and his group at Medical College of Georgia, and later at the University of Iowa, indicated the great value of the flared preparation, in which the apical portion of the canal is enlarged to a specific degree and then the remainder of the canal is enlarged to even wider sizes to attain an exaggerated funnel shape.

An extremely important study by Leeb, in 1983, although not particularly well received at that time, proved to be an important description of the common problems causing the need for flaring. He stated that in teeth with large restorations (Figure 5-10, *center*)—typical of the type of teeth often needing endodontic therapy—the idea of the shape of the canals being treated was erroneous. Most dentists thought that the canals were widest at the orifice and then gradually tapered down to the apex, where they were the most narrow (Figure 5-10, *right*).

In truth, the canals near the orifice are quite narrow (Figure 5-10, *left*), then widen in the middle of the canal, and finally taper down to the apex. Anyone who has searched through heavily restored teeth to find a canal that could be penetrated only slightly with an endodontic explorer and then only allowing a file to be passed through it after countersinking with a small bur, will testify to the correctness of this view. Because in molar teeth many of these canals curve in one direction in the coronal portion and then to the opposite direction more apically, a triangle of dentin exists that guards the approach to the canal. Unless this triangle is purposely removed, it is not possible to gain a straight-line access to the apex. Leeb concluded that early flaring of such canals would simplify treatment.

Many synonyms are used for flaring, including *stepping* and *back-filing*, but they all mean the same thing—proportionally greater enlargement away from the most apical portion of the canal. The studies investigating the use of considerable flaring versus the formerly taught method with minimal taper indicate that both quality of canal cleansing and the ability to seal the apex are greatly enhanced by flaring. Those are very impressive reasons.

The flared preparation has several physical advantages (Figure 5-11):

1. The smaller, more flexible files are used in the apical portion, and the stiffer files need not be forced but are used short of the apex.
2. More apical dentin is available for the dentin matrix; thus if initial files are slightly too long, some dentin can retain gutta-percha within the canal.
3. Studies have shown that in curved canals, files often bind in the coronal portion and then become ineffective at the apex (Leeb's study being paramount here). With the coronal portion larger, files are more effective at cleaning and may retain original canal shape better.
4. Because the canal is much wider, the intracanal irrigants have more room to gain access to the irritants and necrotic debris. This advantage and advantage 3 are reasons why early flaring works so well.
5. The wider coronal portion allows for easier placement of finger spreaders and gutta-percha cones.
6. The desired shape of a canal preparation is obtained: as narrow as possible at the apex consistent with cleaning the canal and as wide as possible at the orifice consistent with not gutting the crown.

Extremely large canals (i.e., canals that will accommodate a size 40 or larger IAF) initially need minimal flaring after attainment of the MAF. The moderately wide and small canals, however, must receive flaring before using gutta-percha for filling.

Canal Enlargement in Moderately Wide and/or Straight Canals

Typical canals for this type of preparation are the maxillary anteriors, wider one-canaled mandibular cuspids and

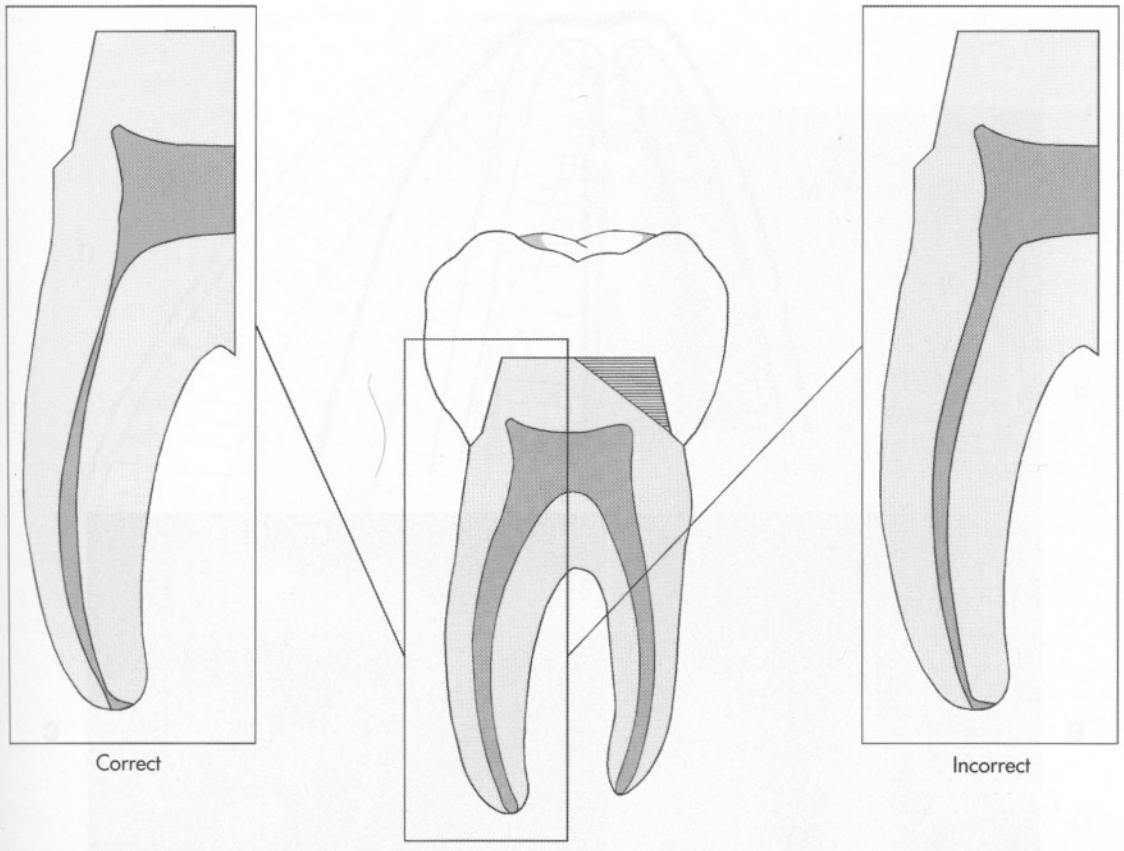


FIGURE 5-10 Schematic representation of Leeb's study. Dentists have an erroneous idea of the shape of canals in heavily restored teeth (*center,* mesial canal enlarged at *right*). It has been assumed that the canal is widest near the orifice and then tapers down to the apex. In truth *(left),* the canal is narrow at the orifice due to the deposition of reparative dentin in response to the restoration. Away from the orifice, the canal widens in midroot and then tapers down to the apex.

bicuspids, one-canaled maxillary bicuspids, and the largest molar canals. Such canals will accommodate a size 25 or larger initial file and an MAF of 40 or larger (see Figure 5-11, *A* to *C*). The traditional method for preparing such teeth will be presented first and then followed by more current thinking using the non-ISO tapered files.

1. Calculate the working length, using the information found in Chapter 6. Make certain that the IAF is quite loose before going to the next larger size or using intermediate sizes.
2. Enlarge the canal to the proper MAF according to Table 5-2. Making the MAF one or two sizes wider than the suggested instrument is acceptable. However, if thorough rasping with circumferential filing is used, this is rarely necessary.
3. Select a file one size larger than the MAF and enlarge the canal 1 mm shorter than the working length.
4. Go back the full working length with the MAF.
5. Select a file two sizes larger than the MAF and enlarge the canal 2 mm shorter than the working length.
6. Repeat step 4.
7. Select a file three sizes larger than the MAF and enlarge the canal 3 mm shorter than the full working length.
8. Repeat step 4.

The technique typically used at present with the non-ISO tapered files is as follows.

1. Calculate the working length, as with 1 (above), and enlarge until the IAF is loose using a rasping action. Retain this file in close proximity on the tray as it will be used periodically during the rest of the preparation.
2. Select a fairly large size .04 non-ISO tapered file (#5, #6, #7), put a stop at the working length minus 2 mm, and file down toward the apex until the file just starts to become tight, but do not go beyond the length indicated by the stop (Figure 5-12, A).
3. Take the IAF and pass it to the working length, using a rasping action.
4. Select the next size larger .04 non-ISO tapered file, put a stop at the same length, and file down the canal toward the apex, but do not go beyond the length indicated by the stop.
5. Repeat step 3.
6. (Optional) Use a larger .04 non-ISO taper in the same manner as in steps 3 and 5. If you wish, you may use a .06 non-ISO taper (Figure 5-13, *A*).
7. Use a file one size larger than the IAF, and continue the preparation up through the MAF.

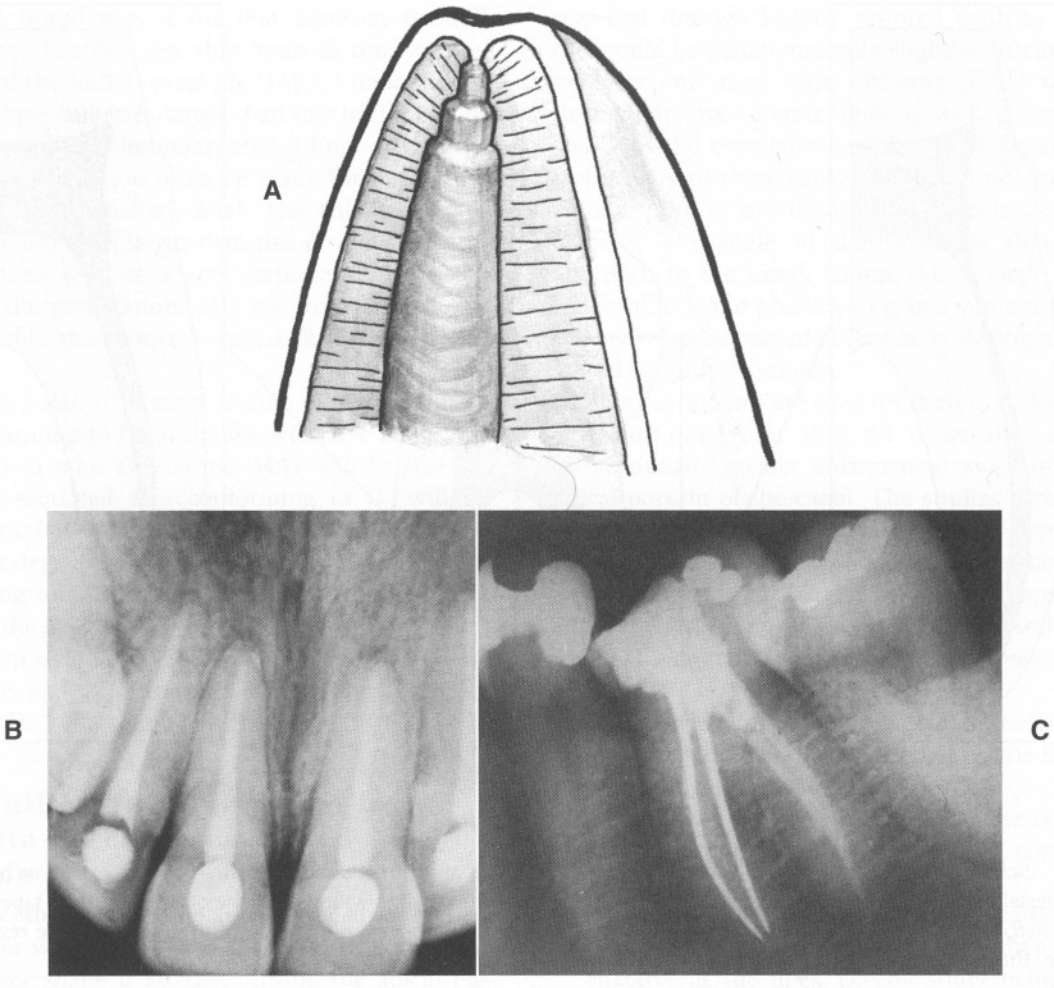


FIGURE 5-11 Flared preparation that enhances keeping the apex as narrow as possible consistent with cleaning the canal and making the orifice as wide as possible without gutting the crown. A, Schematic drawing of flared preparation in a relatively straight canal. Apical area remains relatively small in order to retain the gutta-percha, whereas width increases toward coronal portion of preparation to allow for easier insertion of gutta-percha and finger spreaders. Each step is approximately 1 mm in length, with file widths one size wider than the more apical section. The MAF always is used after any wider file short of the full working length. **B,** Flared preparation in anterior teeth filled with gutta-percha. **C,** Flared preparation was used for distal canal of this mandibular molar, which was filled with gutta-percha. Mesial canals were filled with silver points; therefore no flaring. *Continued*

Rules for using the non-ISO are very important because their action methods for dentin removal are very different than hand files. Because full understanding of their use and differences required added nomenclature, the specific rules for their use are in the segment on Preparation of Severely Curved Canals, later in this chapter.

Canal Enlargement in Smaller, Relatively Straight, Canals

Typical canals for this type of preparation are the mandibular incisors, bicanaled mandibular cuspids, and bicanaled maxillary bicuspids. The smaller molar canals and all narrow or curved canals also are suitable for this type of preparation, but they require a size 10 or 15 as the initial file to bind at the full working length (see Figure 5-11, *D* to *F*). In addition, they may require the use of incremental instrumentation to produce intermediate sizes.

1. Enlarge the canal slowly and carefully with the IAF. Use incremental instrumentation (next section) and clip 1 mm off the tip of the file as described. Use carbamide peroxide (Gly-Oxide) as irrigant up to size 20 and then switch to sodium hypochlorite. Emphasize rasping action.
2. Select an intermediate size .04 tapered file (#3, #4, #5), put a stop at the working length minus 2 mm, and file down toward the apex until the file just starts to become tight, but do not go beyond the length indicated by the stop (see Figure 5-12).
3. Take the IAF and pass it to the working length using a rasping action.

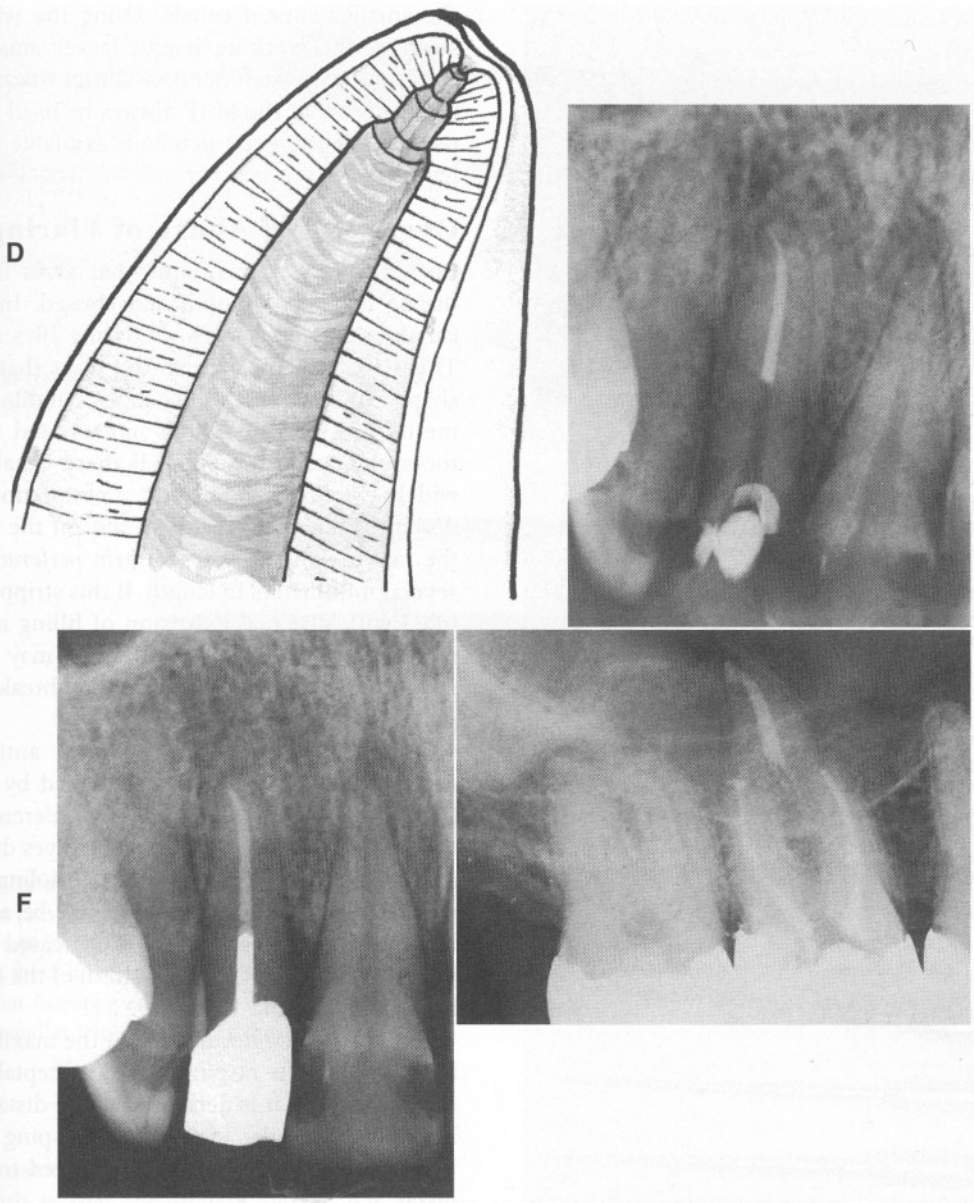


FIGURE 5-11, cont'd **D,** Schematic drawing of flared preparation in a curved canal. Part of preparation is at expense of inner portion of the curve. It is unwise to use more than three or four steps in the flaring because a strip perforation may result. This preparation will allow for placement and condensation of gutta-percha with finger spreaders. **E,** Maxillary lateral incisor enlarged apically to size 35 and flared to size 50, filled with laterally condensed gutta-percha and Wach's paste. (If I were to treat teeth similar to those in *E* and *G* now, I would use early flaring for greater ease of preparation.) **F,** Twelve years after treatment, area has maintained normal condition. **G,** Maxillary first molar with curved canals. Note well-retained original canal shape, filled with laterally condensed gutta-percha and Wach's paste. Palatal was enlarged to size 45 and flared to size 55, mesiobuccal was enlarged to size 30 and flared to size 40, and distobuccal was enlarged to size 30 and flared to size 45. (**F,** Restoration by Dr. Sherwin Strauss, Chicago.)

4. Select the next size larger .04 non-ISO tapered file, put a stop at the same length, and file down toward the apex, but do not go beyond the length indicated by the stop.
5. Repeat step 3.
6. Select the next size larger .04 non-ISO tapered file, put a stop at the same length, and file down toward the apex, but do not go beyond the length indicated by the stop.
7. Repeat step 3.
8. Use one size larger than the IAF and continue the preparation up through the MAF.

Importance of Using MAF as Final Instrument after Using Flaring Files Short of the Working Length

Failing to use the MAF the full working length as the last file in the canal will lead to serious errors, particularly in

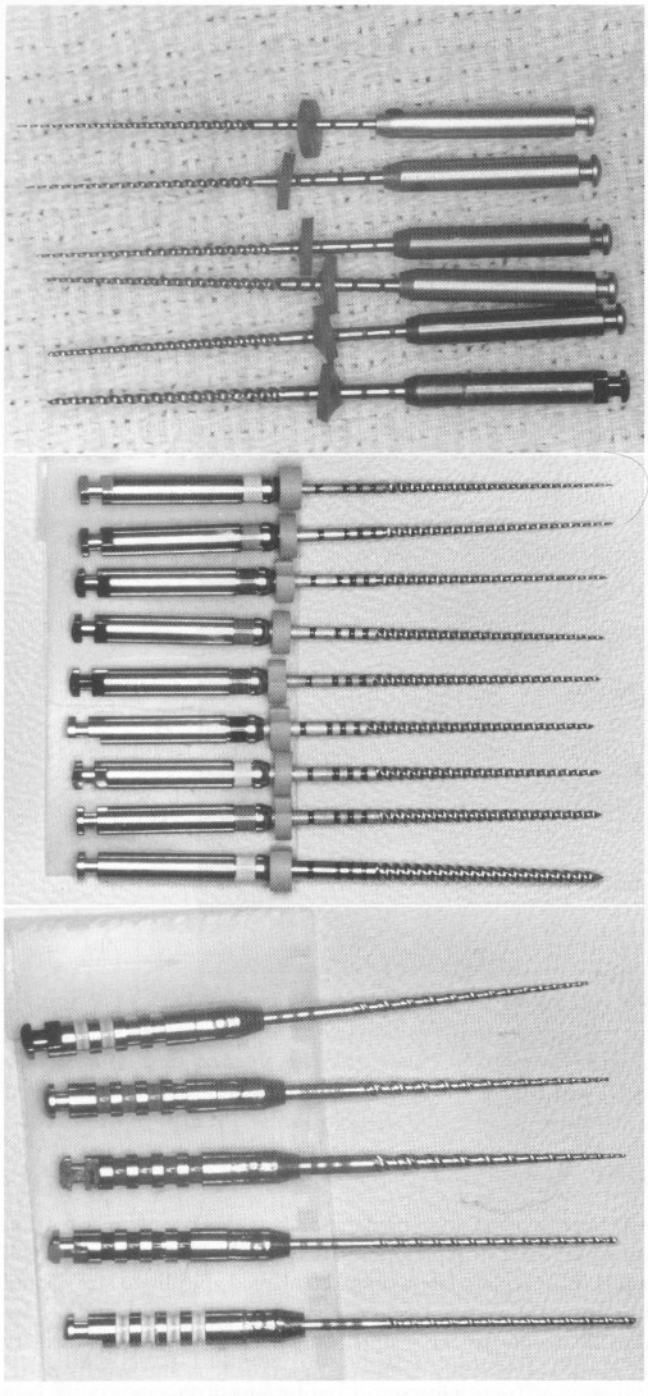


FIGURE 5-12 Typical types of non-ISO tapered instruments. A, .04 tapers with Series 29 designations by Tulsa/Dentsply, *(from top)* #2 (silver handle), #3 (gold handle), #4 (red handle), #5 (blue handle), #6 (green handle), #7 (brown handle). Color coding is a bit different than those used with standardized instruments. **B,** .04 tapers with standardized designations and color coding by Maillefer/Dentsply *(from top)* #15 (white stripe), #20 (yellow stripe), #25 (red stripe), #30 (blue stripe), #35 (green stripe), #40 (black stripe), #45 (white stripe), #60 (blue stripe), #90 (white stripe). **C,** Varying tapers of NT 2000 by NT Endodontics, including instruments with extra-wide coronal taper *(center)* and others that are parallel *(bottom two)*.

the smaller curved canals. Using the wider flaring files short of the working length leaves small ledges in the canal and may pack dentinal filings toward the apex. It is imperative that the MAF always be used last so a smooth passage for the gutta-percha is available the full working length.

Overuse and Abuse of Flaring

Just as with any technique that gives favorable results, flaring may be overused and abused. In smaller curved canals, only three steps or flaring files should be used. This is particularly true in the roots that are figure-eight shaped in cross section, such as mandibular incisors, the mesial root of mandibular molars, and the mesiobuccal roots of maxillary molars. If these canals are flared too widely (Figure 5-14, *A* to *C*), a perforation into the periodontal ligament space will result on the inner portion of the curve. This is called a *strip perforation* and may be several millimeters in length. If this stripped area is solidly filled with minimal extrusion of filling materials (not as in Figure 5-14, *A* to *C*), the area may remain normal. However, in most cases the site breaks down, and a periodontal-type lesion results.

To minimize strip perforations, anticurvature filing should be employed. As investigated by Lim and Stock, this method is substituted for circumferential filing so that the wall toward the depression receives decreased rasping action (Figure 5-14, *D*). In the mesiolingual canal of the mandibular molar, the rasping may be acceptable to the lingual and the mesial, but it is decreased to the distal and buccal because that is the position of the distal depression of the mesial root.

For the mesiobuccal canal of the maxillary and mandibular molars, the rasping may be acceptable to the mesial and buccal, but it is decreased to the distal and lingual. In narrow mandibular incisors, the rasping is acceptable to the buccal and lingual but minimized to the mesial and distal.

Final Test for Completion of Canal Preparation—Placement of the Finger Spreader

When canals are filled with gutta-percha, it is imperative that the apical portion of the filling be condensed and deformed into the seat of the preparation. If the gutta-percha is not deformed at the apex, the canal filling will not achieve its function. Therefore the finger spreaders must be able to reach to within 1 mm of the working length.

To verify that the spreaders can reach that depth of penetration, they must be tried in the canal before the condensation procedure. If they do not reach near the apex before placement of the cones, they surely will have no chance to reach that depth later when cones are in the canal. If they do not reach the desired length, the canal is not ready to receive the filling, and further preparation is necessary.

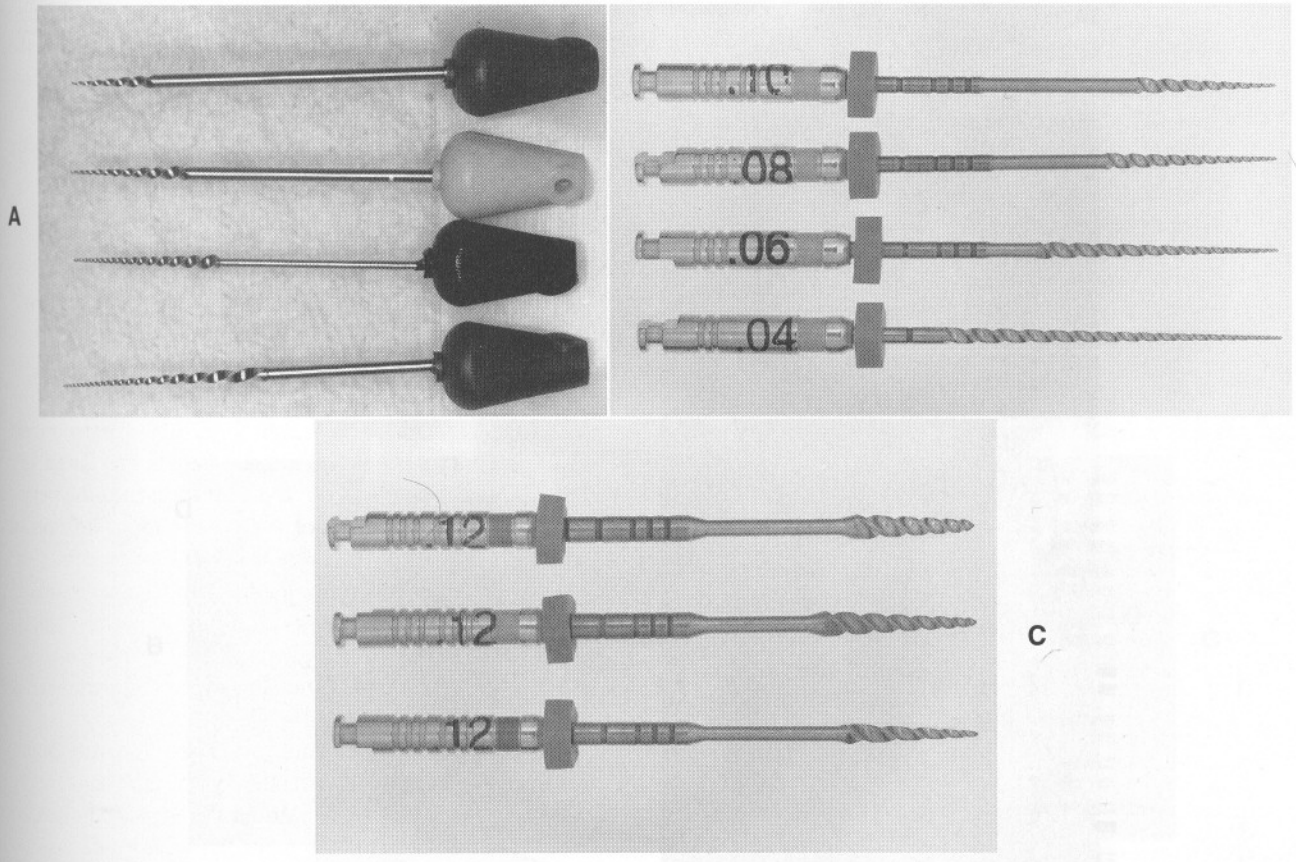


FIGURE 5-13 **Files of greater taper, designed to give increased taper at the orifice area. A,** Second generation of non-ISO tapered files are larger than previously made .04 tapers. Hand files all produced with .20 mm at D_0, with increasing taper but decreasing length of flutes, bottom to top. *(Bottom)* blue handle, .06 taper; black handle, .08 taper; yellow handle, .08 taper; *(top)* .10 taper, red handle. Length of flutes in these instruments is decreased so that widest area of flutes is approximately 1.15 mm. **B,** Third generation were for mechanically driven handpieces and came in 4 sets of sizes, again with decreasing flute length with increased taper. **C,** .12 taper instruments have smaller lengths of flutes due to large taper.

The most consistent reason for spreaders to be short of the desired length is that insufficient flaring has taken place. The exact rationale for this statement appears later in this chapter in the discussion of the elbow. The clinical procedure to follow when the spreader is short is to use more rasping and circumferential filing with the flaring files, not using the MAF more. Always go back to full working length with the MAF after using any larger sizes short of the apex.

AIDS FOR PREPARING DIFFICULT CANALS

At this point, I begin the discussion of preparation for the most difficult types of canals—those with considerable curves. For the clinician who does not desire to treat these types of teeth, preferring anterior teeth and the easier bicuspids, please skip this portion and go on to the discussion on page 215 dealing with the use of ultrasonics.

It would be pleasant if only maxillary central incisors required endodontic therapy. Unfortunately, any tooth in the dental arch may require treatment, and in many cases the canal preparation may become complex. When canals are long, sclerotic, or curved (and any combination of these difficulties may occur and cause even greater problems), only careful and meticulous technique will yield a safe and efficient enlargement.

Problems Encountered in Canal Preparation

The most frequent problems occurring in canal preparation are root perforation, ledging, and instrument breakage (Figure 5-15). Although any of these conditions may happen to even the best operator, it is important to develop the ability to keep such occurrences to an absolute minimum.

These problems usually occur as a result of forcing and driving the instrument, overuse of reaming action, and

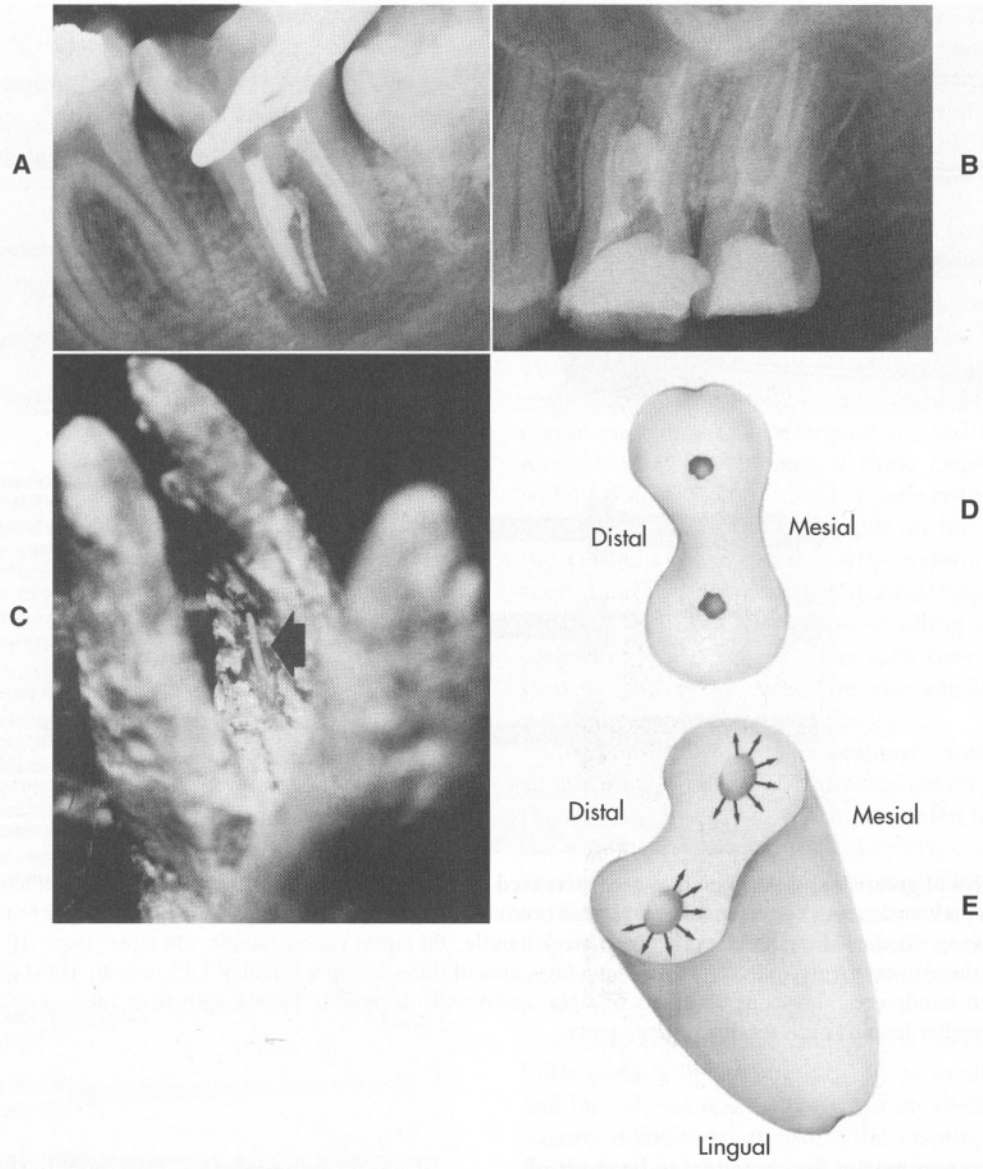


FIGURE 5-14 Problems of strip perforations, often due to overzealous and inappropriate use of flaring. A, Mandibular second molar, mesiobuccal canal was enlarged apically to size 40, but then was flared to size 90—much too widely—and perforation resulted because of the concavity on the distal surface of the mesial root. **B,** Radiograph of maxillary first molar with strip perforation of the mesiobuccal root. **C,** Photograph of an extracted maxillary first molar flared to size 70. A gutta-percha cone was placed into the canal, and the strip perforation is seen on the distal surface of the mesiobuccal root *(arrow)*. **D,** Diagram of mesial root of mandibular molar or mesiobuccal root of maxillary molar when two canals are present. There are depressions (concavities) on both surfaces, but they are much deeper on the distal surface. That fact plus the curve of these roots, first to the mesial and then to the distal, will cause a strip perforation when these canals are enlarged or flared too widely. **E,** To minimize the chances for strip perforations, final flare sizes must be restricted in these roots and circumferential filing (see Figure 5-3) must be modified to avoid the dangerous distal depression. Instead of filing all around the circumference, the anticurvature method is used in these roots. For the mesiobuccal canal, filing to the distal and lingual directions is decreased; for the mesiolingual canal, filing to the distal and buccal directions is decreased.

overreliance on chelating agents. To gain the full length of a sclerotic canal, it is often necessary to turn slightly, wiggle, or otherwise plunge with the initial exploring instrument. However, once the full working length has been obtained and the canal shown to be patent, all other instruments must go easily to place with a straight, inserting action. Because the endodontic enlarging instruments resemble wood screws, it is possible to force them into a canal and then, by using rotating or reaming action, to gain deeper penetration. It is precisely at this point, when the file is pushed against a wall, that a deviation from the original canal shape results, and then the operator creates his or her own shape. When files are forced into the dentin walls and bind, removal may result in breakage.

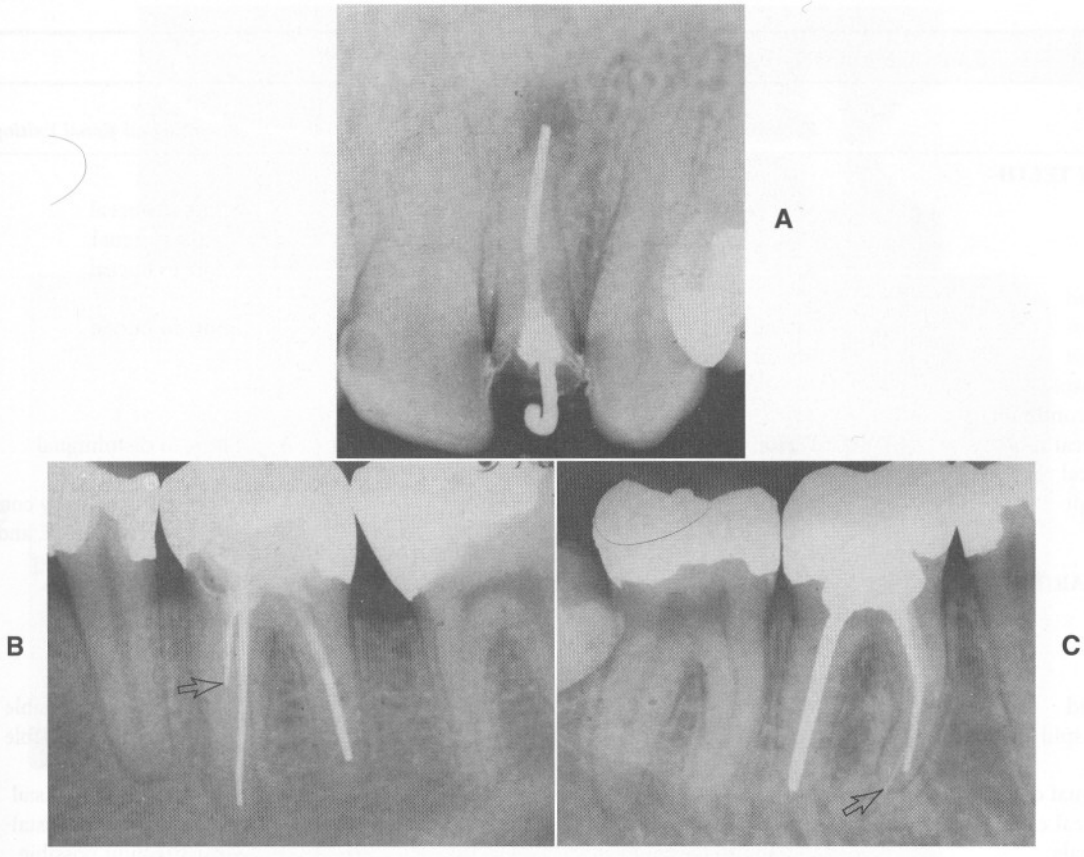


FIGURE 5-15 Typical problems occurring during canal preparation. A, Maxillary lateral incisor treated 6 months earlier, showing root perforation following failure to retain original shape of canal. Although periapical tissue was normal before treatment, a radiolucency is now present, indicating failure. **B,** Radiograph taken 9 months postoperatively, indicating ledging of one mesial canal preventing filling closer than half the distance to apex *(arrow)*. Radiolucency surrounding root, not present preoperatively, indicates probable failure. **C,** Broken file in one mesial canal *(arrow)*; condensing osteitis around root indicates case is in jeopardy. (Although I treated none of these pictured teeth, occurrences of each of these types have been seen in my practice as well, but not since I altered my preparations as described here.)

If chelating agents are heavily used, the canal walls are softened and may be penetrated and altered to even a greater extent by forced files used with reaming action.

Three important techniques may be utilized to prevent root perforation, ledging, and instrument breakage. When files are precurved, original canal shape is more easily maintained, root perforation is lessened, and reaming action must not be used. Incremental instrumentation allows instruments to be placed without forcing, and the correct working length is gained without the need to use forceful reaming action. With the step or flared preparation, the smaller, more flexible files are used to the full working length; however, the larger, more rigid instruments are kept away from the apex and confined to the straighter portions of the canal, where they do not significantly alter original canal shape. The use of the non-ISO tapered instruments greatly aid in this portion of treatment.

Precurving of Files

There are few straight root canals. Frequently the curvature is to the buccal or lingual aspect so that the routine radiographs give the false impression of a relatively straight canal. Palatal roots of maxillary molars often have a buccal curve, whereas maxillary lateral and mandibular incisors may have lingual curves that do not appear on the radiograph because the curve is perpendicular to the film. The typical curvature of roots is seen in Table 5-3.

In addition, as a result of eccentric dentin deposition or debris within the canal, the canal walls may have irregularities, projections, or other obstructions. When straight instruments are placed in such canals, they are stopped by the obstructions. If the file handle is rotated at this point, it will merely drive the tip of the instrument deeper into the impediment and create a ledge.

For these reasons, it is best to enter canals only with files that have been precurved. When this is done, the file will have a better chance to traverse any canal curvatures. Also, if an obstruction is encountered, mild rotation of the handle will allow the tip to slide off and continue toward the apex.

There are two types of precurving. One is placing an extremely sharp curve near the tip of the instrument. This