ENDODONTIC THERAPY

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CHAPTER 5

Intracanal Treatment Procedures, Basic and Advanced Topics

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The major objective of the intracanal treatment procedures is to remove the contents of the canal and adjacent tissues in such a way that the filling procedures that follow will be facilitated. This means not only that the pulp tissue, necrotic debris, microorganisms, and affected dentin must be removed from the treated tooth, but also that the canal walls must be prepared to receive a filling material that will seal the apical foramen.

To describe this aspect of treatment lucidly, Schilder has dubbed these procedures *cleansing and shaping* in emphasis of the need for debridement and development of a specific receptacle for the filling material. I prefer the term *canal preparation* but certainly acknowledge that cleansing and shaping must be performed to reach the desired goal. *Canal enlargement* should not be used; merely widening the diameter of the canal may not produce the correct shape that must be developed, neither does it always remove undesired contents from the canal.

The importance of canal preparation cannot be overemphasized. It is these intracanal procedures that allow for the initiation of healing by removing the irritants to periapical tissue that have been harbored within the canal. When for some reason a longer than routine period of time has elapsed between the start and the completion of therapy, it is not unusual to note radiographic evidence of healing of a periapical lesion on an x-ray film before canal filling (Figure 5-1).

This chapter will discuss the instruments necessary to accomplish the desired objective, the procedures designed to produce results effectively and rapidly, and the adjuncts needed to retain the tooth in a desirable condition until the canals are filled. The treatment of teeth with complex problems will also be described.

The calculation of working length is often included in the discussion of canal preparation, as it was in the first four editions of this book. Because of its importance, this subject now has a chapter of its own, Chapter 6. Working length calculation may be an object of controversy, and I wanted to give sufficient space to each of the several techniques. Popularity of several types of apex locators also has increased recently.

Because aspects of working length are necessarily involved in canal preparation, it is my hope that this subject does not become disorienting to the reader, who notes references to working length while reading Chapter 5, but has not yet read the basis for its calculation. Perhaps this should be viewed as are some aspects of intricate spy novels, where characters and events are referred to but have not yet been introduced fully in the prose.

A

B

FIGURE 5-1 **A,** Preoperative radiograph of maxillary second bicuspid with large periapical radiolucency. Patient was a college student, home only for school vacations. Canal was debrided during Thanksgiving holiday with heavy irrigation of NaOCl, and second appointment was scheduled for Christmas recess. **B,** The tooth received no further treatment until five weeks later, when radiograph was taken for verification of fit for master cone, radiolucency had already healed without canal being filled. Poor fixing and scratches on this film have occurred because it is an intratreatment film developed ultrafast and generally is discarded at the conclusion of the fill appointment. The significance of this radiograph was not realized until later that day.

BASIC INTRACANAL INSTRUMENTS

The basic endodontic instruments used within the root canal are broaches, files (K-type and Hedstrom), and reamers. Although many engine-driven handpieces have been found to be of dubious value, particularly in the more difficult curved canals, recently the introduction of some rotary instruments have been found to be very useful. Because of their specific use for providing enlargement in the more coronal portion of the preparation, these systems will be reviewed a bit later in this chapter.

Broaches

Broaches are available in two types: smooth and barbed. The smooth broach had been used by some practitioners as an initial instrument to explore the patency and the walls of the canal. Most practitioners no longer follow this procedure, preferring to remove tissue bulk before the placement of any instrument near the apex to avoid forcing any inflamed or necrotic tissue through the apex. Therefore smooth broaches now are rarely used.

The barbed broach has been used for many years in endodontics and was originally used in canal preparation. However, because of its ease of breakage, it is confined to removal of soft tissue only. It is a tapered instrument of soft steel that is notched by a shredder to produce sharp barbs extending outward from the shaft (Figure 5-2).

This design is responsible for the frequency of breakage because the notching weakens the shaft by providing a place for fracture if stress or torque is applied. In addition, misuse within the canal may lead to disastrous results. If the operator attempts to force apically a barbed broach within a tightly fitting canal, the barbs will be bent toward the shaft, allowing for deeper insertion. However, when the instrument is withdrawn, the barbs will extend and engage the adjacent dentin. As more force is exerted in removal, the barbs will dig deeper, and further fatigue may result in snapping of the instruments. **Therefore, once the hard surface of the dentin walls is felt, the barbed broach must not be inserted any farther.**

Correct use of the instrument involves its careful insertion through the access cavity until the dentin walls are felt or the approximate length of the canal is reached. The broach is slightly withdrawn, then rotated a few revolutions, and removed. Vital or necrotic pulp tissue and debris become ensnared on the barbs and removed so that much of the bulky content of the canal is debrided before files are placed toward the apical foramen. The barbed broach is similarly used to remove the paper points or cotton pellets of intertreatment dressings, which may defy removal by excavator or explorer.

FIGURE 5-2 Broach has small barbs protruding from shaft notched by a shredder, highly susceptible to breakage when locked in canal.

The smallest-sized broach available has approximately the width of a size 20 instrument. Because broaches should not be used until the canal is wide enough for comfortable accommodation, they are not used initially in narrow buccal canals of maxillary molars and mesial canals of mandibular molars. Once these canals have been enlarged to size 20 or larger, broaches should be used to remove the bulky tissue that has been packed into the apical portion of the preparation.

Methods for Using Reamers and Files

Some confusion exists as to the actions for using enlarging instruments and the instruments themselves. Both reamers and files may be used with either a reaming or a filing motion.

Reaming. Reaming involves placement of the instrument toward the apex until some binding is felt and then turning the handle more than a full revolution. Clockwise turning will remove material from the canal by way of the flutes' revolution, whereas counterclockwise turning will force material apically. The major effectiveness of hard tissue removal by reaming is in the insertion of the instrument by shaving the dentin walls.

Filing. Filing involves placement of the instrument toward the apex until some binding is felt and then removing the instrument by scraping against a side of the dentin wall with little or no revolution of the handle. This dragging against the side of the wall is also referred to as *rasping* action. The major effectiveness of hard tissue removal by filing is in the outstroke or withdrawal of the instrument by dragging the flutes on the dentin walls.

Considerable difference exists between using filing action and pistoning the canal. *Pistoning* involves going up and down forcefully. This push/pull motion tends to pack dentinal filings at the apex and alter canal shape in small, curved canals to create ledges and short fills. Filing involves a passive placement of the instrument to its working length and a heavier drag motion against the canal wall.

Circumferential Filing. Circumferential filing is a method of filing whereby the instrument is moved first toward the buccal (or the labial) side of the canal, then reinserted and removed slightly mesially. This continues around the preparation to the lingual aspect and then to the distal until all the dentin walls have received rasping (Figure 5-3). This technique enhances preparation when a flaring method is used by widening the orifice of the canal considerably, whereas the apical portion is kept relatively small.

Most roots are oval in cross section and are wider buccolingually than mesiodistally (the sole exception being the palatal root of the maxillary molar). If such a root contains only one canal, which many but not all do,

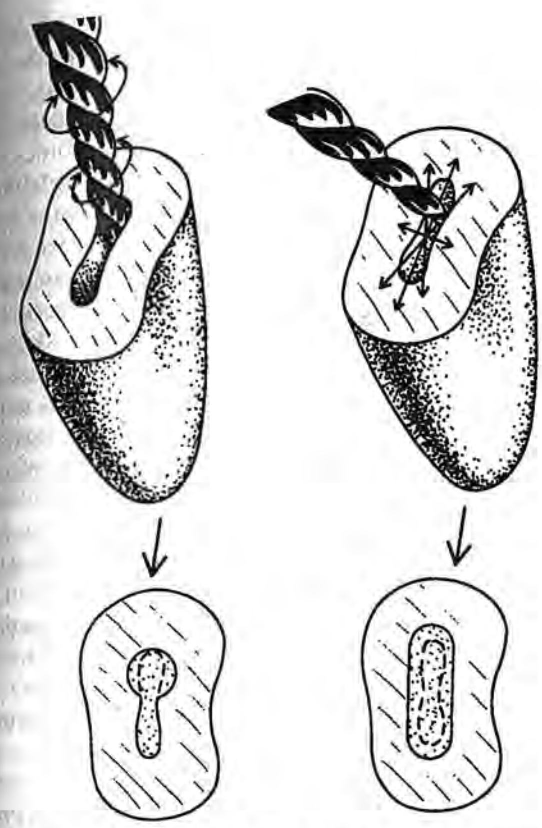


FIGURE 5-3 Many roots are oval in cross section, and yet may have a single oval canal. If the dentist attempts to prepare such a canal with reaming action *(top left)*, the result will be a canal with a keyhole shape *(bottom left)*. This canal is overprepared in one segment *(the upper pole)* and hardly prepared through the remainder of the canal—an undesirable situation. However, circumferential filing *(top right)* involves placement of the file and dragging it out against peripheral walls, emphasizing buccolingual directions. The result *(bottom right)* is a wider oval that is enlarged in all dimensions and may be filled with compressible materials. This method also enhances making the orifice portion as wide as possible without gutting the crown. Circumferential filing is modified in some canals by anticurvature filing (see Figure 5-14, E).

it will be wider buccolingually as well. In these cases the circumferential filing is emphasized in the buccolingual direction. The oval canal is made into a wider and larger oval. This permits easier placement of precurved instruments, gutta-percha cones, and finger spreaders.

Circumferential filing is modified by anticurvature filing (see Figure 5-14, *E*) when flaring the mesial canals of maxillary and mandibular molars and some other curved canals. This alteration will be addressed later in this chapter in response to avoiding strip perforations.

Studies have shown that the action of using the instrument, rather than the instrument used, determines the general shape of the canal preparation. Therefore reaming action produces a canal that is relatively round in shape. The use of filing action develops a preparation that is irregular, usually increasing any eccentricities in the original canal shape.

Reamers

Reamers were the original intracanal instruments, used since the nineteenth century for removal of the contents of the pulp canal and for widening and smoothing the canal walls. They are manufactured by twisting triangular blanks (Figure 5-4, *A*) to produce cutting edges (Figure 5-5, *A*). Because each angle of the blank is approximately 60 degrees, a sharp knifelike edge is available to shave and reduce canal walls. The cross-sectional area of the blank is not excessively wide, so the instrument has a high degree of flexibility.

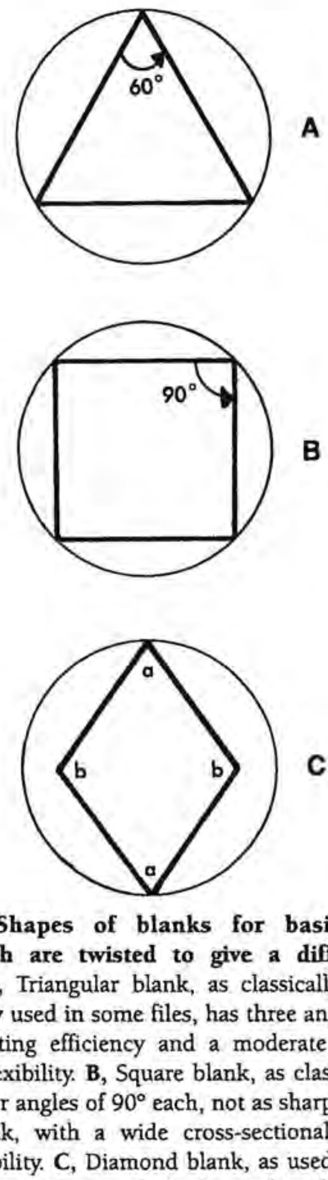


FIGURE 5-4 Shapes of blanks for basic instrument systems, which are twisted to give a different type of instrument. A, Triangular blank, as classically used for the reamer but now used in some files, has three angles of 60° each to provide cutting efficiency and a moderate cross-sectional diameter for flexibility. **B,** Square blank, as classically used for the file, has four angles of 90° each, not as sharp as those of the triangular blank, with a wide cross-sectional diameter that decreases flexibility. **C,** Diamond blank, as used for the K-Flex file, has opposite angles equal. Angle *a* is less than 90°, sharper than those of the square blank, but these are the only two cutting angles. The cross-sectional diameter is narrower than the square blanks of the same size, so this instrument has greater flexibility. Angle *a* plus angle *b* always equals 180°.

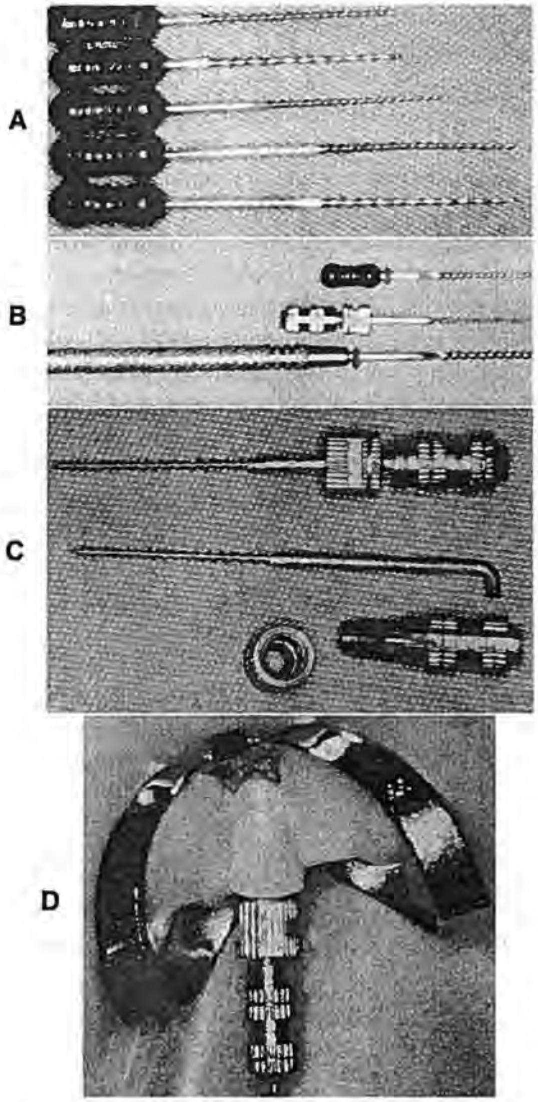


FIGURE 5-5 **A,** Instruments are manufactured in different lengths as well as widths. *From top,* File, 21 mm; reamer, 21 mm; two files, 25 and 31 mm; and reamer, 31 mm. **B,** Different types of handles are available. *From top,* Short plastic handle, measurement control (or test) handle, long metal handle (very rarely used now). **C,** Measurement control handle *(top)* is adjustable to allow for varying canal working lengths. Assembly consists of a file shaft *(middle)* placed in a handle and bolt *(bottom).* **D,** Once correct working length is set, bulky handle prevents overinstrumentation of apex by being physically stopped by incisal edge of tooth.

Reamers are used during canal preparation to shave dentin. When used with a rasping action, they are less efficient than a file. They remove intracanal debris with clockwise reaming action and are used in this manner to remove old gutta-percha canal fillings that have been softened with chloroform or xylene. By turning reamers counterclockwise, the dentist can place materials such as root canal sealer and creamy medicaments in the apical portion of the canal.

Files

Files are useful instruments in endodontics for the removal of hard tissue during canal enlargement.

Whereas the reamer was the original endodontic instrument, the file was developed by changing some of the principles of design in an effort to make a more efficient instrument, one that would remove tooth structure faster. A square blank (see Figure 5-4, *B*) was substituted for the triangular blank and was twisted more to give greater numbers of cutting edges (see Figure 5-5, *B*). Because the Kerr Manufacturing Company was the first to adopt this method, these files were called *K-type* for many years. The square blank had angles of 90 degrees, which did not cut as well as the 60-degree angle of the reamer. However, reamers had a half to one flute per millimeter, whereas files were given one and a half to two and a half flutes per millimeter (see Figure 5-5, *A*) and thus had many more cutting edges. The cross-sectional area of the file (from angle to opposite angle in the blank) was greater than that of the reamer, making it less susceptible to breakage, which was considered a very valuable property in the days of the weaker carbon steel instruments. However, the tighter wind of the file and its greater cross-sectional diameter decreased its flexibility.

The action of the file is to scrape the flutes against the canal walls to gouge a portion of the dentin and pull it from the canal. This action requires periodic cleaning of the instrument by the operator so the dentin shavings do not clog the flutes.

Files are efficient removers of tooth structure in any one of three techniques because of the multiplicity of cutting edges. They may be used with rasping or pure filing action only, in which they are placed in the apical portion of the canal carefully and dragged against one wall of the canal during removal. They may be used with quarter-turn filing, in which the instrument is carefully placed, rotated 90 degrees, and dragged out at the same time. They also may be used with pure reaming action and turned as they enter the canal.

Files alone may be adequately used in canal preparation. Some techniques suggest the use of reamers first and then files of the same size before going to the next greater width. The rationale for such a method is that the reamer used clockwise removes debris remaining within the canal and that, because reamers may be slightly smaller than files, enlargement is facilitated. I have not found this necessary. Heavy and frequent canal irrigation followed by aspiration of excess lavage fluid will satisfactorily remove canal debris and dentin filings. Also, some companies manufacture reamers larger than files, or this difference may occur because of inaccurate quality control of instrument width.

Virtually no innovations in instrument design occurred since Kerr began making files early in the 1900s. Then, suddenly, in a year's time, several startling changes occurred in instrument manufacturing that tremendously widened the choices available. This is an extremely advantageous situation and verifies the important position that endodontics has gained with the general public and the dental community.

Need for Flexible Files. From the start of this century until the 1970s, molar teeth and teeth with sharply curved canals were rarely treated. When they were, a high percentage of failures resulted. In fact, Grossman wrote in his textbooks as late as 1967 that teeth with canal curvatures of 45 degrees and greater could not be treated successfully without surgery. Although this was not known at that time, the reason was that most endodontic files used then were rather inflexible.

As mentioned in the discussion of files, increasing cross-sectional diameter decreases instrument flexibility. Because the triangular blank, used for the reamer (see Figure 5-4, *A*), has a narrower cross-sectional diameter than the square blank, used for the file (see Figure 5-4, *B*), the reamer has greater flexibility than the file in similar sizes. However, files became the dominant instrument for canal preparation, and as such, a total decrease in flexibility of intracanal instruments resulted. Smaller files, such as sizes 10, 15, and 20, have narrow diameters (Table 5-1) and thus have sufficient flexibility to retain canal shape. However, in larger sizes, such as 30, 35, and 40, the files lose their flexibility very quickly, and alterations of canal shape may be devastating (see Figure 5-23).

TABLE 5-1 Diameters of Standardized (.02 taper) and .04 Taper Instruments

	Diameter (mm) at		
Instrument no.	D_0 *(original* D_1*)*	D_{16} *(original* D_2*)*	*.04* D_{16}
08	0.08	0.40	NA
10	0.10	0.42	0.74
15	0.15	0.47	0.79
20	0.20	0.52	0.84
25	0.25	0.57	0.89
30	0.30	0.62	0.94
35	0.35	0.67	0.99
40	0.40	0.72	1.04
45	0.45	0.77	1.09
50	0.50	0.82	1.14
55	0.55	0.87	1.19
60	0.60	0.92	1.24
70	0.70	1.02	1.34
80	0.80	1.12	1.44
90	0.90	1.22	1.54
100	1.00	1.32	1.64
110	1.10	1.42	NA
120	1.20	1.52	NA
130	1.30	1.62	NA
140	1.40	1.72	NA

NA: Not available.

To maintain shape in these curved systems, operators decided to keep canal preparation minimal, which may not have allowed for sufficient cleaning. Also, it was difficult to use a good condensation system to fill these minimally enlarged canals, so failures from inadequate filling were common. The result was that as an increased demand for treatment of these more complicated teeth occurred, it was necessary to develop new file systems.

In its first design change in more than 60 years, the Kerr Manufacturing Company modified its basic blank to develop the K-Flex file (see Figure 5-4, *C*). Rather than using a square or triangular blank, a diamond-shape blank was employed (see Figure 5-4, *C*) to decrease the cross-sectional diameter (the distance between the two *b*s in Figure 5-4, *C*) and impart greater flexibility to the instrument. Because of this shape, only two angles of the K-Flex would cut into the dentin (angles *a* in Figure 5-4, *C*). However, because these working angles were approximately 80 degrees, sharper than the 90-degree angles of the file, their cutting ability was compensated somewhat, even though only two angles were present. Once the blank was twisted, there was an increased space between the working edges so more debris could be removed per outstroke.

The implication of instrument flexibility and other designs for flexible file systems will be discussed later in this chapter, dealing with preparation of curved canals. Because of the improvement in final canal shape provided by flexible files, many other manufacturers developed their own file systems with these properties.

Hedstrom Files. Hedstrom files have flutes that resemble successively smaller triangles set one on another (Figure 5-6). They are manufactured by means of a sharp, rotating cutter that gouges triangular segments out of a round blank shaft in the same manner that wood screws are made. This produces a sharp edge that will cut on the removing stroke only. This process differs from that used for the standard reamers and files, which are made by twisting blades of triangular, square, or other shaped blanks. Several new designs have also been made by gouging, including the U-file and the Triocut.

The Hedstrom file, also called the *H-file,* has two serious drawbacks. It is weakened at each position of gouging during manufacture, resulting in a place for fracture if the flutes bind in dentin and the handle is rotated. Also, if it is handled incorrectly and rotated clockwise after binding in dentin, its screwlike configuration may further drive the instrument apically and crack the weakened and stressed root.

However, the Hedstrom file is an extremely effective cutting instrument because of the sharpness of the flutes. If used carefully, with filing action only, it will successfully plane the dentin walls much faster than the K-type of files or reamers. The Hedstrom files are especially indicated in the instrumentation of immature teeth, where the walls

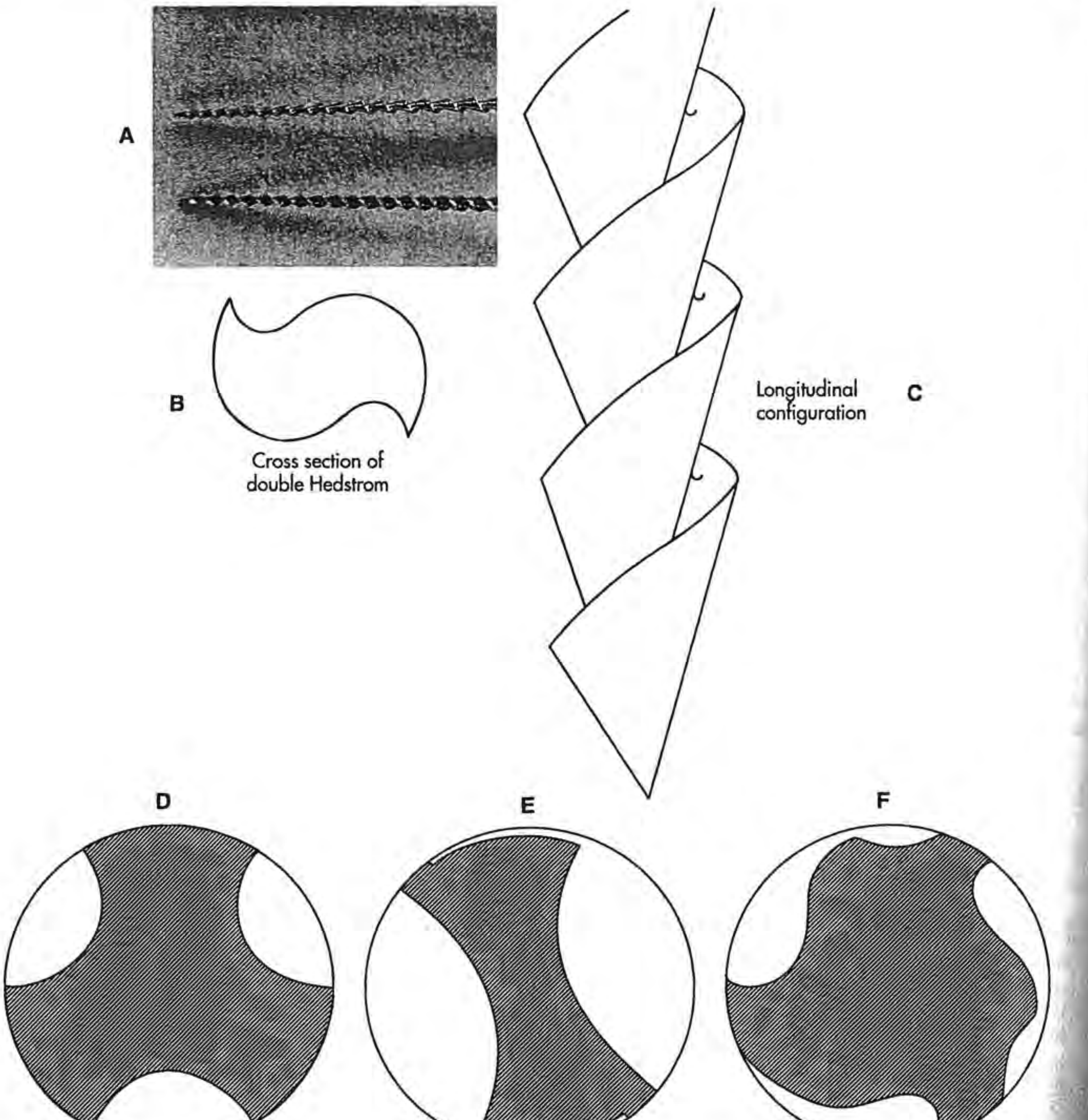


FIGURE 5-6 Types of file systems that are ground, not made from twisted blanks. A, *Top,* Hedstrom file (also called the *H-file*), and, *bottom,* double Hedstrom design, originally called "Burns Uni-File," now called *S-File* because of cross-sectional shape. **B,** indicating two rake angles for increased cutting ability. Wide cross-sectional diameter results in decreased flexibility for the S-File compared with the Hedstrom. **C,** Longitudinal configuration of the S-File demonstrates the design that allows it to cut deeply on the outstroke, minimizing packing of dentin into the apical portion of the preparation. **D,** Cross section of file referred to as *U-file,* because of the three U-shaped cuts ground from a circular blank. This shape is used in the .04 tapered instruments manufactured by Dentsply/Tulsa Dental (see Figure 5-12, *A*) and Dentsply/Maillefer (see Figure 5-12, *B*). **E,** Cross section of file type used in some of the Quantec series now manufactured by Sybron/Kerr. **F,** Cross section of K-3 file, also manufactured by Sybron/Kerr. This is a departure from most other ground blanks in that the segments of the instrument are asymmetrical. Because of the relatively large cross-sectional diameter, this instrument probably is more resistant to fracture but is much less flexible than the other instruments shown.

are irregular and may harbor considerable debris. These instruments are also useful in removing silver points or loose broken instruments from canals. The file is placed alongside the material to be removed, then rotated, and pulled toward the occlusal (or incisal) surface. If successful, the file flutes will hook into the point or broken instrument, break any retention within the canal, and deliver it. When the file is used to remove silver points, canal irrigation with chloroform to dissolve the root canal sealer should precede an attempt at dislodgement.

The Hedstrom and the other gouged instruments are strong, aggressive cutters. As such, they are potentially hazardous in the medium sizes of the apical portion of curved canals. For the same reason, however, they are excellent in widening straight canals or the straight, more coronal portion of curved canals. These files are well suited for performing preflaring or early flaring procedures, widening the orifices of any canals for easier placement of smaller instruments.

Additional Gouged Instruments Recently Developed. Because of the sharpness and the speed afforded by the Hedstrom file, other gouged blank instruments have been introduced in the past 10 years. The U-file is a radial-landed instrument with three grooves in a "U" shape, cut out of the blank. The edge where the groove is cut and the circumference of the file is quite sharp and cuts dentin in either direction when the file is rotated (see Figure 5-6, *D*). This shape is used in the .04 and greater tapered instruments manufactured by Dentsply/Tulsa Dental and Denstply/Maillefer (see Table 5-4) and will be discussed later in this chapter.

The Quantec file system was also created by gouging blanks, but for some of these instruments only two wider grooves were cut and raised edges produce sharp cutting areas (see Figure 5-6, *E*). A very recent entry into this field has been the K-3 file system that has three radial-landed cutting areas, each of a different, or asymmetrical, shape (see Figure 5-6, *F*). This instrument has a wider cross sectional diameter than any of the other ground instruments, so it probably is more resistant to fracture. However, this same increase in diameter means that it also is less flexible. Although the asymmetrical shape makes for an interesting design, it is difficult to see its value when used in a rotating handpiece that delivers the flutes equally around the periphery of its cutting with each complete turn.

Styles of Instruments

Files and reamers come in different lengths and widths and with various types of handles (see Figure 5-5). The shorter instruments are excellent for use in posterior teeth, but extremely long teeth, particularly maxillary cuspids, require those with the longest shaft.

The measurement control handle (or test handle) may appear to be bulky and uncomfortable to use but is extremely useful for the dentist who confines endodontic efforts to single-rooted teeth. The length of instrument is governed by the handle, which physically stops the tip from penetrating too far past the cusp or incisal edge (see Figure 5-5, *C* and *D*). Once the working length of the tooth is correctly established, the files may be set and instrumentation carried out without fear of unintentional overinstrumentation due to misreading of the stop.

For many years it was common practice for any dentist, even a specialist, to use one type of endodontic file system. Whatever type or condition of canal was encountered, that one system had to do the job. Recent studies have indicated that if a large variety of teeth are to be treated, several types of file systems will be necessary, perhaps even including both hand and mechanical instruments. The more flexible files are best used in curved canals but take too long for work in wider, straight canals. Aggressive files or mechanical instruments are well suited for flaring but are dangerous at the tips of curved canals.

Standardization

One of the most significant advances in endodontics has been the installation of a standardized system for intracanal instruments. As originally suggested by Ingle, this logical but long-overlooked development has been one of the greatest aids in bringing endodontic procedures within the scope and ability of the average dentist.

Prestandardization Instruments. Before the establishment of standardization, endodontic instruments were numbered from 1 to 12. There was no system for determining instrument taper. The larger files and reamers usually had a greater taper than the smaller sizes, thereby causing great difficulty in uniformly enlarging the entire extent of the canal.

Gutta-percha cones and silver points similarly differed among manufacturers as to taper and length. Although the same numbering system was used for silver points as for files and reamers, these numbers did not necessarily correspond, even with the same manufacturer. Gutta-percha was identified by complicated descriptive terms—fine-fine, extra-fine, fine-medium, medium, fine, coarse, etc.—that in no way really defined anything about the dimensions of the material.

Landmarks of Standardized Instruments, Original and Revised. In 1957, Ingle established a logical nomenclature for a standardized instrument so that all manufacturers could conform in length, width, and taper to a specific standard. In the instruments of sizes 1 through 12, the numbers themselves meant very little. A size 3 meant that this instrument was larger than a size 2 and smaller than a size 4. The same number did not apply to different manufacturers, and in different years a specific manufacturer could alter any instrument size. Although 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.

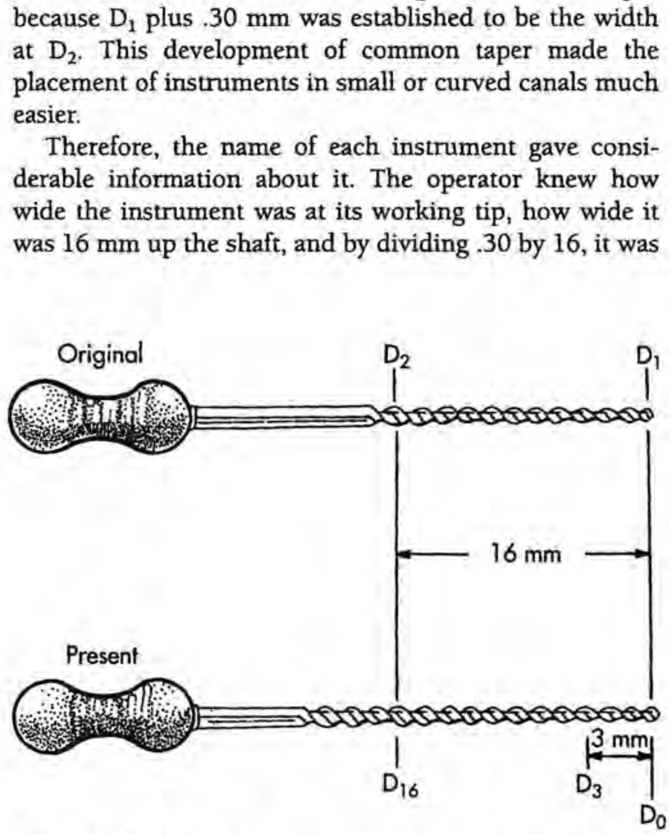


FIGURE 5-7 Original and present (new) standardized instruments. The original standardized instrument *(top)* had the designation of D_1 at the beginning of the flutes and D_2 at the end of the flutes, 16 mm farther up the shaft. Originally the width at these sites was calculated to be $D_1 + .30\ mm = D_2$, 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

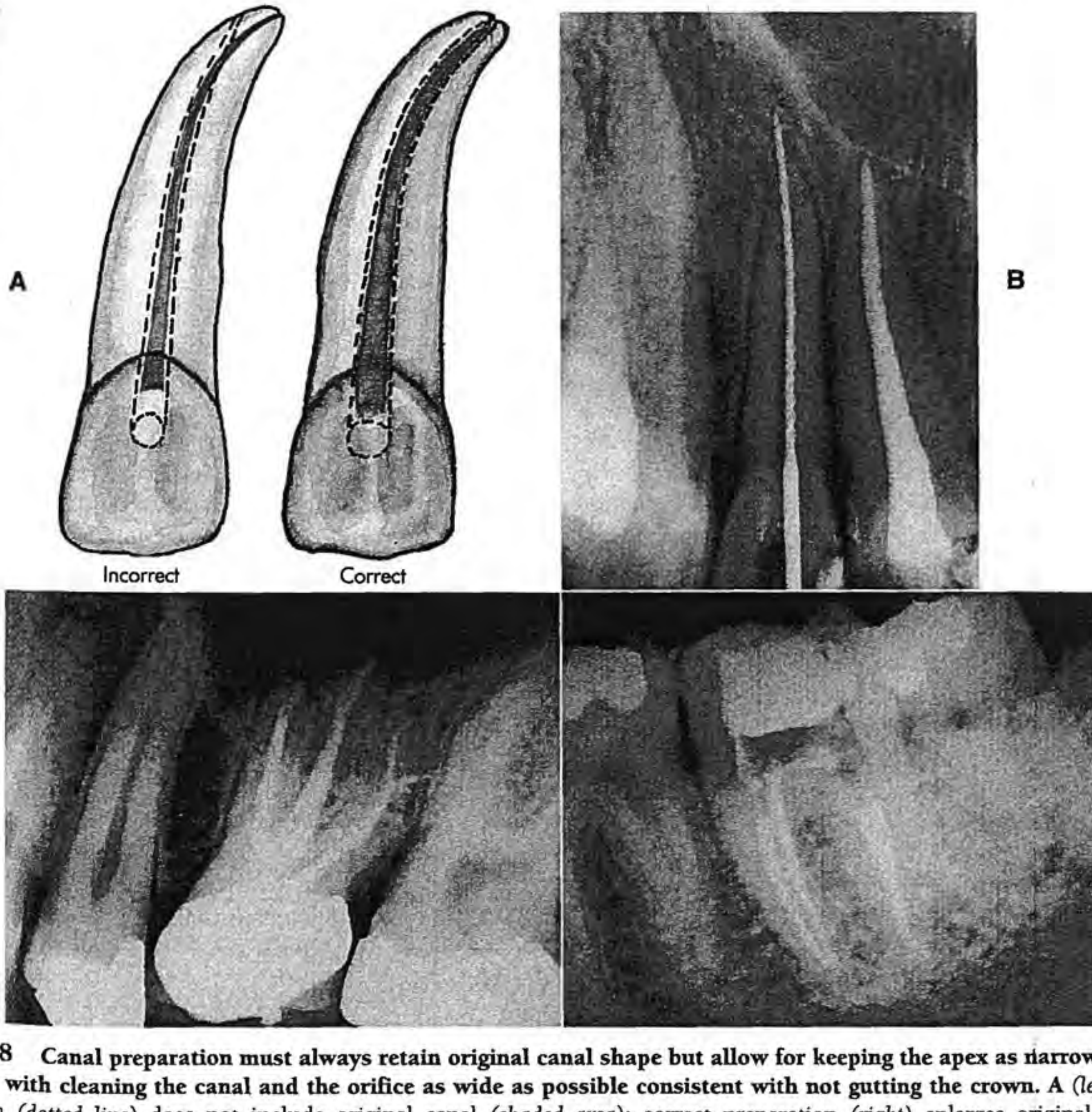


FIGURE 5-8 Canal preparation must always retain original canal shape but allow for keeping the apex as narrow as possible consistent with cleaning the canal and the orifice as wide as possible consistent with not gutting the crown. A *(left),* Incorrect preparation *(dotted line)* does not include original 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

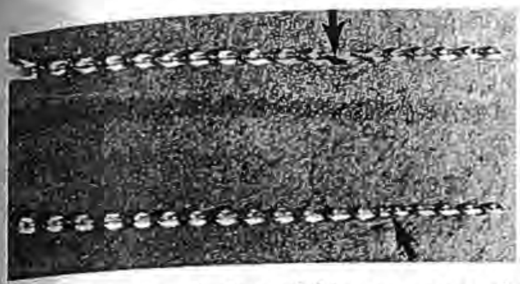


FIGURE 5-9 Flutes with signs of fatigue or stress *(arrows)* must not be used in canal preparation. Instruments must be examined closely every time they are removed from canal for such telltale signs of danger. Should either of these changes be noted, the instrument must be discarded immediately.

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

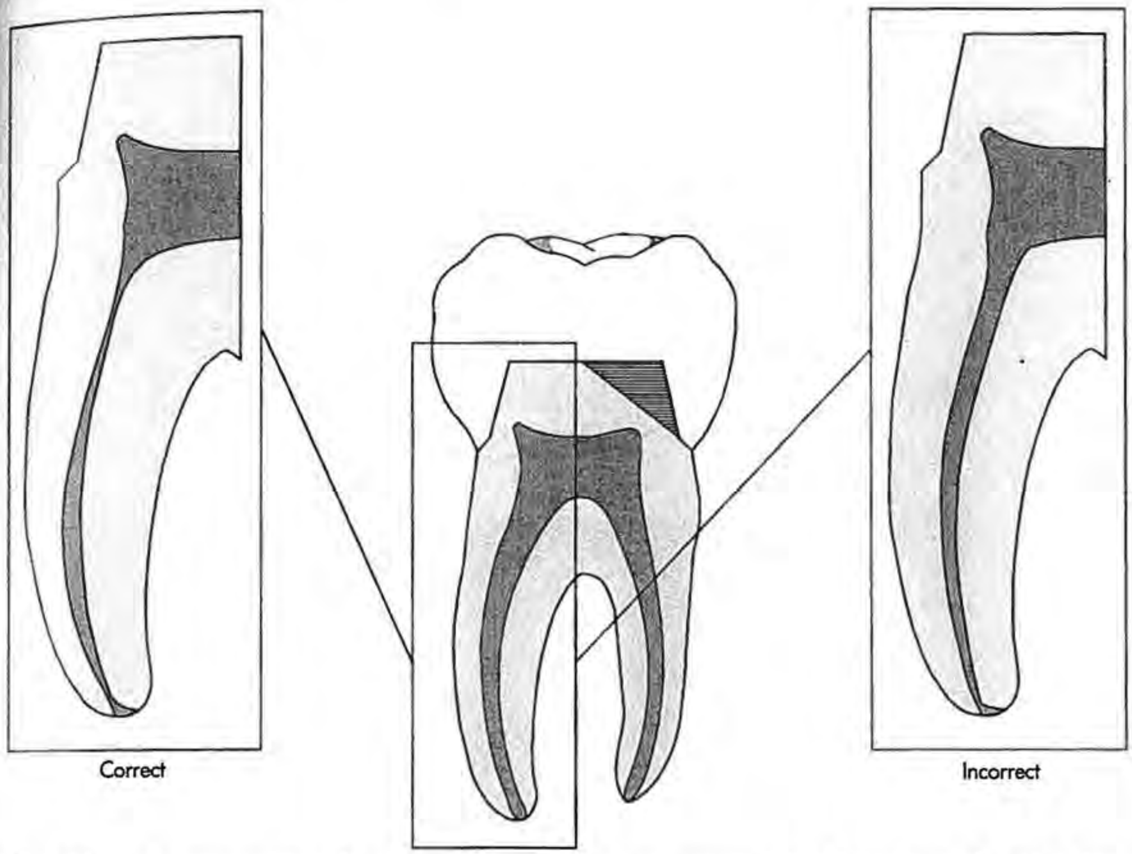


FIGURE 5-10 Schematic representation of Leeb's study. Dentists have an erroneous idea of the shape of canals in heavily restored teeth (*center*, mesial canal enlarged at *right*). It has been assumed that the canal is widest near the orifice and then tapers down to the apex. In truth (*left*), the canal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

A

B

C

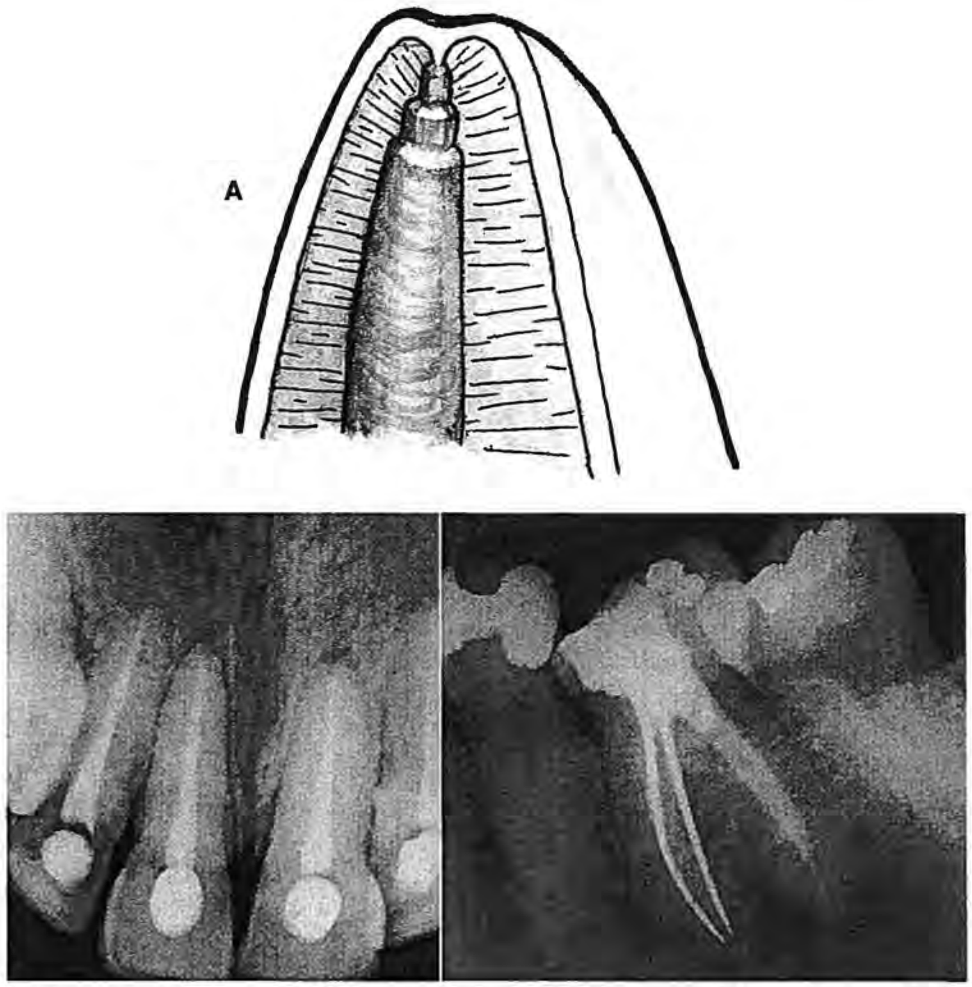


FIGURE 5-11 Flared preparation that enhances keeping the apex as narrow as possible consistent with cleaning the canal and making the orifice as wide as possible without gutting the crown. **A,** Schematic drawing of flared preparation in a relatively straight canal. Apical area remains relatively small 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 rasping action.

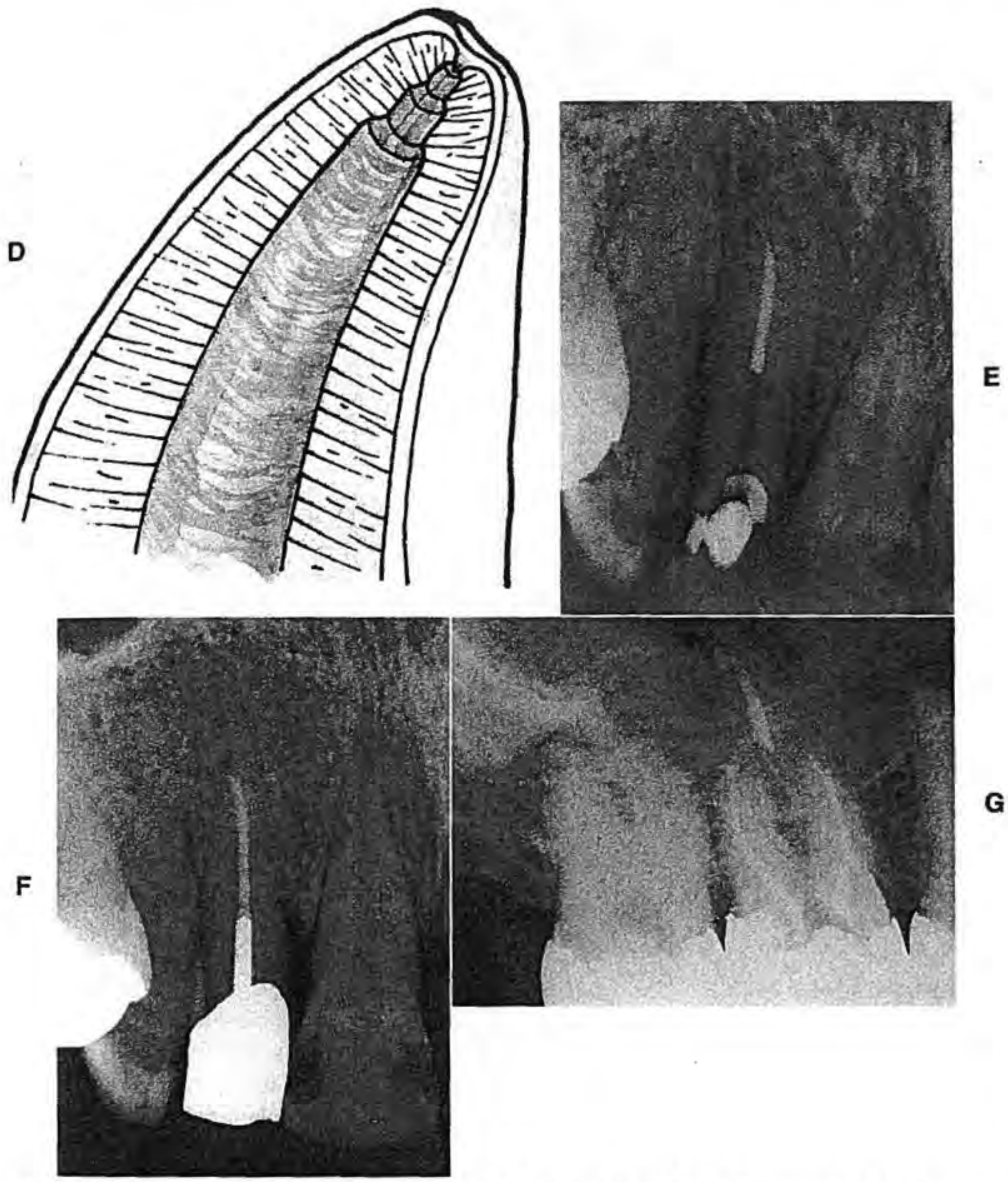
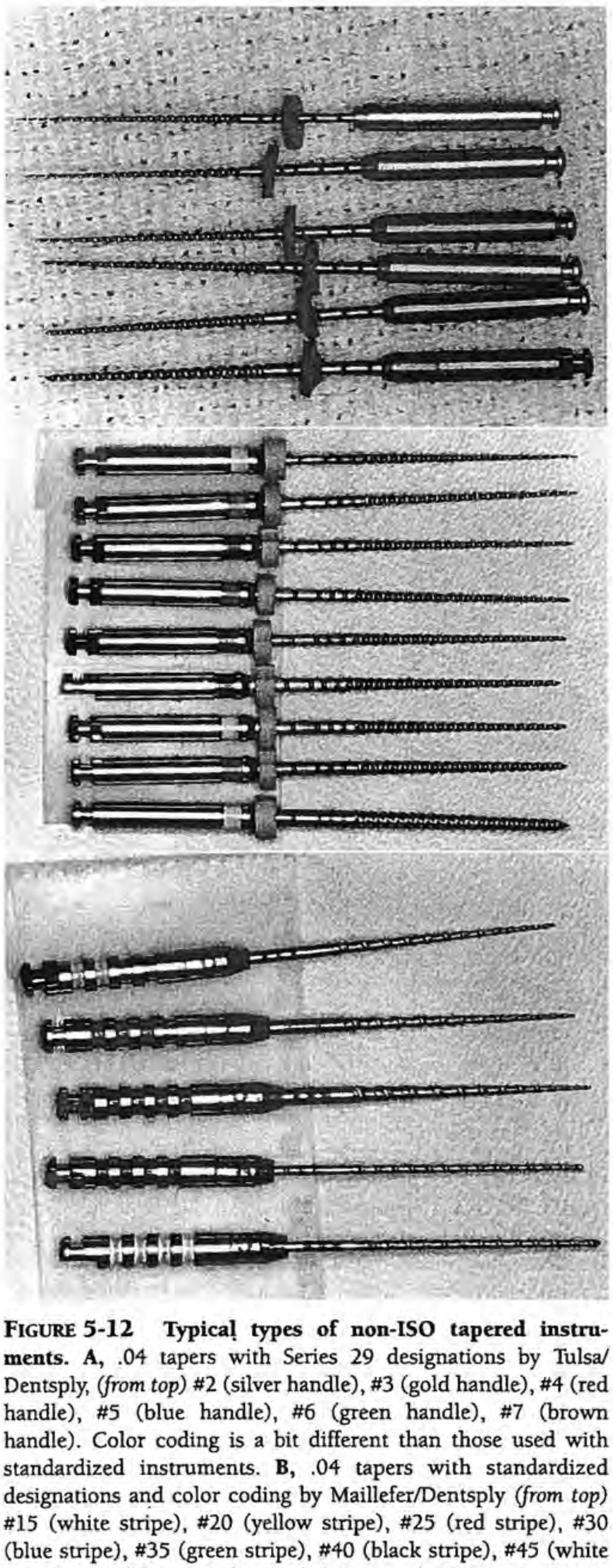


FIGURE 5-11, cont'd **D,** Schematic drawing of flared preparation in a curved canal. Part of preparation is at expense of inner portion of the curve. It is unwise to use more than three or four steps in the flaring because a strip perforation may result. This preparation will allow for placement and 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



A

B

C

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.

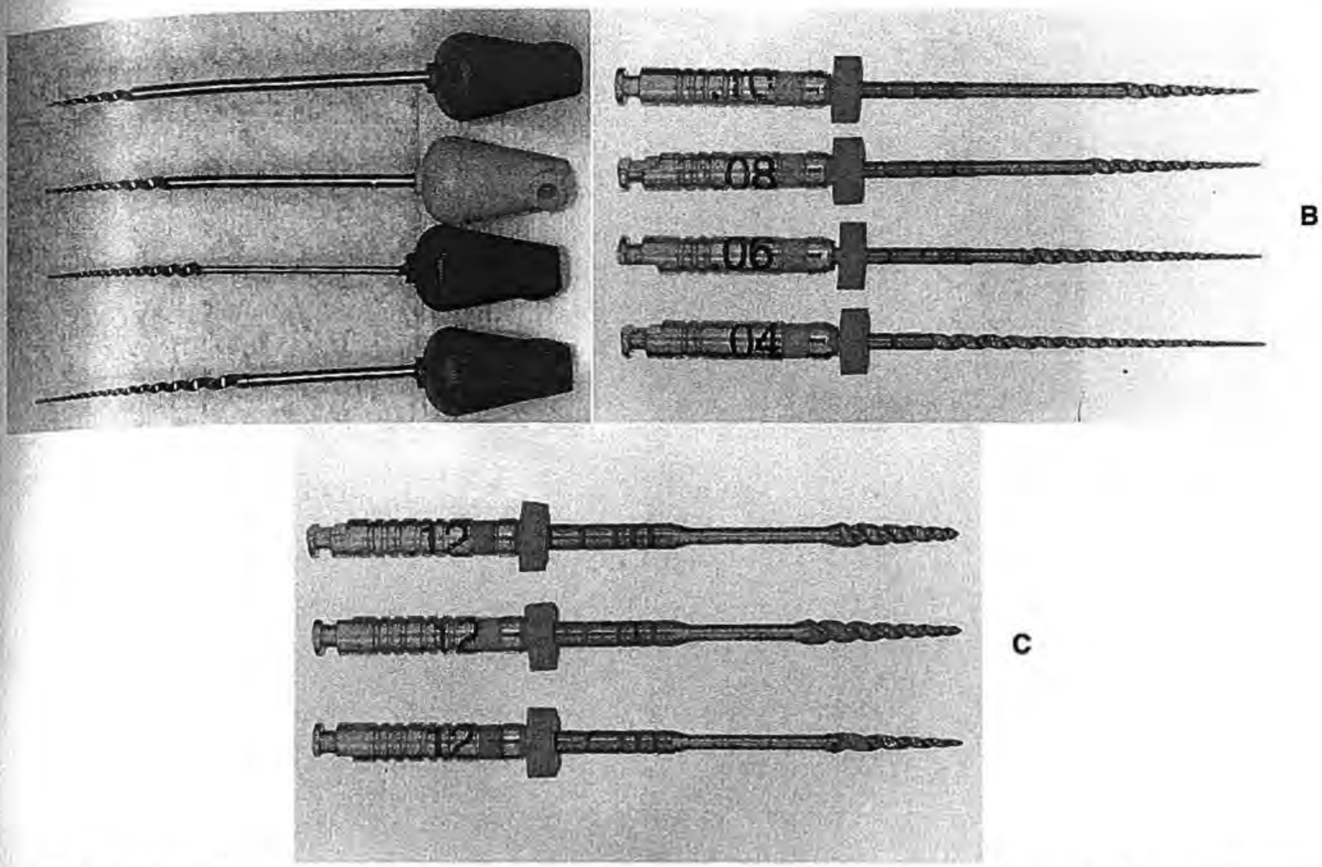


FIGURE 5-13 Files of greater taper, designed to give increased taper at the orifice area. A, Second generation of non-ISO tapered files are larger than previously made .04 tapers. Hand files all produced with .20 mm at D_0, with increasing taper but decreasing length of flutes, bottom to top. *(Bottom)* 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

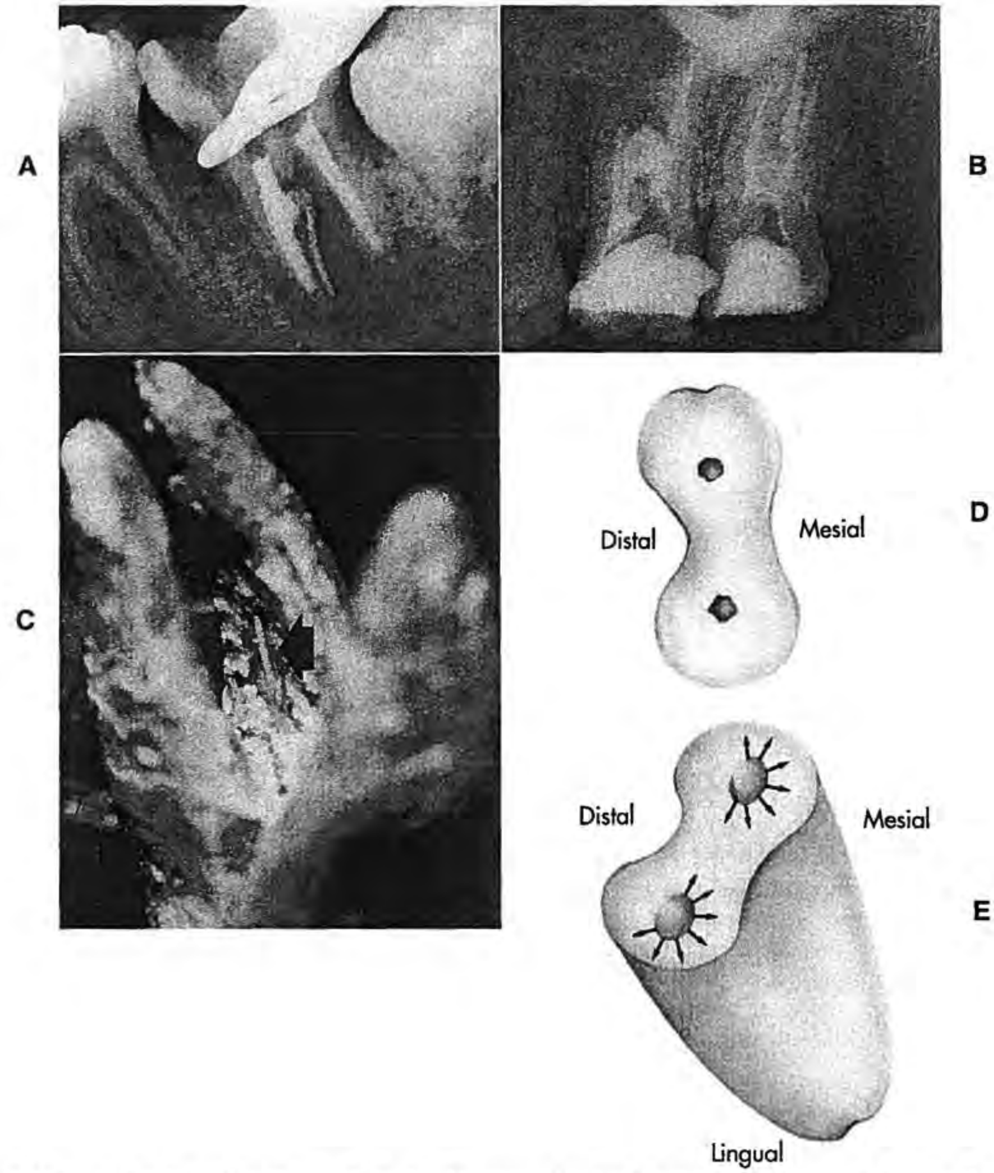


FIGURE 5-14 Problems of strip perforations, often due to overzealous and inappropriate use of flaring. A, Mandibular second molar, mesiobuccal canal was enlarged apically to size 40, but then was flared to size 90—much too widely—and perforation resulted because of the concavity on the distal surface 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.

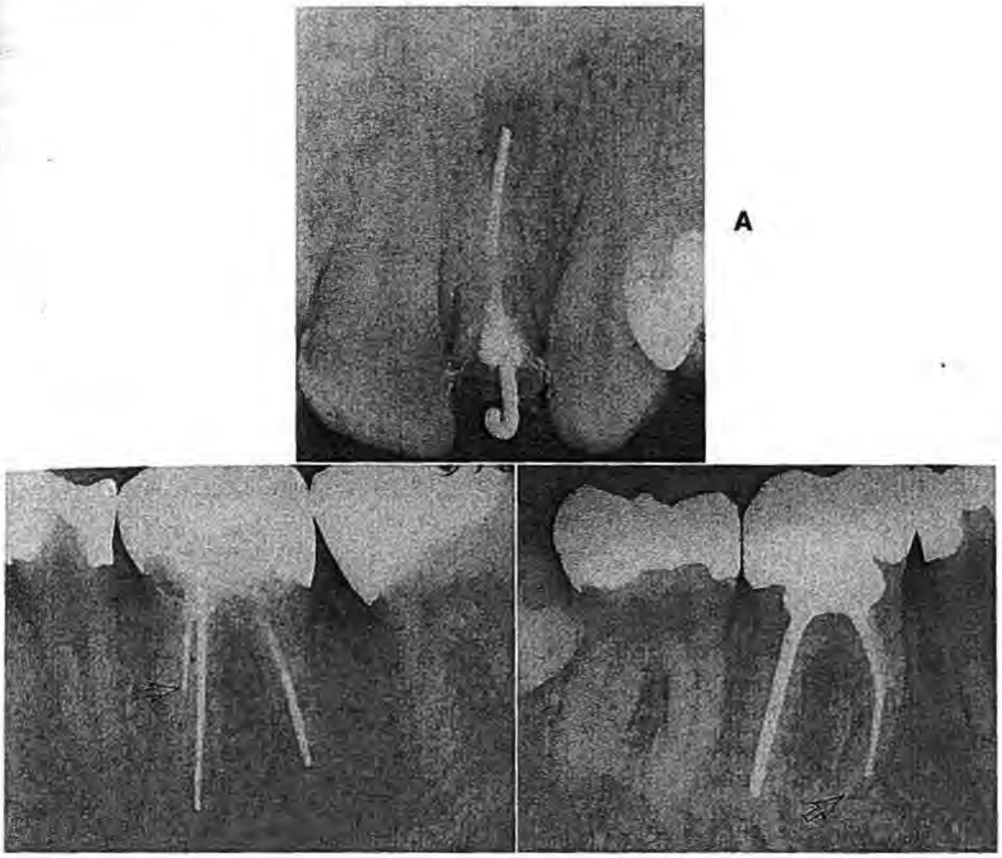


FIGURE 5-15 Typical problems occurring during canal preparation. A, Maxillary lateral incisor treated 6 months earlier, showing root perforation following failure to retain original shape of canal. Although periapical tissue was normal before treatment, a radiolucency is now present, indicating failure. **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

TABLE 5-3 Canal Characteristics Not Seen on Routine Radiographs

Tooth	*Buccolingual Root Curvatures*	*Buccolingual Canal Exiting*
MAXILLARY TEETH		
Central	Very rare	Short to buccal
Lateral	Distolingual common	To distolingual
Cuspid	Rare	Short to buccal
First bicuspid		
Buccal root	Buccal possible	Short to buccal
Palatal root	Buccal or palatal possible	—
Second bicuspid	—	—
First and second molars		
Mesiobuccal root	Distolingual common	Short to distolingual
Distobuccal root	—	—
Palatal root	Buccal very frequent	Short to buccal very common (see Figure 6-2, *E* and *F*)
MANDIBULAR TEETH		
Central	Distolingual possible	Many possibilities
Lateral	More frequently than central to distolingual	Same as central
Cuspid	Distolingual possible	Same as central
First bicuspid		Short to buccal possible
Second bicuspid		Short to buccal possible
First molar		
Mesiolingual canal	Initially to lingual, then to buccal	Almost always to distal
Mesiobuccal canal	Initially to buccal, then to lingual	Almost always to distal
Distal canals	Usually to mesial or distal	Any direction possible
Second molar		
Mesiolingual canal	Similar to first molar	Frequently to distal
Mesiobuccal canal	Similar to first molar	Frequently to distal
Distal canal	Similar to first molar	Similar to first molar

is used when the preoperative radiograph discloses a sharp apical dilaceration or when an obstruction is encountered. The degree of curvature to give the instrument may be estimated by holding the file over the preoperative radiograph and increasing the curvature until the configurations of the file and the canal match. To avoid an obstruction, a short, sharper curve of approximately 30 to 40 degrees is usually sufficient. The other precurve is gradual for the entire length of the flutes and is to be used in all other cases (Figure 5-16).

The sharper precurve is used when attempting to bypass a ledge from previous canal preparation and/or filling. When the dentist is re-treating a failing case that had short and straight canal fillings, the only hope for nonsurgical success is to reach the area of the apical foramen. Once the old fillings are removed or dissolved, using a straight file will merely continue the misdirection of the preparation. However, the sharply precurved instrument might be able to locate the correct direction and reclaim the case (Figure 5-17, *A* to *C*).

The curving may be imparted by drawing the instrument across a metal ruler, cotton pliers, or other sterile instrument (see Figure 5-16, *A* and *C*). The instrument must be resterilized before use if any nonsterile agent was used to give the curve.

Once the precurved file is placed into the canal, there is no way to tell in which direction the curve bends. To avoid this problem, the stop may be altered with a nick or flat end to indicate the curve. A rubber stop with a teardrop shape may be used, with the point showing the correct direction of the curve (Figure 5-18).

The use of early flaring greatly enhances the ease by which precurved files may be inserted. The wider orifice will accommodate these instruments and prevent them from curling back onto themselves, which might happen when they are placed into narrow sites. Particularly in molar canals, without the orifice being widened, it is difficult to keep the curve intact, especially the type that is a sharp curve (see Figure 5-16, *A*).

Incremental Instrumentation

The development of standardization increased the number of instrument diameters available for use, particularly in the smaller sizes. Therefore it became easier to place

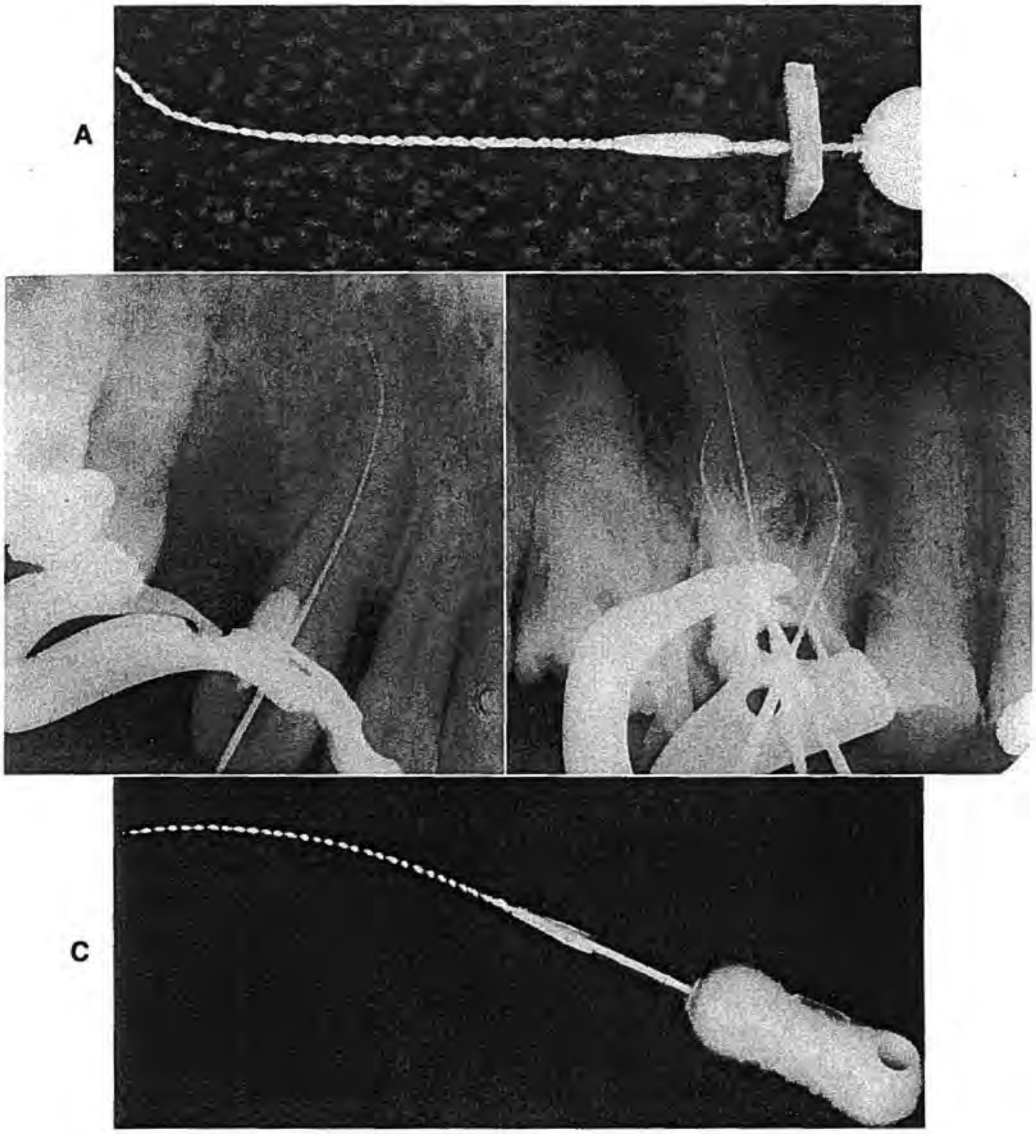


FIGURE 5-16 Sharp bend at tip of instrument **(A)** is used to explore and prepare a tooth with a dilaceration **(B)** or to bypass an obstruction. A gradual bend **(C)** is given all other instruments. Use of straight instruments would make exploration of teeth similar to this maxillary molar **(D)** hazardous. A buccal curve, not revealed in most radiographs (see Table 5-3), is almost always present in the palatal canal. The curves in the buccal canals are obvious. Therefore all three canals have considerable curvatures.

instruments to their correct working length, without the forcing or rotation that might cause breakage or prepare a false canal.

Even so, in difficult cases even the small increment of 0.05 mm between instruments is still too great. A new instrument may not achieve the same position that the previously used smaller size reached. The solution to this problem is to create new intermediate files between the established widths by cutting off a portion of the file tip, thus making it slightly wider in diameter.

As discussed earlier, the rule relating to standardized instruments has established that the distance between D_0 and D_{16} (the minimum length of flutes) is 16 mm and that the difference in diameter between these two points is .32 mm, or .02 mm of width per millimeter of length. Therefore, if a 1 mm increment is clipped from a size 10 file, the instrument becomes a size 12, 1 mm from a size 25 file is a size 27, and so forth.

To utilize this procedure in difficult cases, after using the IAF in small, curved canals (usually size 10 or 15), the dentist should routinely trim 1 mm from it (creating a size 12 or 17, respectively) before going to the next larger size (Figure 5-19). Because cutting the shaft imparts a flat tip, a metal nail file is used to smooth the end and reestablish a bevel after the removal of any segment.

In some extremely curved and very sclerotic canals, cutting off one full millimeter to widen the instrument by 0.02 mm is too great to enable the dentist to reach the full

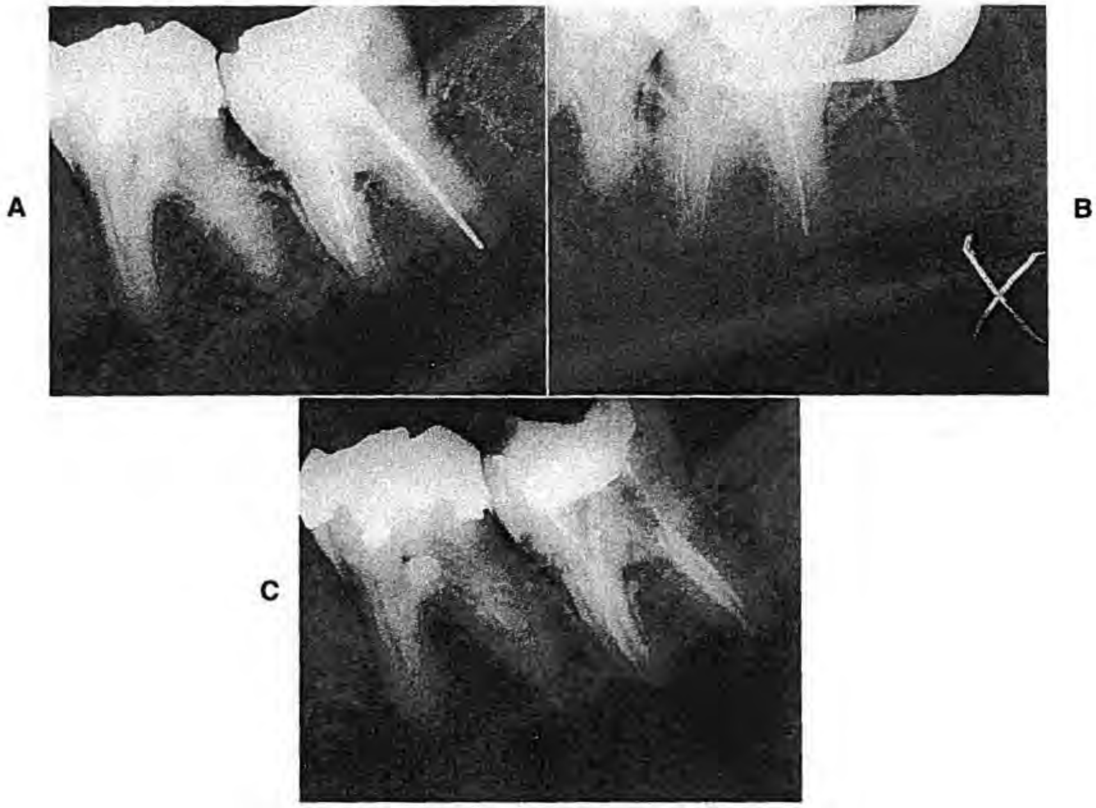


FIGURE 5-17 Bypassing ledged canal by precurving files. A, Preoperative radiograph of mandibular second molar, 1 year after treatment with silver points. The tooth was tender to percussion, and the periodontal ligament space is thickened on the mesial root. Note that the fillings in the mesial root are very straight, even though the canals appear to be curved. **B,** The silver points were removed. If straight files were placed into the mesial canals, there would be no way to bypass the ledges. However, by sharply precurving the files, as shown in Figure 5-16, *A,* the correct position to terminate preparation was reached, according to this radiograph taken from the distal. A second distal canal was also located. **C,** Final filling of four canals with laterally condensed gutta-percha completes a successful re-treatment.

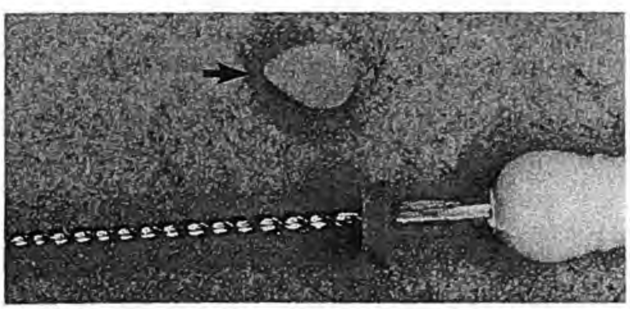


FIGURE 5-18 Teardrop stop will aid in using the precurved file. Point of the stop *(arrow)* indicates direction of curve even when instrument is within canal. (Courtesy Dr. Arthur Rybeck, Jr., Wheeling, W. Va.)

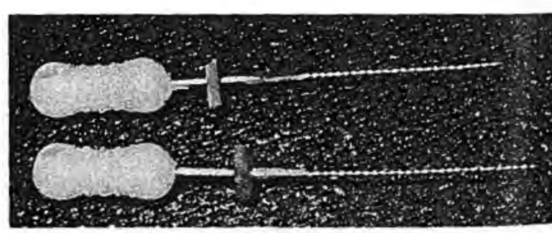


FIGURE 5-19 Making intermediate sizes. Size 10 file *(bottom)* is compared to an instrument of similar size in which 1 mm has been removed from tip to produce a size 12 instrument *(top)*. Note that stop has been moved toward handle of size 12 file to retain correct working length.

working length easily without forcing and/or using reaming action and thus potentially altering original canal shape. Therefore in these cases only 0.5 mm increments are trimmed, increasing the instrument width by 0.01 mm and making a size 10 into a size 11, a size 15 into a size 16, and so forth. Again, the nail file is used after each trimming. In these extremely difficult cases, successive trimming of 0.5 mm and 1 mm segments can bring an initial instrument to a greater width than the next standard size. This works well, because of the possible variance in even quality-controlled instruments, to avoid the use of an incorrectly sized or marked second file.

which might ledge a well-started difficult case. Unfortunately these successive cuttings reduce flute length; after 5 to 7 mm is removed, too little cutting distance remains to be effective, and the remaining instrument has lost much of its flexibility.

New Instruments with Intermediate Sizes

Because of the logic for making intermediate-sized instruments when treating the more difficult canals, several companies have now manufactured file systems that incorporate aspects of this technique.

Golden Mediums, made by Maillefer, are files made according to the standardized principles in the sizes that until now were available only by clipping. These files are available in sizes no. 12, 17, 22, 27, 32, and 37. They were manufactured so that the clinician did not have to clip files but instead had a readily available size in between the normally manufactured sizes.

However, the best way to ensure that one size file is slightly larger than the previous file used is to clip the file. Any other method chances an error, no matter how tightly the manufacturing process is controlled.

Another recently introduced file system is the Series 29. Schilder has stated that even with the increased number of small-sized files introduced by the standardized system (sizes no. 08, 10, and 15) as opposed to the old 1 to 12 system (old no. 1 was usually slightly larger than new no. 10; old no. 2 was usually intermediate between new no. 15 and no. 20), more small sizes were needed in difficult canals. I certainly concur with the recommendation of intermediate files. Schilder proposed that instead of increasing each small file by 0.05 mm between sizes, they should be increased by 29%. Therefore, if size no. 10 (D_0 to be 0.10 mm) were to be established as a key size, the file smaller than it would be 0.077 mm at D_0 and the file larger would be 0.129 mm at D_0. This system works well in these small sizes, but the difficulties begin after the fourth step, when one must go from a D_0 of 0.216 mm to that of 0.279 mm and then up to 0.360 mm. I do not believe this would be possible in a difficult, small, and curved canal. The only available solution, again, would be to clip the file to utilize intermediate sizes.

As of this writing, the technique has not caught on well with practitioners generally, and it seems that the major users have been Schilder's graduate students. Mention of this system is made here because the tip size of the .04 tapers by Tulsa Dental use this Series 29 designation.

Need for Remeasurement When Preparing Curved Canals

As enlarging instruments are placed in and removed from curved canals, the flutes cut more deeply into the portion of inner surface of the bend. As preparation progresses, this tends to straighten out the canal to some degree (Figure 5-20, *A*). In addition, through removal of this portion of the curve, the working length may be decreased because less length of file is required to go around the bend. Continuing to file at the original length may lead to overinstrumentation and resultant periapical tenderness. Because it is so important to have an apical matrix to pack the filling material against, failure to allow for this decrease in working length will complicate the filling of

FIGURE 5-20 **A,** When curved canal is being enlarged, flutes of enlarging instruments rasp more against inner border of curve *(large arrows)* and thus decrease working length. Because curved instrument tends to straighten, some pressure is also forced against opposite wall near apex *(small arrows)*. This may lead to a preparation that has an irregular taper with an elliptical apical portion, best filled by a condensation technique. **B,** Central incisor filled after an elliptical apical preparation. Note that from the access opening the canal tapers, but then it widens a few millimeters from apex. Drawing *A* closely resembles preparation of lateral incisor shown, but with the original canal shape retained.

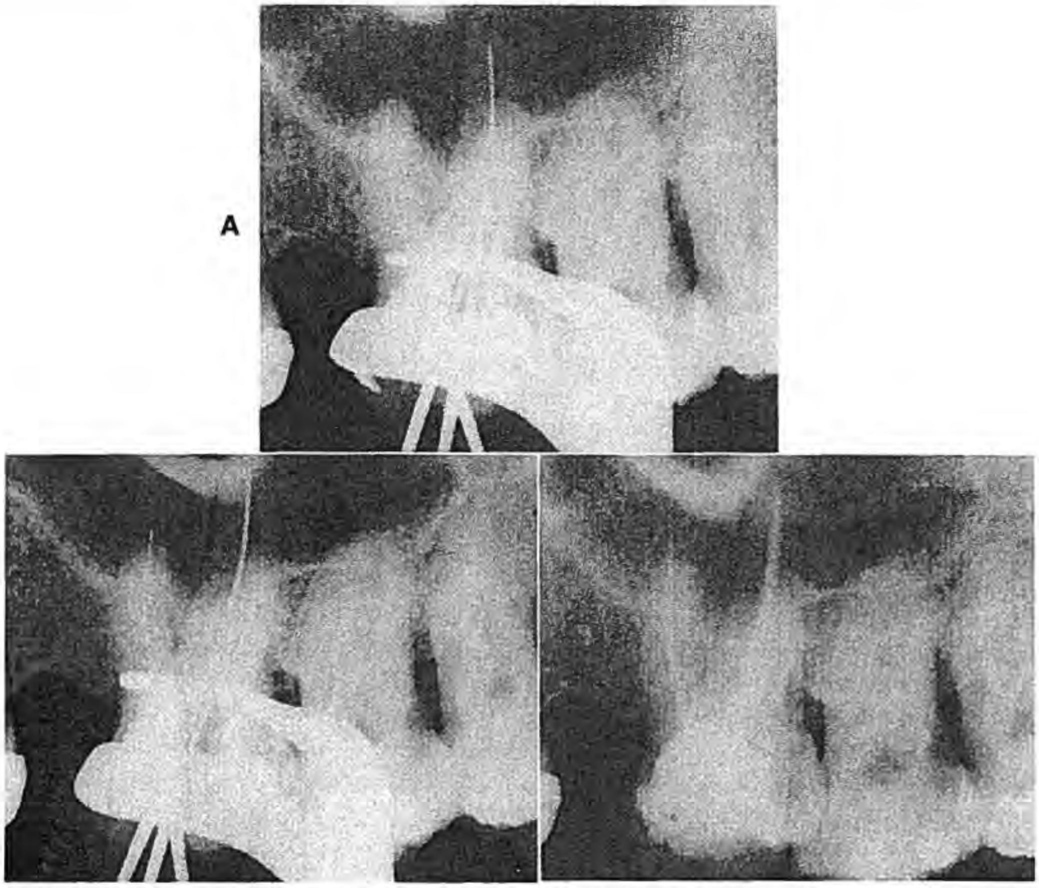


FIGURE 5-21 **A,** Initial radiograph for length determination. Size 10 file in mesiobuccal canal measured 18.5 mm from mesiobuccal cusp and appeared to be in correct relation to apex. **B,** Verification after some canal enlargement. Size 25 file in mesiobuccal canal still 18.5 mm from mesiobuccal cusp. However, because of a decrease in working length by elimination of much of inner portion of the curve, file now passes through apical foramen. **C,** Because mesiobuccal apex was overinstrumented, no solid matrix of dentin was present to pack gutta-percha against, leading to overextension of canal filling.

the canal (Figure 5-21). Therefore, when curved canals are enlarged, radiographs to check for a new working length should be taken for every three increments of file width (e.g., if a size 15 file is the first instrument used, at size 25 a new radiograph is taken) and any decrease in working length calculated.

PREPARATION IN EXTREMELY CURVED CANALS

Many methods and techniques of canal preparation work well in the larger and relatively straight canals. However, when the canal curvature reaches 30 degrees or more, the complexity of the case increases markedly, and the techniques that render good results in the simpler cases may or may not be successful. This section will deal with the preparation of very curved canals.

Determination of Canal Curvature

Before the initiation of treatment, an estimate should be made as to the degree of curvature of the canals to be treated. As described originally by Schneider and then Jungman et al, the method for making this determination is quite simple (Figure 5-22). In most instances a radiograph will indicate that the curved canal has two segments, one extending from the floor of the chamber down the long axis of much of the coronal two thirds of the root and the second from the apex of the root extending back to the occlusal through the apical third of the root. These two lines will intersect and form four angles. The interior angle is the estimate of the degree of canal curvature.

Because it is calculated from a two-dimensional radiograph, this is merely an estimate and determines the mesiodistal curvature only without taking into consideration any buccolingual curvature. The operator should be aware of the teeth that typically have buccolingual curvature and take this into consideration. Common buccolingual curvatures are summarized in Table 5-3. The operator should also be aware of the shape of the initial files after they are removed from the tooth. Often some small, abrupt, or unnoticed curves will be indicated by an

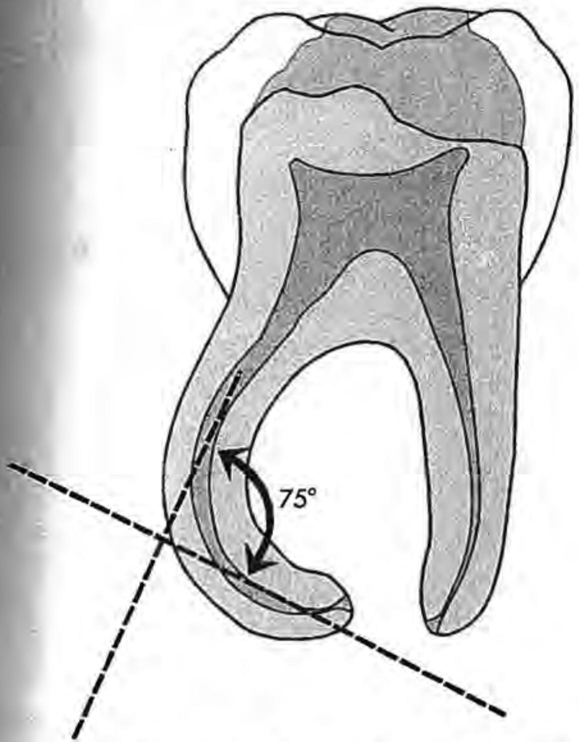


FIGURE 5-22 To estimate degree of curvature, imagine a straight line from orifice through the coronal portion of the root and another straight line from apex through apical portion of curve. The interior angle formed by intersection of these lines is the degree of curvature. Such an estimate is of mesiodistal curvature only and does not take into consideration any buccolingual curvature. Table 5-3 gives information on buccal, lingual, and palatal curvatures.

unusual shape in the file that corresponds to the true curvature within the canal. It is important to utilize this knowledge when further preparation is performed.

Observations That Canal Shape Changes

As illustrated by Figure 5-8, it is important to retain original canal shape. However, it has been noticed for many years that the original canal shape may be ever so slightly altered with each file in a curved canal. Individually there is only a slight alteration between one file size and the next larger instrument, but the net change can be quite drastic (Figure 5-23).

Performance of endodontic preparation has one significant disadvantage compared with that for operative or crown and bridge procedures. When preparing for inlays, onlays, crowns, amalgams, composites, or foils, the dentist may visualize the entire preparation at all times. However, during canal preparation in the course of endodontic treatment, only the orifice is visible; the critical apical areas are never seen by the naked eye. Only the radiograph gives some scant knowledge about what happens near the tip of the root.

In these more sharply curved canals, the shape changes more rapidly and may be undesirably altered, leading to potential failure (see Figure 5-23). Virtually everyone who has performed endodontic treatment on a number of extremely curved canals has observed these changes, which are more than merely subtle.

Plastic Block Studies

In an attempt to clarify the actions of the instrument during canal preparation, acrylic blocks were prepared that would simulate intracanal treatment conditions and allow for complete visualization of the procedures (Figure 5-24, *A*). Small silver points were bent into a curve to simulate curved molar canals. The points were lubricated and placed in a mix of clear acrylic casting resin.* When the plastic hardened, the points were removed, and a canal was left in the block. The Knoop hardness number of the blocks was 22, compared to 40 for dentin near the pulpal wall. According to Patterson, the number could be reduced to as low as 7 for dentin exposed to ethylenediaminetetraacetic acid (EDTA). The filing of the blocks felt similar to the filing of normal teeth.

These blocks were distributed to a number of endodontists and general dentists who had considerable endodontic experience. The practitioners were asked to prepare these canals in their routine manner. Some fascinating information was gleaned from analyzing these preparations (Figure 5-24, *B*). For years it had been thought that after the completion of preparation, the narrowest point of the canal was at the apex. This was taken for granted, because it had to be true if endodontic therapy were to experience predictable successes. However, whereas the widest portion of the canals prepared in the blocks was at the orifice, *the narrowest site was never at the apex but was a few millimeters short of the apex.*

When the paper describing this study was reported by Weine, Kelly, and Lio, many strongly doubted its authenticity. They could not accept that in a curved canal which could be completely visualized at all times and with the file seemingly guided, as it could never be in a true clinical case, it was impossible to gain a preparation narrowest at the apex. This cast considerable doubt over the veracity of the use of silver cones in curved canals because of the impossibility of the solid silver cone filling the biconcave shape. Even vertically or laterally condensed gutta-percha would have considerable problems here because a perfect funnel does not exist to allow for the packing down to the narrowest diameter at the tip.

In actuality, a study by Gutierrez and Garcia 7 years earlier on extracted teeth had reported many of these same

*Dexter's clear polyester casting resin (no. 63-23505), Lee Ward's Creative Crafts, Elgin, IL 60120.

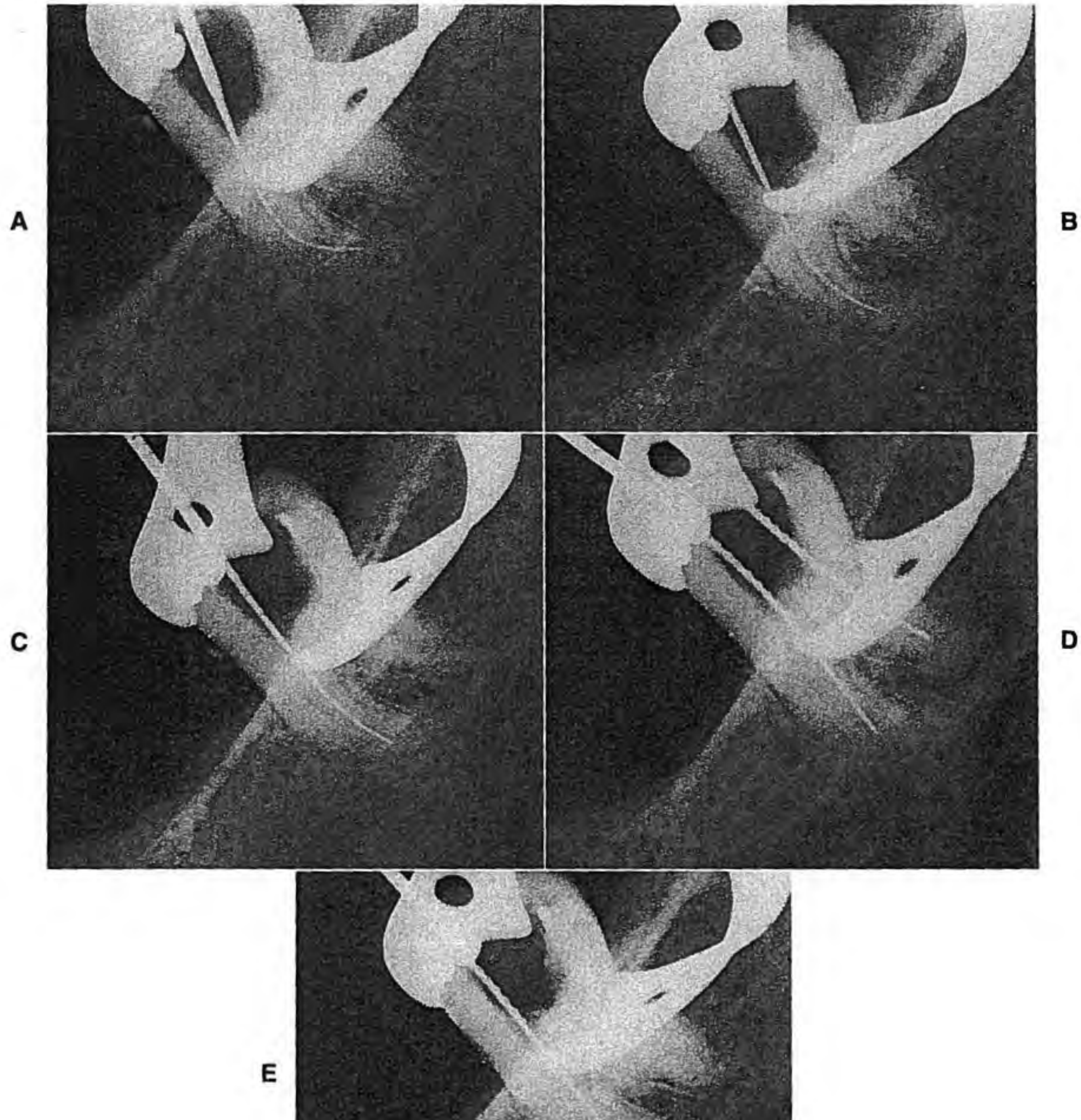


FIGURE 5-23 Mandibular second molar with well-placed size 10 file in the single mesial canal. A, Shape is excellent, and working length perhaps slightly too long. **B,** Size 15 file in place at 0.5 mm shorter than working length in *A*. Still looks good. **C,** Size 20 file in place starting to deviate. At apex it is too close to mesial, whereas in body of canal it is too close to distal. **D,** Size 25 file in place in mesial, increasing the error in shape. **E,** Size 30 file, disaster completed.

observations, particularly concerning the tip of the preparation. These authors had stated that an hourglass shape existed at that site whereby the narrowest point was not at the tip of the preparation but was several millimeters coronal from the tip. This was emphatically verified by the plastic block studies.

A further observation was made during the course of instrumentation in the curved plastic block canals (Figure 5-24, *C*). During insertion or withdrawal, each file attempted to straighten within the canal, whether precurved or not. Therefore the file rode the inner portion of the canal between the orifice and the narrowest point of

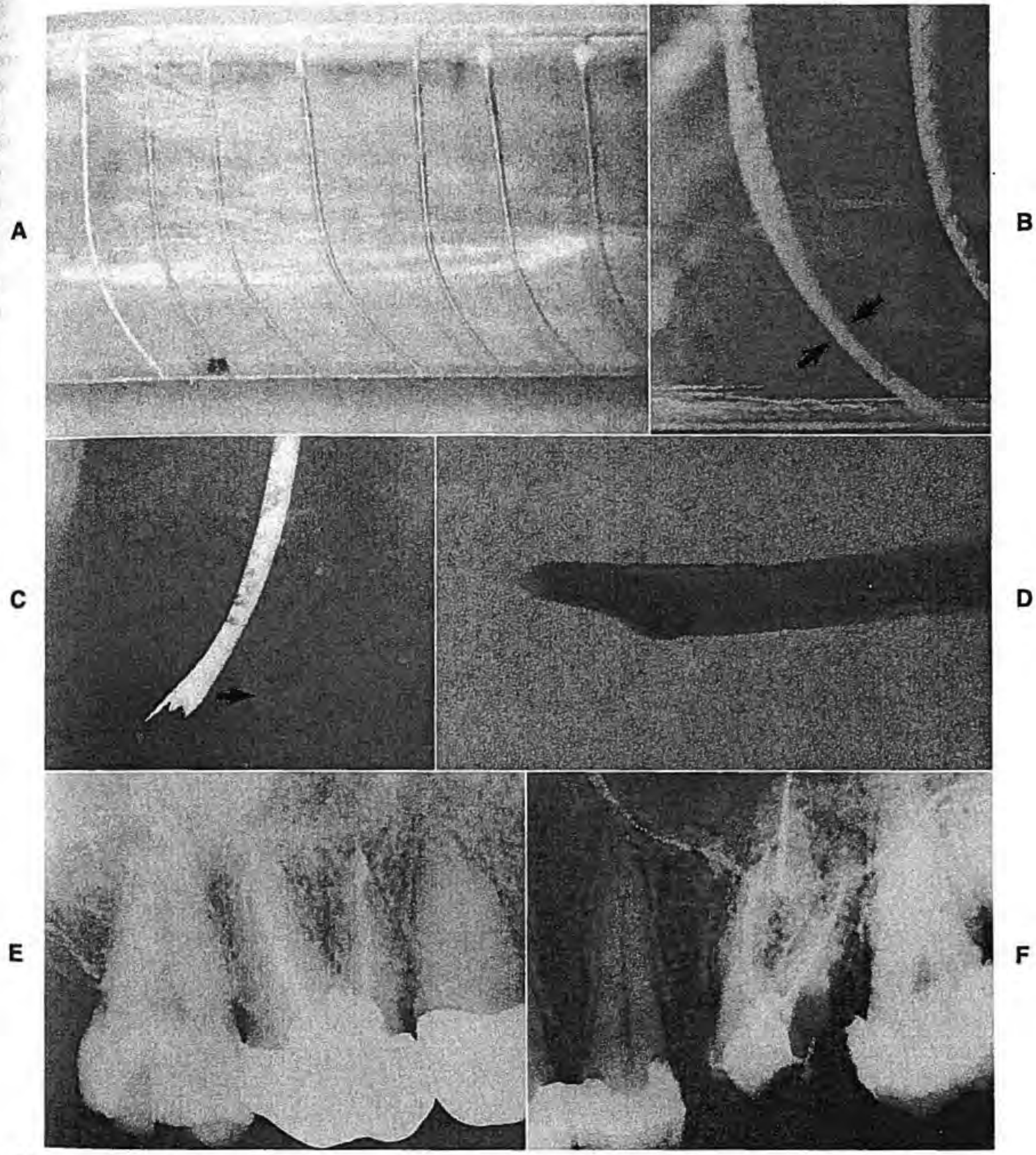


FIGURE 5-24 **A,** Plastic block made to simulate curved canals prepared by curving silver points and pouring acrylic casting resin. **B,** Typical canal preparation *(left)*, which is not narrowest at apex but rather several millimeters from the apex *(arrows)*, illustrates hourglass shape. **C,** Canal prepared completely within block and enlarged to size 30. Path of the size 10 file was to the left and went perfectly around the curve. However, every file in canal after that went farther and farther away from curve in apical portion *(in direction of arrow)*. Even with a completely visualizable system, which is obviously impossible in a clinical case, it would be impossible to insert any file back down along the inner portion once the canal was enlarged to an appreciable extent. **D,** Cross section of block at level of arrow in **C,** demonstrating teardrop shape position *(left)* of size 10 file. Every instrument after that went farther to the right, with the 30 file farthest. **E,** Radiograph of maxillary first molar filled with laterally condensed gutta-percha. Sealer is exiting from mesiobuccal canal with a teardrop shape, demonstrating what has been done to tip of that root. **F,** Final radiograph of maxillary first molar. Note that mesiobuccal root was slightly overinstrumented and appears to be perforated. In actuality, apex has been moved severely to the mesial due to opening up of large files away from the curve.

the preparation, whereas the file worked only on the outer wall between the narrowest point and the tip of the preparation. Between the narrowest point and the tip, each succeeding file went farther and farther away from the inner portion of the curve. It was impossible to avoid this tendency, even with increased precurving or attempting to redirect the file visually, which could be done with the transparent blocks but obviously not in a clinical case.

Viewing the base of the blocks, one could see that which would conform to the apical foramen gave an interesting perspective. In none of these blocks were the sites of exiting round, or even elliptical, but were teardrop shaped (Figure 5-24, *D*). The narrowest portion of the teardrop was where the initial smallest files exited from the block with the sharpest portion of the curvature. As each larger file exited farther and farther away from the inner portion of the curve, it widened the teardrop to that direction.

This situation may occur in a clinical case as well. When the final radiograph is viewed (Figure 5-24, *F*), it might be assumed that the root tip had been perforated. In actuality, this is not a perforation but a slit or teardrop in the root tip. A perforation has two canals, the true canal and the false canal. In the apex that has been teardropped, the initial files made the curve but slightly overinstrumented the apex. Each succeeding file opened up slightly away from the curve, completing the error.

Because of this teardrop shape seen in Figure 5-24, *D*, no possibility exists for such a preparation to be filled adequately by a silver cone. Condensed gutta-percha might be able to seal such a shape, but only at the cost of an overfill (Figure 5-24, *E*), which will probably invoke a rather severe postoperative tenderness and cause problems in healing.

In addition to those critics who assailed the original Weine, Kelly, and Lio paper as inaccurate, many attacked the use of the plastic block as a substitute for extracted teeth studies or actual clinical cases. This view has now been reversed 180 degrees, and the use of plastic blocks has become quite dominant. In fact, if a new preparation technique or new endodontic instrument is introduced without an accompanying plastic block study, its veracity would remain in considerable question.

Standard Preparation in the Sharply Curved Canal

Observations of these block studies led to a number of interesting conclusions that were verified constantly, regardless of which operator was performing the preparations. The initial flexible files in a curved canal are able to make the curve and stay within the confines of the true canal (Figure 5-25, *A*). However, as the larger, flexible instruments are used, they do more work on the inner portion of most of the canal and on the outer portion of the canal near the tip (Figure 5-25, *B*). The result is the misshapen canal that is so difficult to fill (Figure 5-25, *C* and *D*). For want of any better names, the site where the canal is the narrowest was called the *elbow*, and the wider irregular area at the tip of the root was called the *zip*. A cross-sectional view of the tip is the teardrop-shaped site, and a canal prepared in this manner is considered *zipped*.

Applications on Extracted Teeth

To clarify their study further, Weine et al slightly overprepared canals in teeth where the apical foramen came off shorter than routine, which therefore could be prone to such preparations. The results of these preparations verified that the plastic block studies were accurate. Custom mounts were prepared for these teeth so they could be rephotographed in virtually the same position before, during, and after preparation. The canals were prepared in a normal manner, and the results analyzed (Figure 5-26). In these teeth the teardrop shapes at the apices were clearly demonstrable. Radiographs taken during the course of treatment verified the existence of the apical zip, elbow, and hourglass shape. The correlation between these findings on extracted teeth and those of clinical cases is unfortunately true (Figure 5-27).

Avoiding the Apical Zip and the Elbow

Once these tendencies could be categorized and verified, potential solutions were devised. It seems obvious that in order to reduce the apical zip, we must prevent the file from opening up at the apex. The method I use employs the diamond-edged nail file, suggested for incremental instrumentation procedures (page 185) and using Leeb's principles for early enlargement of the coronal portion and removal of the triangle of dentin guarding the orifice.

When the tip of the endodontic file is clipped to produce the intermediate sizes, the diamond-edged nail file is used to rebevel the tip of the instrument. To avoid the apical zip, after the clip is made to gain an intermediate size, I drag the nail file against the outer portion of the precurved endodontic file to remove the cutting flutes (Figure 5-28) and thus produce a customized file—a file for that canal shape only. This should not be accomplished with a stone mounted in a handpiece. The distance between the elbow and the apex is estimated on the preoperative radiograph, and that length of flutes is removed from the outer surface of the endodontic instrument. I do this whenever the file is clipped to provide intermediate sizes. If it were done on every instrument in the canal, there would be no preparation on the outer portion of the curve near the apex, and the canal would be overprepared in the opposite direction.

The elimination of the elbow is much less difficult to accomplish. All that is needed is to provide adequate canal flaring. This opens up the bottleneck of the elbow and leads to a truly tapered canal (Figure 5-29), which can be filled by a multiplicity of techniques and materials.

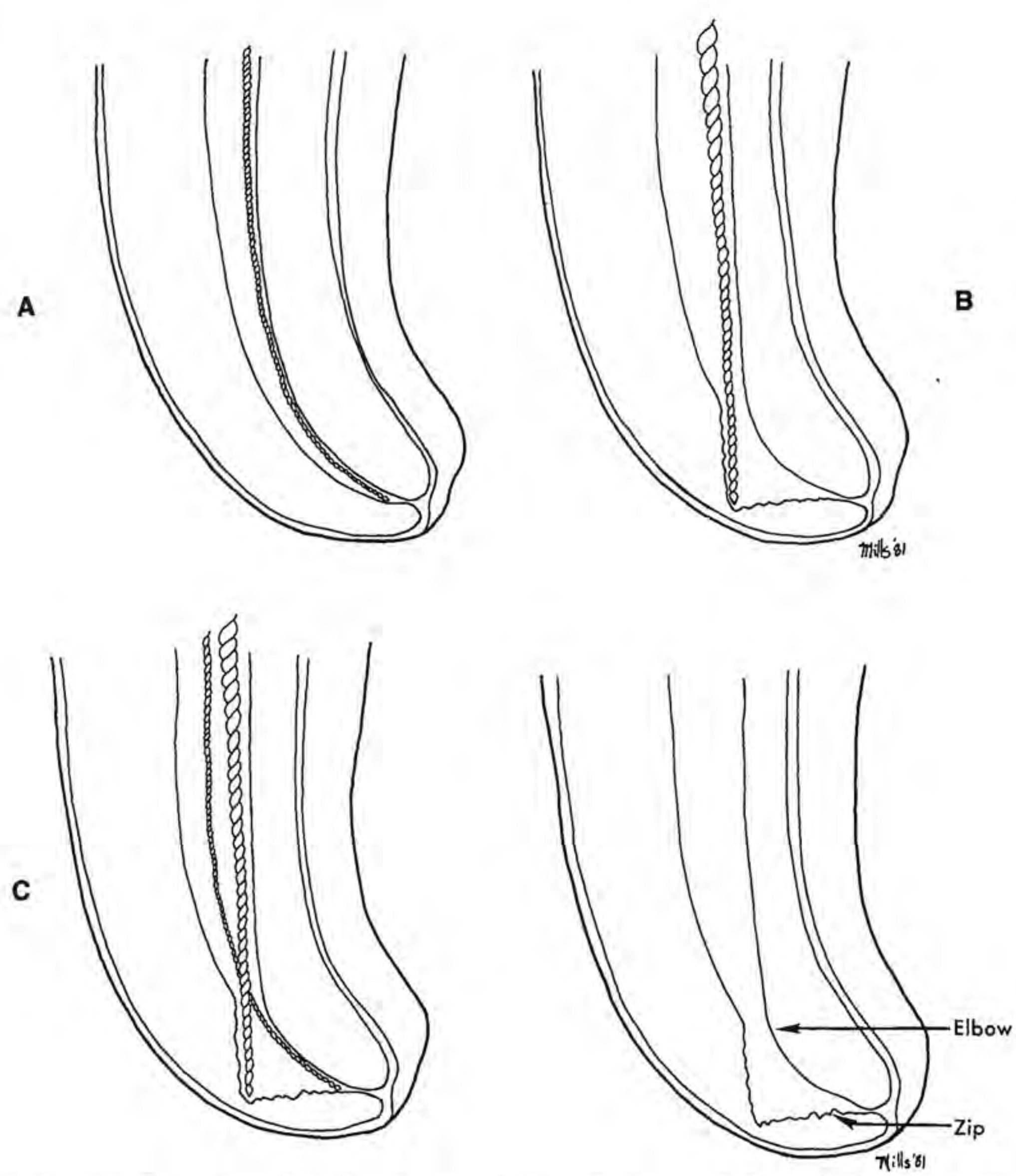


FIGURE 5-25 Schematic drawing of subtle changes in canal shape that cause zipping and the elbow. A, Small files are flexible and able to traverse the curve with minimal difficulty. Virtually no alteration in canal shape results. **B,** As wider, stiffer files are used, each opens up away from curve near tip and gets closer to inside of curve between the tip and the orifice. **C,** Superimposition of *A* and *B* then results in **D,** the altered shape of a typical zipped canal. Preparation is not narrowest at tip but rather several millimeters from tip. This site is called the *elbow.* The zip, which is wider than the elbow, is the apical irregular area caused by opening up of files away from curve. A cross-sectional view near tip of zip is teardrop in shape.

Application to Clinical Cases by Using Customized Files

When these ideas and methods were applied to clinical cases, I found that the degree of apical zipping was tremendously reduced and that canal shape was retained in a high percentage of cases. The curvature and the distance from the apex to the elbow must always be estimated in advance of the enlargement procedures. This is accomplished by measuring these distances on the preoperative radiograph and then verifying by the initial measurement films. On removing the first flexible file from the canal, the operator should examine the configuration that the instrument has assumed. Frequently the curvature of the canal will be indicated by the curvature on this file.

When the canal has a curvature of 30 degrees or less, removal of flutes usually is not necessary. The canal should be prepared slowly and carefully, and if the curvature approaches 30 degrees, a flexible file system should be used to prepare the apical portion. In canals with curvatures of 30 and greater, flute removal is mandatory, in my opinion, at least for the IAF and the next clipped size. Use of the non-ISO tapered instruments has greatly

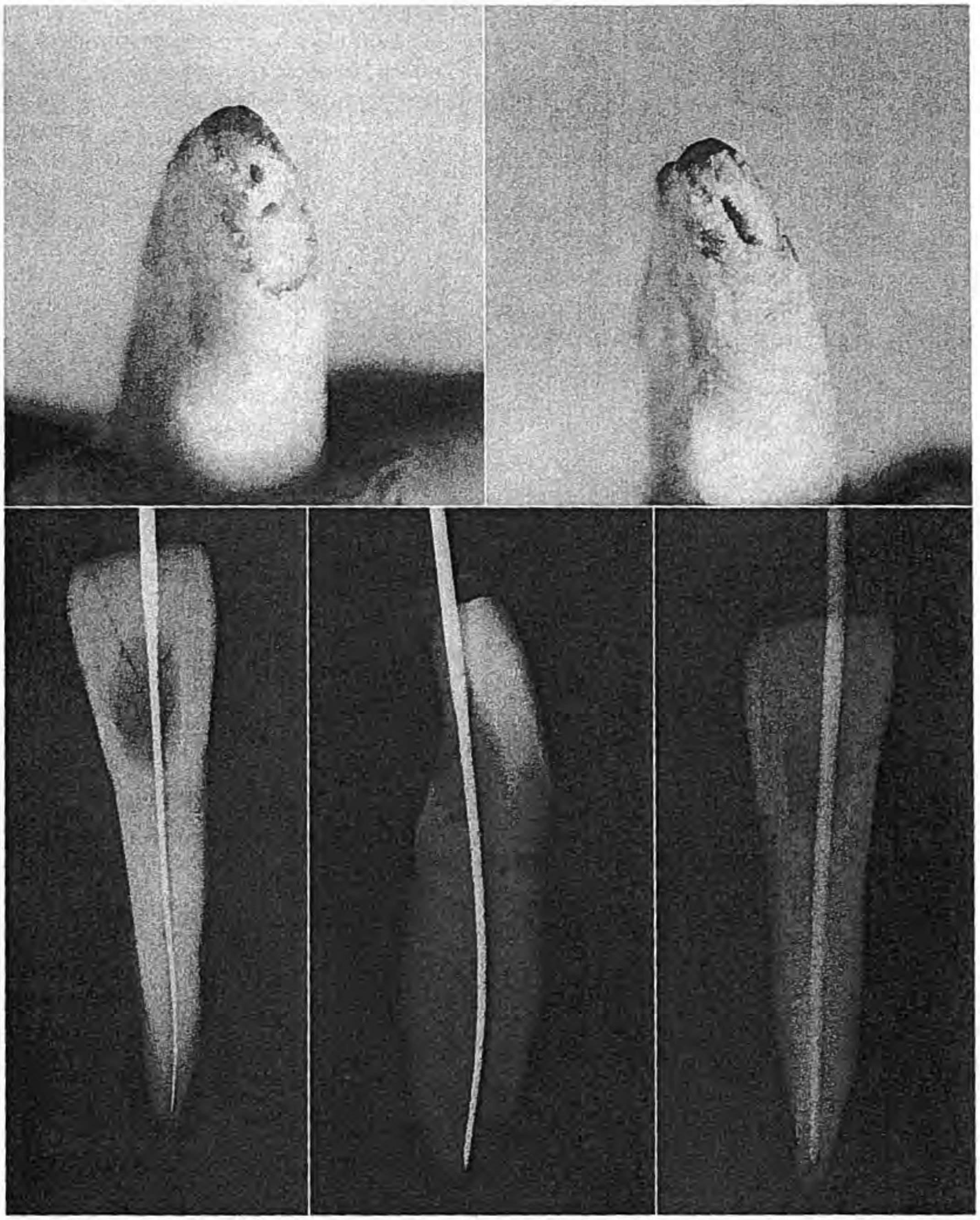


FIGURE 5-26 Zipped, teardrop shaped mandibular incisor after preparation through apex. A, Apical view of mandibular incisor root with canal exiting short of apex to the buccal. This is a tooth that typically will be overinstrumented. **B,** Radiograph of file in place seems to be well within confines of the tooth. **C,** Profile radiograph of labiolingual view, never seen with normal projection. Canal will be overinstrumented at a length that might seem satisfactory. **D,** Apical view after canal enlargement to size 35 at length indicated in C. This canal would be difficult to seal. **E,** Master gutta-percha cone size 35 appears to be approximately 0.5 mm too short. In fact, it was at least 0.5 mm too long.

lessened the need for clipping and removing of flutes for the more severe curves. However, if larger sized instruments do not seat easily at the apex, the ability to clip and/or remove flutes remains available.

I prefer to call these files with flutes removed according to the position of the elbow *customized files* because they are prepared for canals with specific dimensions and therefore can never be reused in another canal. Some prefer to use the words *modified files* to connote that a regulation file as it would come from the manufacturer would be altered for use. Further discussion of modified files will appear later in this chapter.

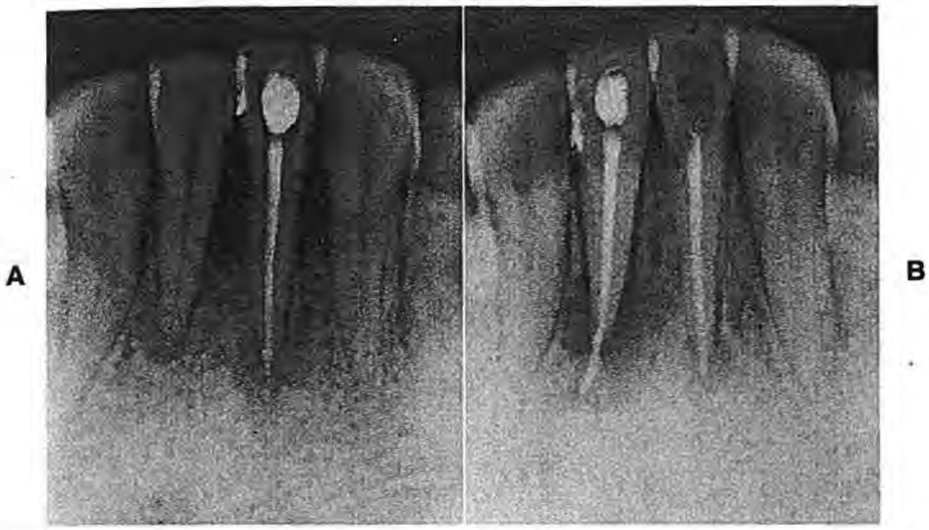


FIGURE 5-27 Condition in Figure 5-26 is not uncommon. A, After canal filling of tooth no. 24. Although I thought an apical dentin matrix was present, obviously I was incorrect; a considerable amount of sealer went past the apex. Poor as that case was, however, it was not as faulty as my attempt to fill no. 25 **(B)**, in which I forced much sealer plus master and auxiliary cones past the nonexistent apical dentin matrix. Obviously these teeth both had apical configurations similar to those shown in Figure 5-25.

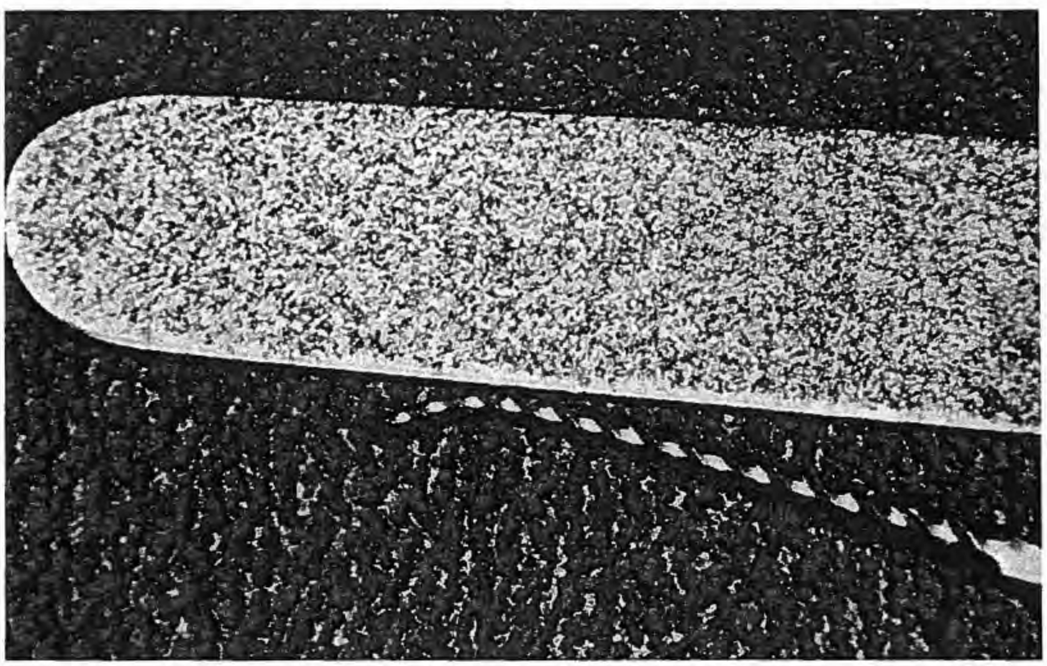


FIGURE 5-28 Producing a customized hand file. Diamond-edged fingernail file is used to remove flutes from outside edge of instruments of intermediate sizes in treatment of curves of 30° or greater. Flutes are removed from tip of file to approximate area of the elbow.

Theories for Flaring in Complex Cases Versus Crown-Down Preparation

The method of flaring presented earlier is the presently preferred development of flaring whereby the coronal portion of the preparation is flared before the completion of the apical portion. Four aspects of preparation are carried out. First, minimal filing is done at the tip, followed by enlargement of the coronal portion. Then the apex is completed, and finally, apical flaring is performed.

A type of flaring different than the type described in this book was adopted by some dentists 10 to 15 years ago, referred to as the *crown-down method.* In this technique, the canal was prepared from the coronal portion down to the apex using larger files first and then

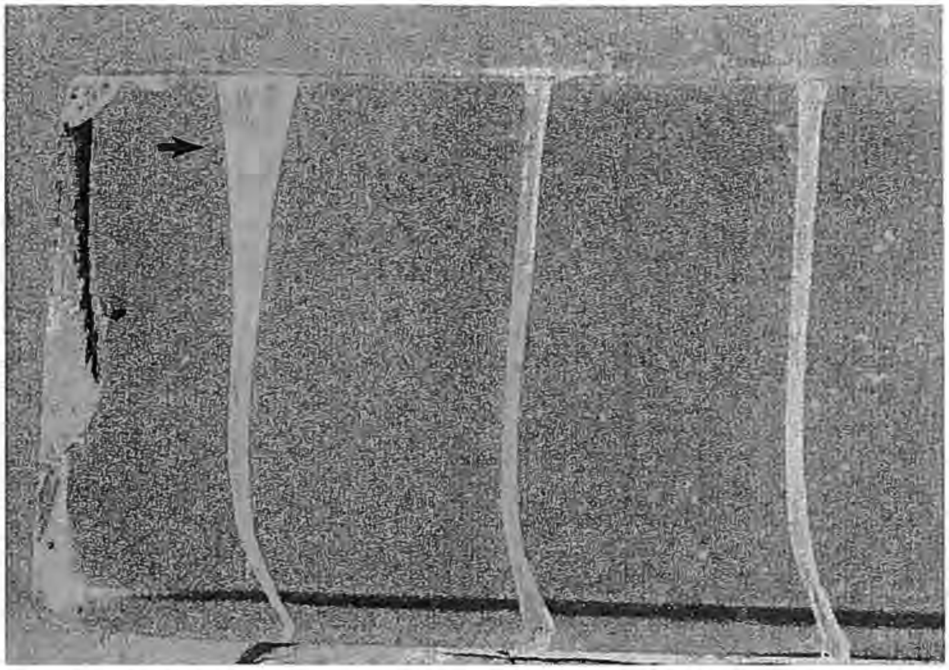


FIGURE 5-29 Plastic block canals enlarged with several techniques. Canal to left *(arrow)* was prepared by removing flutes for sizes 12, 17, 22, and 27 files, enlarging to size 30 apically, and flaring to size 45. Removal of flutes has prevented apical zipping, and the flaring has eliminated the elbow. This preparation is narrowest at apex, widest at orifice, and may be filled with many types of materials and techniques. Preparation was entirely with hand files because non-ISO rotary tapers were not yet introduced. Center canal was enlarged with a mechanical handpiece and has an elbow and zip. Canal at right was enlarged, by reaming action, apically to size 30 and demonstrates an elbow and a zip.

decreasing to smaller sizes. This was opposed to the classical method of enlarging first at the apex with small files and then working up coronally using successively larger files.

If the crown-down method is used in relatively straight canals, it seems to work satisfactorily and, in all probability, more quickly than classical preparation. This is because by opening the orifice area early in the preparation, the files do not bind prematurely and more effective preparation in the apical area occurs. The problem is that comparatively few canals are perfectly straight. In molar teeth, virtually all canals are curved. In these cases, the crown-down method works well in the coronal portion where the canal is relatively straight (see Figure 5-22). However, as the curve begins, larger, less flexible files stay straight and often will ledge and block the apical portion. With the advent of the non-ISO tapers, the suggested preparation went from the coronal portion with large files down through the smaller files near the apex (Figure 5-30).

As stated earlier, my strong preference has always been to use a small file to the apex (such as the IAF) after using any larger file short of the apex. The validity of this view has been proven because most early endorsers of the crown-down technique have modified it to include the use of the smaller files to the apex between the larger files usage.

The coronal portion of flaring may be performed by hand instruments, ultrasonic devices, or mechanical instruments such as the Gates-Glidden bur or Peeso reamers. Before the use of the non-ISO tapers, these alternatives were used with generally good results. However, in my opinion, the new instruments specifically designed for flaring give even better results, which will be discussed in the next section.

The third edition of this textbook suggested early flaring only for canals with curvatures of 60 degrees or greater. Since that time I have used such flaring more and more, and now I recommend its use in every complex case. It may be used in all endodontic cases, even those that are relatively simple.

New Instruments for Early Flaring. Because of the immediate popularity attained by early flaring, it was only a short time later that several new instruments were developed specifically for this technique. All of them have used some deviations from the ISO taper of standardized instruments.

If one wants to enlarge only the coronal portion of the canal to a greater extent earlier in the preparation procedure, examination of Figure 5-11, *A* and *D*, suggests that a useful instrument would be one that is quite wide from the middle of the file up the shaft, but narrower as you approach the apex. Such an instrument would have an

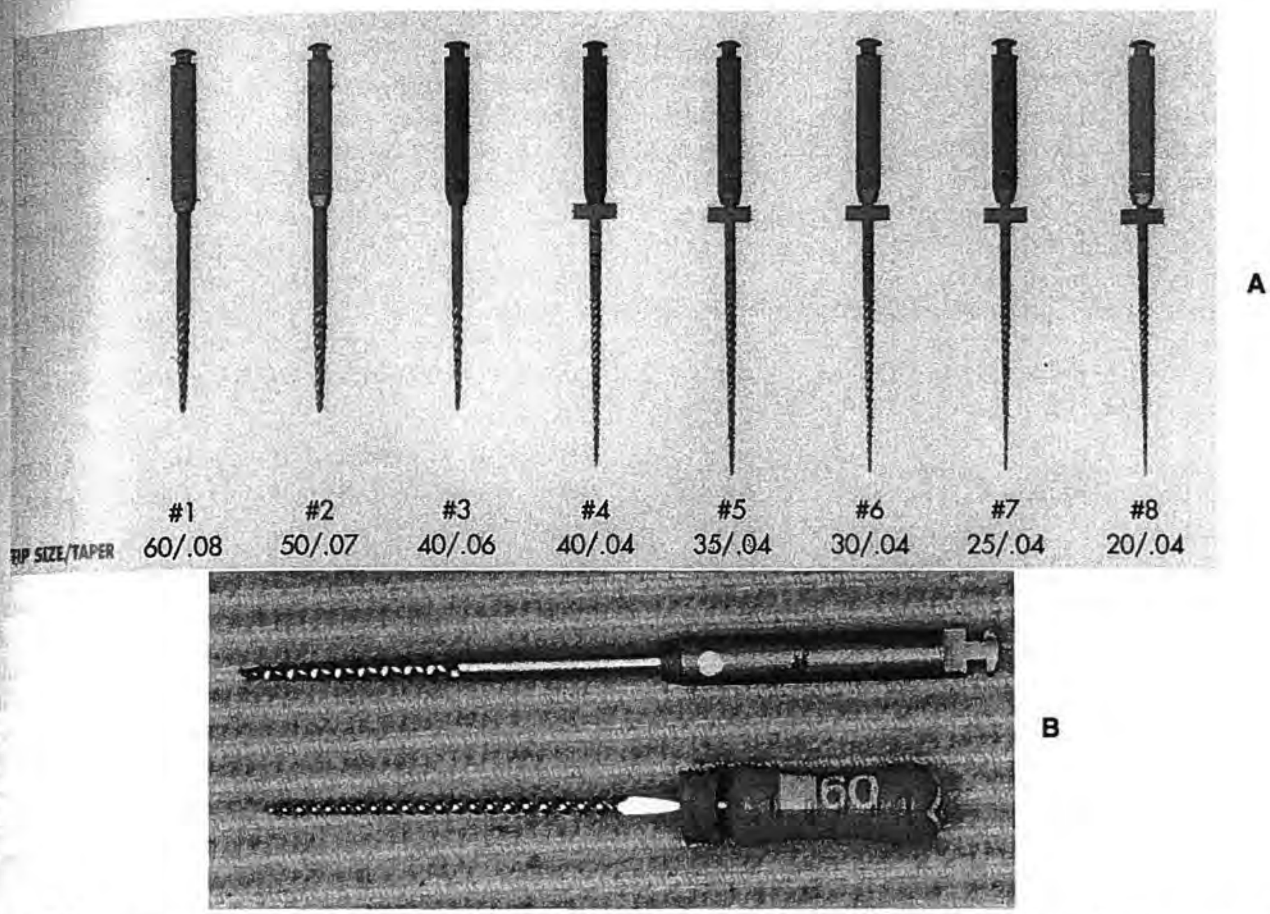


FIGURE 5-30 A, Instructional guide for use of non-ISO tapered instruments, in crown-down technique. Sizes of greater taper and .04 tapers are placed sequentially in order of use from left to right. Note that the first, second, and third files are intended to reach short of the apex but are quite wide (tapers .08, .07, and .06, respectively) and very inflexible. The other files, #4 through #8, are in descending order of width. Note, no MAF is indicated for use. Such a preparation technique is fraught with dangers such as ledging and perforation. **B**, .08 taper size 60 *(top)* compared with size 60 hand file *(bottom)*. If the .08 tapered instrument was run down even 10 mm in the tooth shown in Figure 5-14, B, it would surely cause a strip perforation.

increase over the standard degree of tapering. This is exactly what has been accomplished with these new instruments that have been made with non-ISO standard tapers.

As described in the discussion of the standardized hand instrument, the taper of .02 mm of width per millimeter of length is present. For the instruments designed for early flaring, the taper has been increased (Figure 5-31). The .04 tapers* are mechanical instruments produced to be used in a gear-reduction handpiece. They are made of nickel-titanium metal with a taper twice as great as standardized instruments. The widths of the .04 tapers at D_0 and D_{16} are listed in Table 5-1.

*Tulsa/Dentsply, Tulsa, OK 74136.

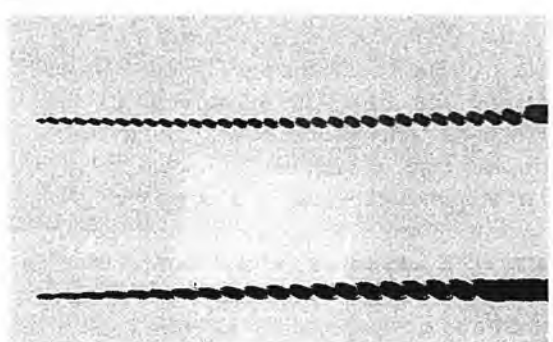


FIGURE 5-31 Shadowgraph of .04-taper instrument *(bottom)*, approximately size 25 at the tip, but 0.89 mm at D_{16}, compared to a size 25 Flex-o-file *(top)*, which is 0.57 mm at D_{16}. The .04-taper instruments are made for a low-speed/high-torque mechanical handpiece out of nickel-titanium material.

Rules Governing the Use of Non-ISO Tapered Instruments

Because of their difference in design and usage from the standardized files, there are important rules to follow when using the non-ISO tapers:

1. The instructional tapes present in the early packaging of these instruments have errors (based on current usage) and may be incomplete.
2. Do not use these instruments to the apex of curved canals due to the problem of file breakage. This was a serious problem in the early use of the non-ISO tapers. Calculate the distance from a cusp tip to the *elbow*. Set the stop to this length and do not go any further. (Complete instructions on locating the elbow will be presented shortly.)
3. Do not drill into the canal. Place the apical few millimeters of the file into the canal and then move the handpiece apically. Only go as far as the file goes easily.
4. Use a gear-reduction handpiece—do NOT try to use regulation slow speed and govern the RPM with the rheostat. The correct speed is between 300 and 350 rpm (see Figure 5-46, *B*)
5. Practice, practice, practice. Do not attempt to treat a considerably curved root as soon as you start using these systems. You will have serious problems and will feel that the technique is flawed. We are fortunate that we have several useful and realistic substitutes for practicing all endodontic situations (e.g., extracted teeth and plastic blocks) (see Figure 5-24, *A*). Use these aids to gain experience with the system. Then try a few clinical cases where the curvatures are mild and work up to the more complex situations.

Several other dental firms also produce varying tapers similar to the .04s. The closest to the one I usually use is made by Maillefer, of Switzerland, also a subsidiary of Dentsply, and a company with many years of manufacturing quality endodontic instruments. Their non-ISO tapers* (see Figure 5-12, *B*) come in the standardized, rather than Series 29, designations and the color coding is also that of the ISO standards. The instruments are well made and can easily be substituted in the specific directions for preparation that will follow.

Another type of non-ISO tapers has been produced, using the prefix of "Quantec" plus a year designation. These instruments were designed by McSpadden, who has introduced a number of other applications for endodontics. The McXim (pronounced "maxim") file system** was introduced approximately 10 years ago, utilizing five to six files of the same tip size and varying tapers from .03 to .055. I used this system with reasonable success, both clinically and in research on plastic blocks. Then in 1999, McSpadden introduced the Quantec 2000,* which was a more complicated system with many sizes and taper designs ranging from no taper to severe tapers and several flute designs (see Figure 5-12, *C*). Several adjustments were made from the original system, but the Quantec files do not seem to be widely used at this time.

When any of these instruments are used, it seems easier to prepare curved canals, and less time is required to accomplish this normally difficult task. Still the quality of treatment is maintained at a very high level (Figure 5-32).

Effect of the Non-ISO Tapers on Canal Curvature and Resultant Changes in Canal Shape

Using the theories of Leeb, use of the non-ISO tapers, especially at the low speeds of 300 to 350 rpm, allows the operator to remove the triangle of dentin that often protects the orifice of the curved canal. The Gates-Glidden and Peeso reamers essentially are centering burs, that is, drill down the center of the canal and widen it in all directions. The slower revolving non-ISO tapers may be pressed toward and directed to eliminating this triangle and effectively reduce the canal curvature (Figure 5-33). Reducing the curvature lessens the chances for serious and destructive zipping.

The ability to work effectively at lower speeds allows the placement of the non-ISO tapers directly against a canal wall, enhancing anticurvature filling (see Figure 5-14, *E*).

Typical Cases

The instrumentation for typical cases is discussed next. Early flaring is used in this preparation schedule, and the apical portion of the canal is slightly enlarged prior to any flaring. This is provided by clipping the IAF and making an incremental size, called the *temporary master apical file* (TMAF) and is used to the full working length after each flaring file, or any other file, used short of that distance. Flaring with non-ISO standard instruments is included in the step-by-step preparations of the complex curved canal systems that follow.

Curvatures of 30 to 60 Degrees. First I will describe the treatment provided on two maxillary molars. The first is for the mesiolingual canal (fourth canal) on a first molar with a short distance between the elbow at the apex. The second is for the mesiobuccal canal on a second molar with a relatively long distance between the elbow

*Maillefer/Dentsply, Balligues, Switzerland
**NT Co., Chattanooga, TN 37421.

*NT Co., Chattanooga, TN 37421.

FIGURE 5-32 **Maxillary second molar, the first tooth that I treated with early flaring by .04-taper instruments. A,** Preoperative radiograph of maxillary molar area. Periapical lesions are associated with palatal and mesiobuccal roots. **B,** Film of files in place, indicating curvature of almost 90° in mesiobuccal canal and curves near the apices of the palatal and distobuccal canals. **C,** Canals were flared using .04-taper instruments. Once this was accomplished, canal preparation seemed to proceed more easily than anticipated in this difficult case. Note that the orifice of the mesiobuccal canal has been moved to the mesial, thus decreasing the curvature to approximately 60° (compare to *B*). Canals were filled with laterally condensed gutta-percha and Wach's paste, with post room prepared. **D,** Perfect periapical healing is apparent in this film taken 9 months later. **E,** Eighteen months after original treatment. **F,** Seven years after original treatment, normal appearance of periapical tissues. (Restorations by Dr. Phil Finkle, Chicago.)

FIGURE 5-33 Reducing angle of curvature by use of non-ISO tapered files. A, Maxillary first molar with initial files in place, no. 10 files in buccal canals. The angle of curvature in the MB canal is approximately 50° and in the DB canal is approximately 45°. Note that the 2 files in the buccal canals cross in the middle of the access cavity. **B,** After using an IAF, a TMAF, and #2, #3, and #4 non-ISO tapers, the 2 files cross beyond the occlusal surface of the tooth because the triangles guarding the orifices have been removed and the files have straightened. Now the curvature of the buccal canals is approximately 30°.

and the apex. Instrumentation for these cases with early flaring is as follows.

Maxillary first molar (re-treatment), mesiobuccal root, mesiolingual canal (Figure 5-34):

Curvature = 35 degrees
Distance from elbow to apex (estimated) = 2 to 3 mm
Working length = 15 mm (measured from reduced cusp with temporary bridge removed)

The silver points and posts were removed with an ultrasonic, which was also used on the floor of the chamber, exposing the orifice to the mesiolingual canal.

1. File with no. 10 file at 15 mm.
2. Clip 1 mm from no. 10 file (making it a no. 12); remove 2 to 3 mm of flutes from outside of curve and file at 15 mm. This file becomes the TMAF and will be used after each file during early flaring.
3. Select a no. 2 non-ISO taper, set the stop at 12 mm (working length of 15 minus 3 mm distance to elbow) and file orifice portion of the canal. (File will probably not go more than 8 mm but, in any case, do NOT go past the stop.)
4. Go back to TMAF, using no. 12 at 15 mm.
5. Select a no. 3 non-ISO taper, set stop at 12 mm, and file the orifice portion slightly deeper than step 3. (File will probably go no more than 9 mm.)
6. Repeat step 4.
7. Select a no. 4 non-ISO taper, set the stop at 12 mm, and file the orifice portion slightly deeper than step 5. (File probably will not go more than 10 mm but, in any case, do NOT go past the stop.)
8. Repeat step 4. Early flaring is now completed; the apical portion of the canal has been minimally prepared without zipping, and the orifice portion has been widened considerably. The files now used at the apex will work more effectively and the irrigants will penetrate throughout the canal.
9. Place a no. 15 flexible file to 15 mm. If this file does not go easily to measured length, go back to the previously TMAF and make it an incremental no. 14. Use this instrument until it is loose and then retry the no. 15. Use rasping action.
10. Place a no. 20 flexible file to 15 mm. File using rasping action.
11. Place a no. 25 flexible file to 15 mm. File using rasping action. The apical portion of the preparation is completed and this no. 25 file becomes the MAF.
12. Place a no. 30 file to 14 mm. File using rasping action.
13. Go back to the MAF, using the no. 25 file at 15 mm.
14. Place a no. 35 file to 13 mm. File using rasping action.
15. Repeat step 13.
16. Place a no. 40 file to 13 mm. File using rasping action.
17. Repeat step 13.
18. Use the previously used #2 taper. This time it should go easily to 12 mm.
19. Repeat step 13.
20. (Optional) You may use the #3 and #4 non-ISO tapers or the finishing files (Figure 5-35) to further widen the orifice, always using the MAF after any file short of the apex to maintain length.
21. Verify completeness of preparation by finger plugger insertion.

Maxillary second molar, mesiobuccal canal (see Figure 5-32):

Curvature = 60 degrees (Figure 5-32, *B*)
Distance from elbow to apex (estimated) = 6 to 7 mm
Working length = 24 mm (verified by Figure 5-32, *B*)

FIGURE 5-34 **A,** Preoperative radiograph of maxillary first molar, treated with silver points 6 years earlier. A periapical radiolucency is associated with the MB root. The points and pins were removed with ultrasonics, which were also used on the floor of the chamber, exposing an untreated ML canal. The temporary bridge had been removed. **B,** Immediate postoperative film, four canals filled with laterally condensed gutta-percha and Wach's paste, post room prepared. **C,** Eighteen months later, lesion is almost totally healed, view from the distal (see Chapter 4). (Restorations by Dr. Steve Pothashnick, Chicago.)

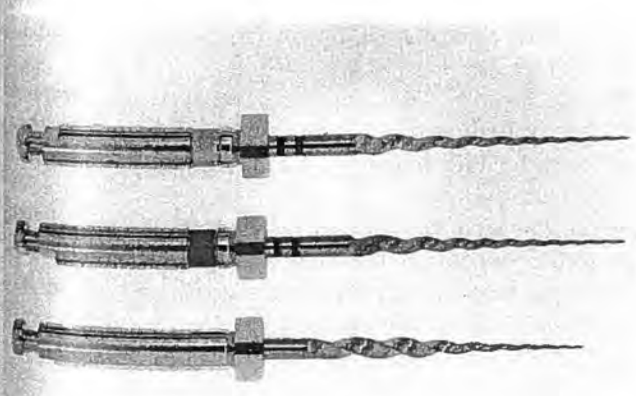


FIGURE 5-35 Finishing files, used to widen orifice areas after apical preparation in revised crown-down technique. There are variable tapers throughout the files, most pronounced in the "shaper" file *(bottom)*.

1. File with no. 10 file at 24 mm.
2. Clip 1 mm from no. 10 file (making a no. 12 file); remove 6 to 7 mm of flutes from outside of curve and file at 24 mm. This file becomes the TMAF and will be used after each file during early flaring.
3. Select a no. 2 non-ISO taper, set the stop at 17 mm (working length of 24 mm minus 7 mm distance to elbow), and file orifice portion of the canal. (File probably will not go more than 11 to 12 mm, but in any case do NOT go past the stop.)
4. Go back to TMAF, using no. 12 file at 24 mm.
5. Select a no. 3 non-ISO taper, set the stop at 17 mm, and file the orifice portion of the canal slightly deeper than step 3. (File probably will not go more than 12 to 13 mm.)
6. Repeat step 4.
7. Select a no. 4 non-ISO taper, set the stop at 17 mm, and file the orifice portion of the canal slightly deeper

than step 5. (File probably will not go more than 13 to 14 mm.)

8. Repeat step 4. Early flaring is now completed; the apical portion of the canal has been minimally prepared without zipping, and the orifice portion has been widened considerably. The files now used at the apex will work more effectively, and the irrigants will penetrate throughout the canal.
9. Place a no. 15 flexible file to 24 mm (this is a normal no. 15 file of a flexible system as it comes from the manufacturer with no flutes removed or tip reduced). This file probably will go easily to the full working length.
10. Place a no. 20 flexible file to 24 mm. If this file does not go easily to the measured length, go back to the previously used size no. 15 file and make it an incremental size no. 17. Use this instrument until it is loose and then retry the no. 20. Use rasping action.
11. Enlarge the apical portion to size no. 25 or no. 30. Don't hesitate to make any file an incremental size if the next file does not go easily, but this probably will not be necessary. Continue to use rasping action. The size no. 25 or no. 30 becomes the MAF.
12. Place a file one size larger than the MAF to 23 mm. File using rasping action.
13. Go back to the MAF at 24 mm.
14. Place a file two sizes larger than the MAF to 22 mm. File using rasping action.
15. Repeat step 13.
16. Place a file three sizes larger than the MAF to 21 mm. File using rasping action.
17. Repeat step 13.
18. Use the previously used #2 taper. This time it should go to the elbow.
19. Repeat step 13.
20. Use the previously used #3 taper. This time it should go close to the elbow.
21. Repeat step 13.
22. Use the previously used #4 taper. This time it should go to within 2 mm of the elbow.
23. (Optional) You may use the finishing files (Figure 5-35) to further widen the orifice area, always using the MAF after any file sort of the apex to maintain length.
24. Verify completeness of preparation by fitting finger plugger.

Points to remember:

1. Keep all canals heavily irrigated. I prefer to irrigate up to size 20 with large amounts of carbamide peroxide (Gly-Oxide) and lesser amounts of sodium hypochlorite (NaOCl). Sizes 25 and above, I use mostly NaOCl, with lesser amounts of Gly-Oxide.
2. Be certain to set the indicator direction on your stop (see Figure 5-18), so you know where the flutes are removed when the files that have been trimmed are within the canal.
3. Do *not* rotate the file, or you will distribute the flutes to portions of the canal where you do not want them.
4. Be prepared to make additional file clips if the next size of file does not go to place easily.
5. Proceed slowly. Use flexible file systems only when working apical to the elbow (Table 5-4).
6. Any customized files—those clipped to make incremental sizes and then flutes removed to decrease zipping—must be discarded after use because they are made to prepare canals with certain specific dimensions. Use of these files in other canals may be detrimental.
7. Despite the fact that many steps are listed (over 20), you will find that the total preparation time is much shorter when using the non-ISO tapered files once you master the system.

The treatment of a mandibular molar with a relatively long distance between the elbow and the apex will now be described:

Mandibular second molar, mesiolingual canal (Figure 5-36):

Curvature = 50 degrees (Figure 5-36, *B*)
Distance from elbow to apex (estimated) = 4 to 5 mm
Working length = 17 mm (verified by Figure 5-36, *B*)

1. File with no. 10 file at 19 mm (Figure 5-37).
2. Clip 1 mm from no. 10 file (making a no. 12 file); remove 4 to 5 mm of flutes from outside of curve and file at 17 mm. This becomes TMAF and will be used after each flaring file in flaring procedure.
3. Select a #2 non-ISO taper, set the stop at 12 mm (working length of 17 mm minus 5 mm distance to elbow), and file orifice portion of the canal. (File probably will not go more than 7 to 8 mm, but in any case do not go past stop.)
4. Go back to TMAF, using no. 12 file at 17 mm.
5. Select a #3 non-ISO taper, set the stop at 12 mm, and file orifice portion of the canal slightly deeper than step 3. (File probably will not go more than 8 to 9 mm).
6. Repeat step 4.
7. Select a #4 non-ISO taper, set the stop at 12 mm, and file orifice portion of the canal slightly deeper than step 5. (File probably will not go more than 9 to 10 mm.)
8. Repeat step 4. Early flaring is now completed; the apical portion of the canal has been minimally prepared without zipping, and the orifice portion has been widened considerably.
9. Place a no. 15 flexible file to 17 mm. This file probably will go easily to full working length.
10. Place a no. 20 flexible file to 17 mm. If this file does not go easily to measured length, go back to the previously used no. 15 and make it a no. 17 file. Use this instrument until it is loose and then retry no. 20. Use rasping action.

TABLE 5-4 Relative Ability of File Systems

Instrument Type	*Manufacturer*	*Process, Blank*	*Penetrating Ability*	*Flaring, Early Flaring*	*Use in Curved Canals*	*Best Use; Comments*
Reamer	Many	Twisted, triangular	*	*	* + $\frac{1}{2}$*	1st intracanal instrument (?); place sealers, medicaments, remove gutta-percha with solvents
K-file	Kerr, then many	Twisted, square	Nos. 08 and 10* Nos. 15 and 20**	**	0	1st improved instruments; straight canals, flaring above elbow
Hedstrom	Many	Ground	$\frac{1}{2}$*	*** (above elbow, only)	Only small sizes	Aggressive cutting, flaring; use in irregular canals as for child patients
K-Flex	SybronKerr	Twisted, diamond	*	** (past elbow) * (above elbow)	***	1st instrument designed for curved canals; slow cutter
Flex-R-Files	Moyco	Ground, safety tip	0	** (past elbow) $\frac{1}{2}$ * (above elbow)	**	1st file manufactured with noncutting tip
Flex-o-file	Dentsply/Maillefer	Twisted, triangular, chlorinox metal	*	** (past elbow) $\frac{1}{2}$ * (above elbow)	***	Curved canals; may be slightly undersized
Golden Mediums	Dentsply/Maillefer	Twisted, triangular, chlorinox metal	*	** (past elbow) $\frac{1}{2}$ * (above elbow)	***	Intermediate sizes only; used for narrow, curved canals
Pathfinder	SybronKerr	Twisted	***	0	*	Penetrating narrow, sclerotic canals, non-ISO taper, about .013; old Kerr No. 01
NiTi	Many	Ground, Nickel-Titanium alloy	–*	*	**	Different metal than previously listed files; used in most rotary files
Rotary Files						
Pro File.04 Tapers	Dentsply/Tulsa Dental	Ground, NiTi, safe tip, U-shape	0	***	*** (only to elbow)	Excellent use for over 10 years; non-ISO taper, mechanical low speed/high torque; series 29 sizing
Pro File .04 Tapers	Dentsply/Maillefer	Ground, NiTi, safe tip, U-shape	0	***	*** (only to elbow)	Same as above, only standardized sizing
Greater Tapers	Dentsply/Tulsa Dental	Ground, NiTi, safe tip, U-shape	0	** (see comments)	*** (well above elbow)	.06 relatively safe, .08-.12 must be used with care, especially on roots with proximal depressions
Quantec 2000, 2001	Originally NT Co., now SybronKerr	Ground, NiTi, some have H-shape	0	**	**	Gone through several design changes; H-shape improves flexibility
K-3	SybronKerr	Ground, NiTi, K-shape	0	***	*** (well above elbow)	K-shape decreases flexibility; good cutter

0, None; $\frac{1}{2}$, poor; *, fair; **, good; ***, excellent.

FIGURE 5-36 **A,** Preoperative radiograph of mandibular second molar. Occlusal caries under a poor crown had caused pulp exposure of long standing. The pulp is necrotic and periapical and distal lesions are present that seem to communicate. **B,** Files are in place in the distal and ML canals. Although I knew a MB canal was present, I had not located it as yet. The file in the ML indicates a curvature of approximately 60°. **C,** The files shown in Figure 5-37 were used in the ML canal, removing the triangle of dentin over the orifice, reducing the angle of curvature to approximately 30° with this no. 20 file. **D,** The non-ISO tapers were moved toward the MB, exposing that orifice and now all three canals have files to working length. **E,** At the next appointment, all canals were filled with laterally condensed gutta-percha and Wach's paste. Note the communicating distal and periapical lesions still present. **F,** A temporary bridge was constructed while other procedures were performed and to allow for evaluation of healing. This film was taken 6 months after canal filling, indicating perfect healing of the lesions. **G,** Radiograph taken 2 years after original treatment, indicating complete healing and normal appearance of periapical tissues, and treated tooth is functioning well as posterior bridge abutment. (Restorations by Dr. Kerry Voit, Chicago.)

11. Enlarge the apical portion to size no. 25 or no. 30. Don't hesitate to make any file an incremental size if the next fill does not go easily, but this probably will not be necessary. Continue to use rasping action. The size no. 25 or no. 30 becomes the MAF.
12. Use a file 1 size larger than the MAF and file to 16 mm. Use rasping action.
13. Go back to the MAF at 17 mm.
14. Use a file two sizes larger than the MAF and file to 15 mm. Use rasping action.
15. Repeat step 13.
16. Use a file three sizes larger than the MAF and file to 14 mm. Use rasping action.
17. Repeat step 13.
18. Use a file four sizes larger than the MAF and file to 13 mm. Use rasping action.
19. Repeat step 13.
20. Use the previously used #2 non-ISO taper. This time it should go easily to 12 mm.
21. Repeat step 13.

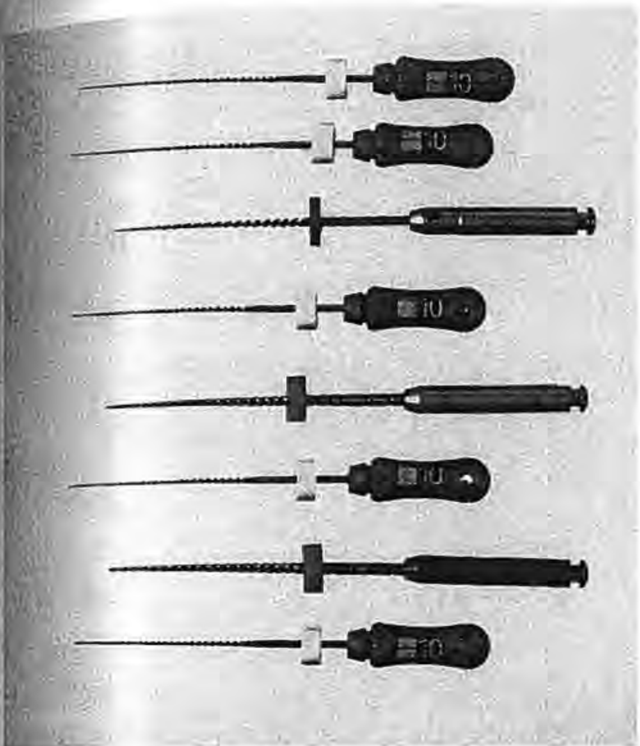


FIGURE 5-37 Files used sequentially in ML root of case shown in Figure 5-36. *From top,* no. 10 file (IAF), no. 12 file (TMAF), #2 .04 taper, TMAF, #3 .04 taper, TMAF, #4 .04 taper, TMAF. Preparation was completed to MAF of size 30.

22. (Optional) You may use the #3 and #4 non-ISO tapers or the finishing files (see Figure 5-35) to further widen the orifice, always using the MAF after any file short of the apex to maintain length.
23. Verify completeness of preparation by fitting finger plugger, and prepare for filling.

Curvatures of Greater Than 60 Degrees. The previous three sample preparation schedules can be modified for curvatures of 30 to 60 degrees. In canals with curvatures even greater, it is still possible to gain a desirable result (Figures 5-38 to 5-40) by clipping 0.5 mm increments and removing flutes to produce many incremental, customized sizes, if necessary. Cases of this type should not be attempted unless the operator has had considerable experience in curved canals and has mastered completely the techniques for lesser curvatures. Also, it is difficult to enlarge these canals safely apically beyond size 25. Therefore, in order to fill these canals, the dentist must be able to manipulate gutta-percha cones for that narrow diameter.

The critical portion of the preparation technique recommended for curvatures of 60 degrees and greater is the very small amount of increase in file tip width for successive files used to widen the apical portion. It has long been known that in these very difficult canals, everything may seem to be going smoothly, but suddenly, when a new file is introduced, a ledge, zip, or other undesired incident results.

Consequence of Position of the Elbow. The objective for using a customized file technique is to prepare an instrument for the individual variabilities of a canal. The position of the elbow can vary tremendously, from only 1 or 2 mm (see Figure 5-34) to 6 mm or more (see Figure 5-36). This calculation must be made in each case and retained throughout the preparation phase for optimal results.

Preparation of Bayonet-Curved Canals. The bayonet, or double-curved, canal often poses considerable problems during endodontic therapy, and not without cause (Figures 5-41 and 5-42). In actuality, it is not as complicated as it appears and can be safely enlarged and filled as long as several factors are kept in mind.

1. Protect against the zip in the area of the more apical curve, but the more coronal curve is straightened to gain better access to the apex. The distance to the elbow and the angle of curvature are calculated as before. Flutes will be removed from the outer side of the curve accordingly.
2. Once the working length is established with a small file, that file must not be totally removed from the canal until it is very loose. In many instances, the initial small flexible file will reach to the apical portion of the canal. However, if the file is removed prematurely, it becomes extremely difficult to gain the correct length with another file, even one of the same size. Therefore, once the correct working length is established by radiograph, the file is not removed but is worked up and down only several millimeters per movement until minimal resistance is felt. Only then may the instrument be removed.
3. Clip minimal increments from each file, working up at not more than 0.5 mm removals and then only when that file is very loose within the canal. The danger of enlarging the bayonet curve is that the file becomes stuck at the first curve and ledges or starts to perforate at that site. If the operator panics and attempts to force the instrument, the condition will quickly worsen. Working up too rapidly through the sizes only increases the chances for this undesired ledging.
4. Flare very carefully, but widen the orifice portions liberally and early in a buccolingual direction. It is more critical to flare extensively in bayonet cases than single curvatures. Because the more coronal curve will be greatly straightened, that portion of the canal is not enlarged evenly, and it does not retain its original shape.
5. The reader should realize that the cases presented in Figures 5-41 and 5-42 came out extremely well.

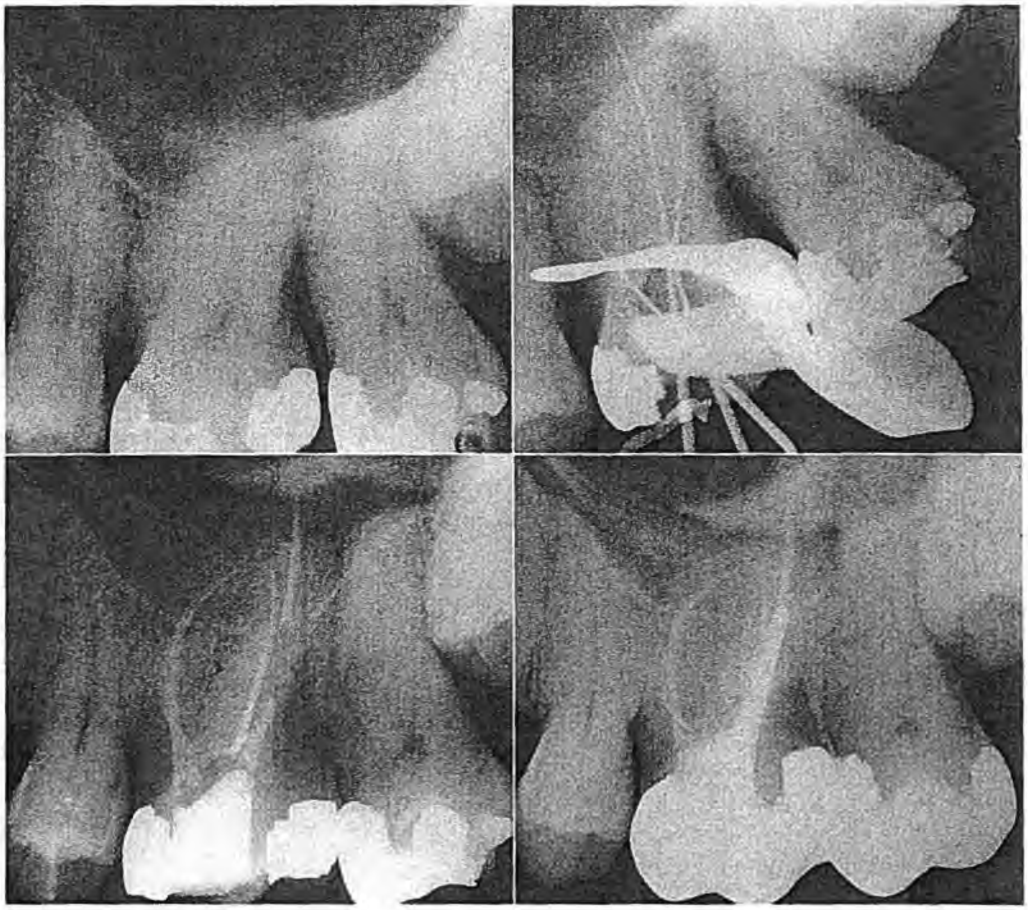


FIGURE 5-38 **A,** Preoperative radiograph of maxillary first molar; canals obviously are quite curved. **B,** Files in place indicate a curvature in the mesiobuccal of approximately 55° and an elbow at 7 to 8 mm. The curvature in the distobuccal is approximately 30°. The curvature in the palatal appears much less because the root is curving directly toward the x-ray cone (see Table 5-3), but it is probably greater than 30°. To prepare the mesiobuccal canal, early flaring was used followed by customized files in sizes 12, 14, 17, 19, 22, and 24 (this was before the introduction of .04 tapers). **C,** The canals were filled with laterally condensed gutta-percha and Wach's paste. **D,** Three years later. (Restorations by Dr. Richard Lammermayer, formerly of Kenilworth, Ill.)

However, I have attempted to treat many other similar teeth, and often the results are not nearly as excellent.

NEW FILE SYSTEMS FOR PREPARATION OF CURVED CANALS

In the past 15 years a plethora of new file system designs have been introduced for preparation of curved canals. As usual with most new products, several of these have been very useful and efficacious, but others have been worthless, and some have been potentially detrimental. Table 5-4 provides a listing of older and newer file systems and their usefulness for various aspects of canal preparation.

There have been three major areas of development for these systems: (1) increase in flexibility by changes in file designs, (2) increase in flexibility by changes in file metals, and (3) files that do not zip because of flute removal or modified tips.

Effects of Increased Flexibility on Final Canal Shape

One of the major reasons why larger files alter canal shape so quickly as opposed to the smaller sizes is that the instruments decrease in flexibility as the sizes increase. In this context, I am defining the word *flexibility* to mean the ability to stay bent in a curved canal and not attempt to straighten. The degree of flexibility may differ from manufacturer to manufacturer and even among batches of instruments by the same manufacturer.

In general, when a difference in flexibility is present in the same size of files by different companies, the more flexible files will alter canal shape less than will the less flexible files of the same sizes (Figure 5-43). By the same

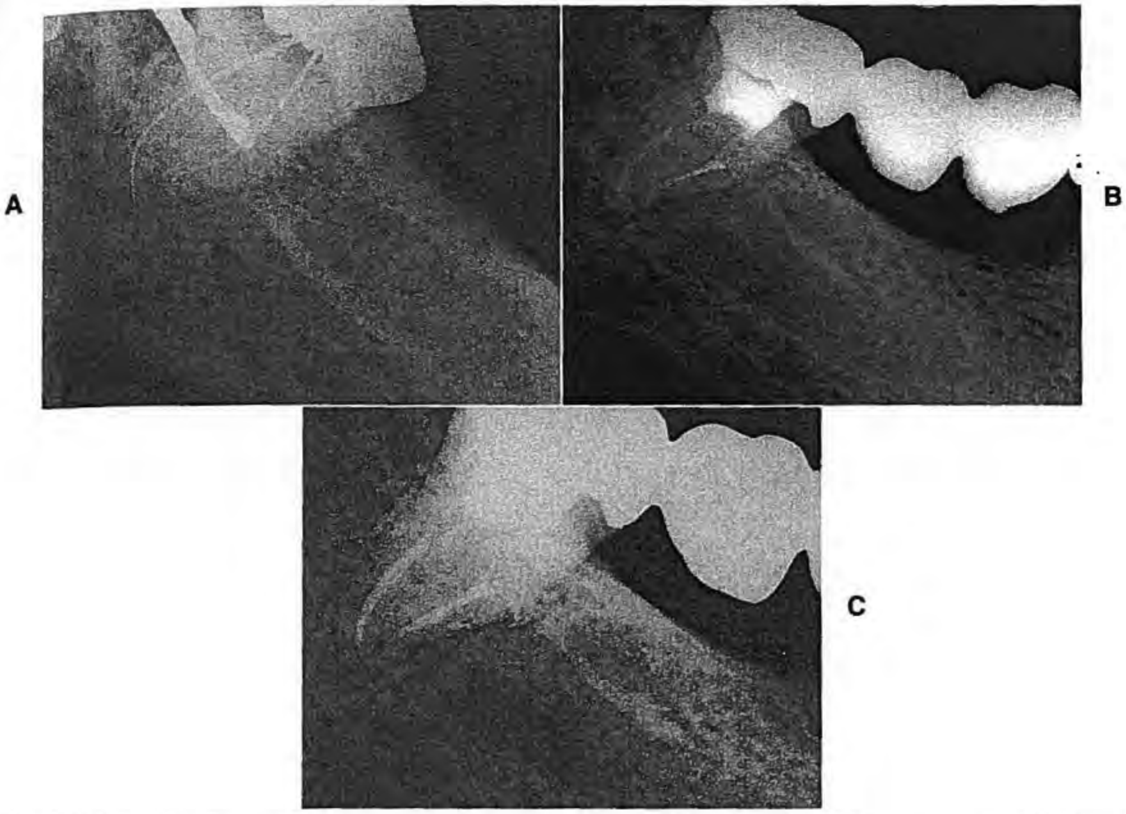


FIGURE 5-39 **A,** Files in place in mandibular second molar, extremely curved distal canal with elbow approximately 2 mm from apex. Compare to Figure 5-38 in which elbow was approximately 7 mm from the apex. **B,** Canals filled with laterally condensed gutta-percha and Wach's paste. Note how the curvature in the distal canal was maintained by careful use of customized files. **C,** Two years after completion of treatment, normal periapical areas maintained. (Restoration by Dr. Steve Labkon, Kenilworth, Ill.)

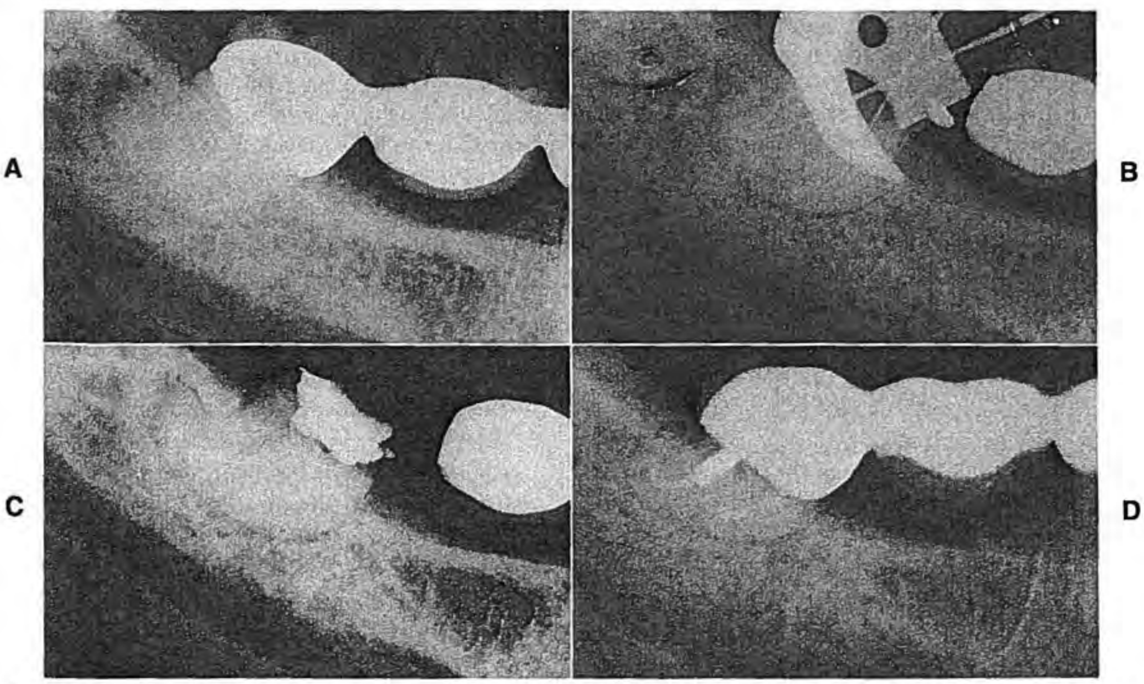


FIGURE 5-40 **A,** Mandibular third molar with extreme curvature of both roots, distal apical radiolucency, and distal bridge abutment. **B,** Files in place, indicating curve on mesial of 85° and on distal of 120°. Both canals were prepared with clips of 0.5 mm and enlarged apically to size 25 with flaring to size 40. **C,** Canals filled with laterally condensed gutta-percha and Wach's paste; post room in distal. **D,** Excellent healing 1 year later. (Restorations by Dr. Steve Mele, formerly of Oakbrook, Ill.)

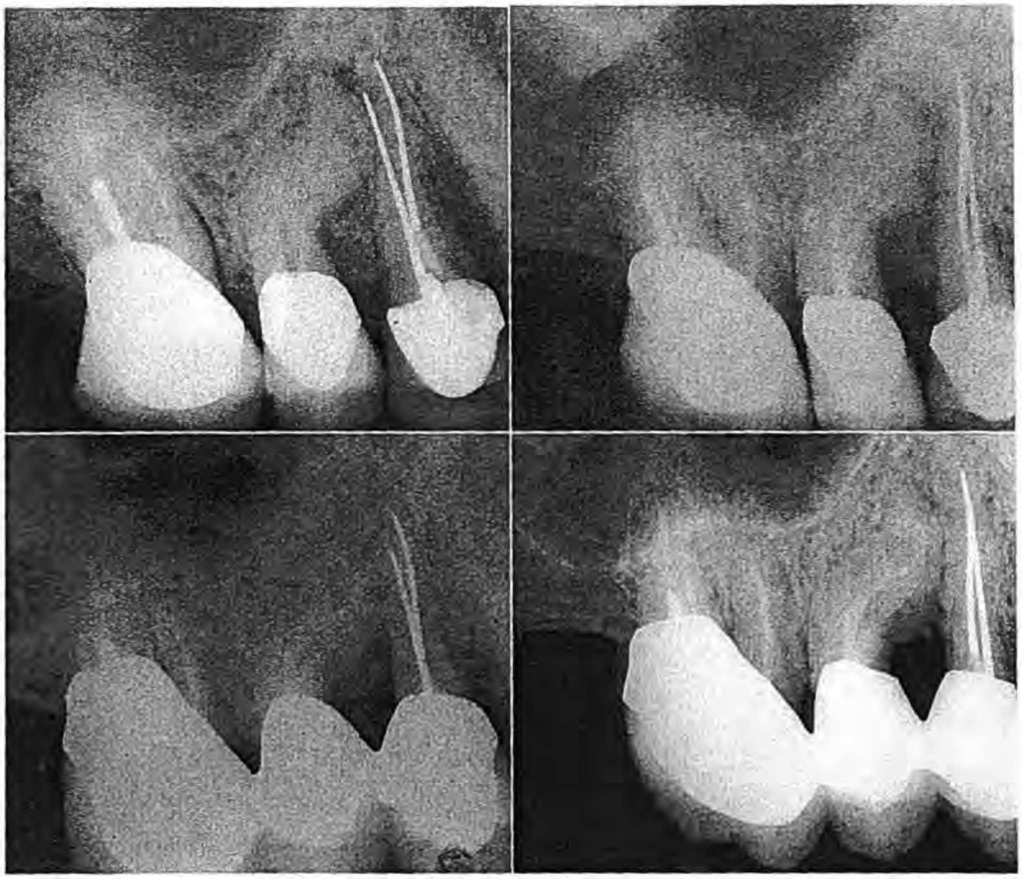


FIGURE 5-41 Double-curve successfully treated with customized files prior to introduction of .04 tapers. A, Preoperative radiograph of maxillary posterior area. Treatment had been performed on the first bicuspid 12 years earlier and on the first molar 7 years earlier. A periapical lesion is seen associated with the second bicuspid, and a double curvature is present in that root. **B,** Maximal reverse flaring was performed for the two canals, and flutes were removed for 4 mm on the mesial side of customized files to protect against mesial opening of the file at the tip. Canals were filled with vertical condensation using a modified chloropercha technique (see Chapter 7). I removed the crown during treatment and did not cement it correctly. Periapical lesion has decreased considerably since the treatment was started 1 month earlier. **C,** Nine months later, periapical lesion has healed and a splint is in place. Periodontal surgery had been performed on the mesial of the second bicuspid. **D,** Six years after original treatment, periapical lesion has healed and remained in normal condition. Area of periodontal surgery also has improved. Bicuspid and molar now 18 and 13 years postoperative, respectively. (Restorations by Morton Schreiber, Highland Park, Ill.)

token, the more flexible files remove less tooth structure than do the less flexible files, assuming the same unit of time. When one uses the more flexible files, which seem more desired in the curved canals, the aspect of flaring must receive particular attention so the more coronal portions of the canal are made wide enough to allow for the filling procedures.

Flexible File Systems

As mentioned earlier in this chapter, the first flexible file to be introduced as an aid for preparation of curved canals was the K-Flex (see Figures 5-4, *C*, and 5-45, *bottom*). These files quickly increased in popularity because it was clearly seen that they minimized drastic change in the shape of canals with moderate curves (approximately 30 degrees). Examination of plastic blocks (see Figure 5-43) and cases treated with these new instruments (Figure 5-45) clearly indicated their usefulness.

The success of the K-Flex led to further attempts to design more flexible file systems, and the next entrant into this field was the Flex-o-file.* This instrument utilized a triangular blank, as used for the reamer (Figure 5-45, *top*; see also Figure 5-4, *A*), with the flutes twisted more tightly to give more cutting edges but maintaining the same narrow cross-sectional diameter for increased flexibility.

*Caulk/Dentsply, Milford, DE 19963.

FIGURE 5-42 Double curve treated with customized files and .04 tapers. A, File is placed in maxillary second bicuspid with double curves of approximately 45° each and a periapical lesion. **B,** The size no. 10 file was worked up and down several mm to the working length for approximately 10 minutes to establish a clear path through the canal system. This was followed by using #2, #3, and #4 .04 tapers to the first curve, always followed by the IAF to the apex. Customized files were used from no. 10 through 25, including a number of intermediate sizes. At the third appointment the canal was filled with gutta-percha and Wach's paste. **C,** Six months later, the lesion has decreased in size. **D,** One year after treatment, the lesion continues to decrease, although it is difficult to see behind the implant. (Restorations by Dr. Kerry Voit, Chicago.)

Nickel-Titanium Files

More flexible systems were also developed by changes in the metal from which the files were made. Instead of the carbon steel (used for the old 1 to 12 designations and in a few of the more modern systems) or stainless steel (used in most file systems presently), nickel-titanium was introduced for endodontic use. Called *NiTi files,* these instruments have the ability to return to their original shape, even if bent severely and held in this position for a long time (Figure 5-46, *A*). They have minimal resistance to pressure, and thus have been considered to be "flexible." Whether or not they are truly flexible is a matter of semantics. I believe they have great memory and usually will return to their original (straight) shape. If this happens at the tip or through the apex of the tooth, overinstrumenting the canal, the result may be undesirable. Files that straighten at the apex or through the tip of the canal will produce zipping (see Figure 5-20, *A*).

Because they have so little resistance to pressures, the NiTi files cause little change in canal shape when they are used by hand. However, by the same token, when used by hand, these files do very minimal preparation for given time periods. Therefore, it has been suggested that they be used in mechanical handpieces to complete preparation in a reasonable amount of time (Figure 5-46, *B*).

Minimizing Zipping by Flute Removal and Modification of Tips

The first article dealing with flute removal, by Weine, Kelly and Lio, was published in 1975. Although the paper indicated that the technique was effective in reducing alteration of canal shape in curved canals of both plastic blocks and clinical cases, only a small number of dentists were moved sufficiently to utilize the method in their own endodontic treatments.

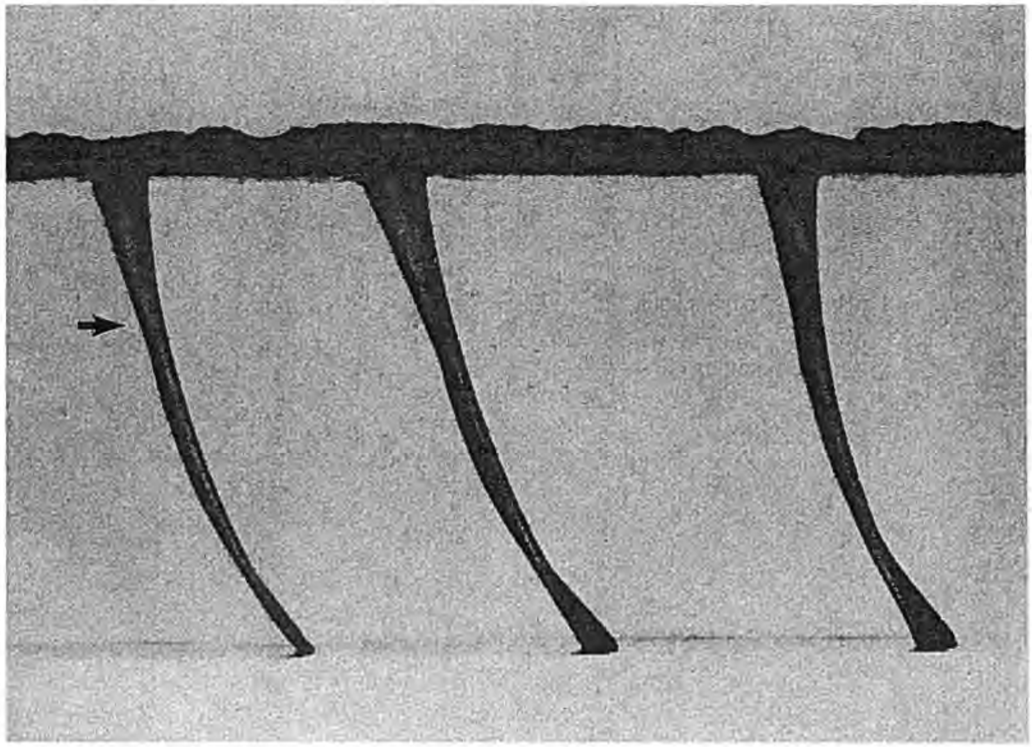


FIGURE 5-43 Plastic block canals prepared with files of various flexibilities. Canal at left *(arrow)* was prepared with Kerr K-Flex files to size 30 and no removal of flutes. Minimal elbow and virtually no zip. Center canal was prepared with files to size 30 from a company that manufactures very inflexible files. Narrow elbow and wide zip. Right canal was prepared to size 30 by the most inflexible files I could find, regardless of the manufacturer. Considerable zipping and constricted elbow.

This original paper did spark a number of investigations, virtually all of which endorsed its conclusions. Gradually, more techniques and modifications were introduced that attempted to alter the shape, position, or presence of file-cutting ability to maintain canal shape.

In 1985 and 1986, papers were written by Roane, Sabala, Powell et al and others from the group at the University of Oklahoma, suggesting a new preparation technique, called "balanced forces." Among other aspects of therapy, this method recommended use of file rotation, filing to the radiographic apex, and the use of only three preparation regimens to cover every type of canal width, length, or degree of curvature. These theories are all completely contrary to my own. In these reports, however, a new type of file was suggested for use with this technique, the Flex-R-File.* This file had its tip modified so that there were no cutting edges or surfaces present (Figure 5-47). Studies indicated that this new shape reduced ledging and root perforation because the nonworking tip acted merely as a guide for the instrument to pass through the curved portion of a canal without removing dentin. Since that time, many companies have changed their file tips to this new shape.

In theory, tip modification is the next evolutionary change after removal of flutes because the cutting ability in the apical area is restricted and therefore zipping is reduced. I believe that it is the Flex-R-File, not the theory of balanced forces, that has enabled cases treated with that technique to be successful. Benenati et al addressed iatrogenic strip perforations treated successfully at the University of Oklahoma. To obtain the sample size necessary to report on this procedure, a huge number of molar teeth had to be available with strip perforations, a common problem with the file rotation recommended in balanced forces but uncommon in a rasping-only method. Sabala et al also reported that in a technique course using balanced forces at that school, instrument breakage was 17%. This number is incredibly high, but again, typical of a rotation technique, although very rare of when using rasping only.

A similar modification recently introduced is the pilot tip, used for the Canalmaster,* where a noncutting tip of 1.5 mm is present, followed by several millimeters of cutting flutes and then a more narrow smooth shaft. Several other instruments have pilot tips.

*Union Broach Co., New York, NY 10010.

*Brasseler USA, Savannah, GA 31419.

FIGURE 5-44 **A,** One of the first molar teeth to be treated with a flexible file system. Film of files in place of mandibular second molar, indicating curves of approximately 30° in the mesial canals and large periapical lesion. Canals were prepared with K-Flex files to the full working lengths and apical to the elbow, incremental instrumentation used to create intermediate sizes, and Hedstrom files for flaring coronal to the elbow. **B,** Film taken after canal filling with laterally condensed gutta-percha and Wach's paste, with post room prepared. Minimal zipping despite no flutes removed during preparation. **C,** Eight years after treatment, excellent healing. (Restoration by Dr. John Davis, Park Ridge, Ill.)

Disadvantages of Flexible Files

When the new flexible instruments were introduced for treatment, they became very popular almost immediately for use in small, curved canals because they performed the function of enlargement very well. However, some portions of this type of preparation were not clearly understood.

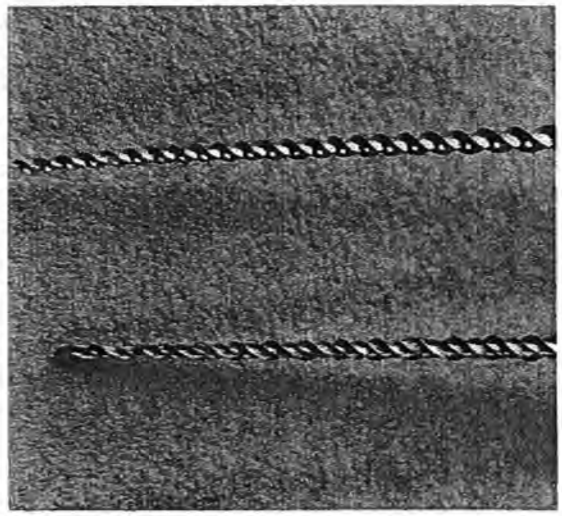


FIGURE 5-45 Flutes of two popular flexible file systems. The K-Flex file *(bottom)* is the result of twisting a diamond blank (see Figure 5-4, *C*) to give cutting edges. Close examination reveals that only every other edge is a true cutting edge. However, this skip of cutting edges helps to remove more dentin and debris from the canal. The Flex-o-file *(top)* uses a triangular blank (see Figure 5-4, *A*), as typically used for reamers, but it is twisted more tightly to give more cutting edges. The triangular shape yields the narrowest cross-sectional diameter among the variously shaped blanks for twisting.

Three different functions must be performed by instruments for treating curved canals, and a single file system rarely performs all of these. They are (1) penetration, the ability to gain access to the tip of a narrow canal; (2) need for flaring and early flaring; and (3) maintaining the shape of the curve. The flexible file systems, while being excellent for maintaining curves, are very poor in penetrating to the tip of these channels, often lined by sclerotic dentin deposits that make the walls very irregular. When flexible files were used in an attempt to traverse such canals, many would buckle, just like a wet noodle, particularly when the small sizes (nos. 08 and 10) were used. Clearly, for this function, the older, unmodified tipped instruments are superior. The files available with their primary functions are listed in Table 5-4.

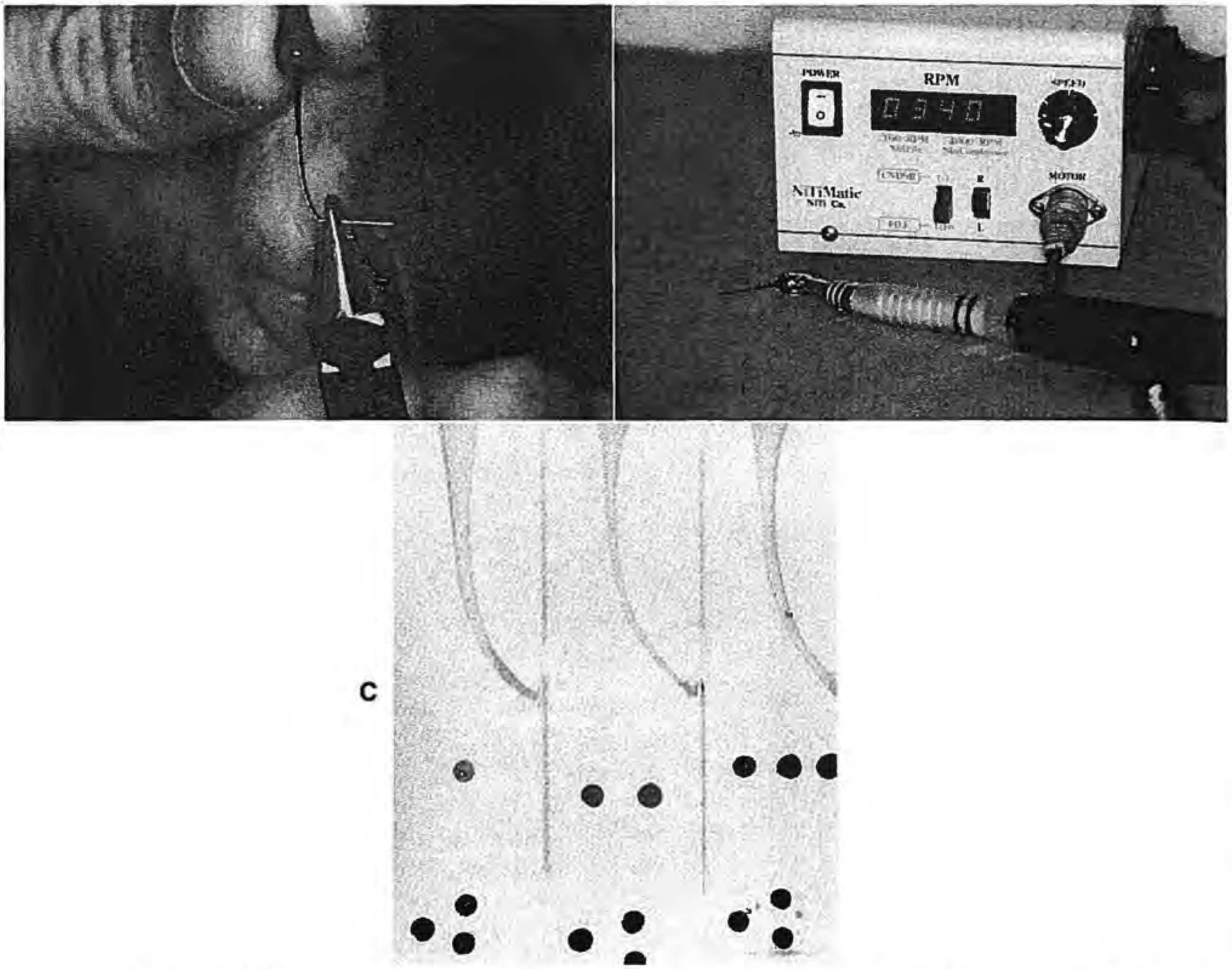
Non-ISO Taper File for Penetration

To perform the function of reaching the apex of a curved, sclerotic canal, another type of file was needed. In the old 1 to 12 system, Kerr* had manufactured such an instrument as its no. 1.

The old Kerr no. 1, not having been manufactured with any thought of accordance with a standardized taper, in fact had a very narrow taper of approximately 0.015 per millimeter of width for every 1 mm of length. With a tip size of approximately 0.12, the D_{16} width was only

*Sybron Endo, Orange, CA 92687.

A



B

C

FIGURE 5-46 Use of NiTi files. A, Files made of nickel-titanium have been described as "superelastic" because of their ability to return to their original shape. This NiTi was bent with a pliers at 90° for 1 hour, but when released, it returned to being straight. **B,** Because the NiTi instruments are slow cutters, canal preparation is very slow and removes minimal amounts of tooth structure unless the instrument is used with a mechanical handpiece. **C,** Three plastic blocks, all prepared for the same length of time, all with early flaring. *Left,* NiTi with mechanical handpiece; *center,* NiTi by hand; *right,* customized files with flutes removed (similar to Figure 5-28). *Center,* NiTi by hand indicates a minimally prepared canal. The two side blocks are fairly similar, with the mechanical NiTi canal *(left)* having a smoother taper than the hand-prepared canal *(right),* with a more irregular taper. (Courtesy Dr. Mary Campbell, LaCrosse, Wis.)

0.40 mm. However, this non-ISO taper gave it better ability to be twisted and forced into a small, tortuous canal than the flexible instruments, particularly because the metal used was carbon steel.

PREPARATION OF TYPE II CANAL SYSTEMS

As shown in Figure 4-2, four common canal configurations are possible. The Type II system consists of two canal orifices exiting the chamber, then merging within the body of the root into a single canal to the site of exiting. This system is most frequently found in the mesial roots of mandibular molars and maxillary second bicuspids, but it also may occur in any bicuspid, the distal root of mandibular molars, and mesiobuccal root of maxillary molars.

The most difficult root with a Type II system is the mesial of the mandibular molar, where curvatures complicate the relationship of the two canals. However, a Type II system still is easier to prepare and fill than a Type III system of similar canal width and curvature.

The standard method for preparation of a Type II system is to select one of the branches to be the master canal, prepare that completely, and then file the other, dependent, canal merging into it. Although that is not difficult in most bicuspids, the mesial root of the mandibular molar may cause problems (Figure 5-48). In the mandibular first molar the mesiolingual should always be selected as the master canal. In the mandibular second molar, the mesiolingual usually is preferable as the master

FIGURE 5-47 Tip of the Flex-R-File, indicating total absence of cutting ability, which should eliminate ledging and greatly diminish zipping. (Courtesy Union Broach Co., New York.)

canal, but in some cases the mesiobuccal is the better choice. In bicuspids the choice varies between the buccal and palatal canals. The master canal is chosen on the basis of being the canal most consistent with the root curvature.

It may seem logical to file the master canal to its entirety, then file the dependent canal to the site of merging. Doing that, however, may cause dentin shavings from the dependent canal to block off the master canal at the point of confluence and prevent filling to the desired end point.

The correct method involves alternating preparation between the two canals, starting and ending in the master canal but also enlarging the dependent canal between work on the master. A typical case of this type is shown in Figure 5-49; the working length of the mesiolingual (master canal) was verified at 19 mm, and the site of confluence (working length of the dependent mesiobuccal canal) was 17 mm. The mesiolingual was enlarged with a size 10 file to 19 mm, then the mesiobuccal with a size 10 to 17 mm, and then the mesiolingual again to 19 mm to prevent dentin from packing at the point of confluence. When a size 15 could be used, it was passed down the mesiolingual to 19 mm, then into the mesiobuccal to 17 mm, and back into the mesiolingual at 19 mm. This system was continued until the MAF was reached and until flaring was performed similarly. Reverse flaring, removal of flutes, or customized files might be used as necessary.

The key step in these preparations is to pass the file the full working length in the master canal following every file used in the dependent canal to ensure patency to the apex. Type IV canal systems (see Figure 4-2), one main canal that branches into two separate and distinct canals at the apex, are very complicated to prepare. Once each branch (buccal and lingual) has been located and measured, preparation will be easier if the main segment is widened buccolingually so that the files will find the apical branches more readily. This may be accomplished by early flaring.

A

B

FIGURE 5-48 **Incorrect method for preparation of Type II canal system. A,** Radiograph of files in place for treatment of mandibular first molar. The file in the mesiolingual went 20 mm, and the file in the mesiobuccal canal joined it at 18 mm (this view was slightly from the distal). The mesiolingual was made the master canal and was enlarged to size 30 at that length and flared to size 45. Then the mesiobuccal canal was enlarged apically to size 30 at 18 mm and flared to size 40. Unfortunately the filing from the mesiobuccal canal packed off the mesiolingual canal at the point of confluence. **B,** When the canals were filled, a ledge was created at 18 mm, and no filling material could be packed past that site. The case was jeopardized by the error in preparation.

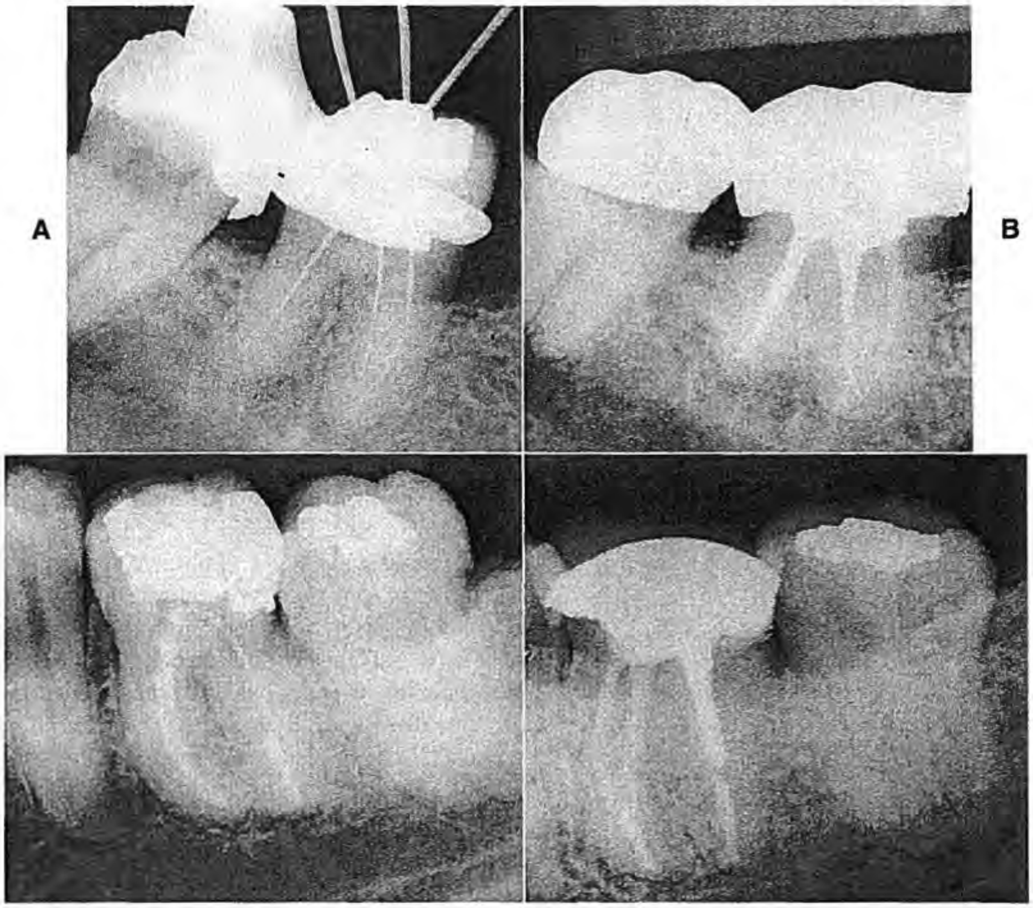


FIGURE 5-49 Correct preparations for Type II canal systems. A, Radiograph of mandibular second molar with files in place, angled from mesial. Canals merged short of the apex, and the mesiolingual was made the master canal. It was filed to the apex with a no. 10 file, the mesiobuccal canal was filed to the point of confluence with the no. 10 file, and then the mesiolingual was filed the full length with the no. 10 file. This procedure was continued through size 30 to the full working length and flared to size 45, alternating between the mesiolingual and the mesiobuccal and always ending with the mesiolingual. **B,** One year after treatment, very extreme angle from the mesial indicates that the mesial canals have been filled to their full lengths. **C,** Mandibular first molar, similarly treated, straight-on film immediately after filling. **D,** Extreme angle from the mesial 1 year after treatment, indicating that the canals in the mesial root have been filled to their full lengths. (Restorations by Dr. Robert Salk, Chicago.)

COMPLETE ENDODONTIC TREATMENT OF PRIMARY TEETH

In most instances complete endodontic treatment—that is, total canal preparation and filling with gutta-percha—is not required in primary teeth. Pulpal involvement without apical spread of inflammation or infection may be treated by pulpotomy, and even if the periapical tissues do become involved, the canals may be prepared routinely but filled with a medicated paste (see Chapter 14). However, if a primary tooth with no permanent successor develops pulpal or periapical involvement, I prefer to treat with complete routine methods of therapy (Figure 5-50).

In single-canaled teeth this is usually no problem (Figure 5-51) because the canals are relatively large and straight, although shorter than those of the permanent teeth. Even though permanent successors are absent, the primary teeth may still display some apical resorption; thus preparation of the dentin matrix must be carefully done. Because the roots are not large, canal preparation wider than size 40 is discouraged. Flaring may be minimal because the roots are so short and straight.

However, complete treatment of primary molars is as complex as any procedure in endodontics. The canals may be quite wide buccolingually yet narrow mesiodistally (Figure 5-52, *B*). The roots are much more curved than in permanent teeth because they have the shape that is supposed to act as a crypt for the permanent tooth. In the maxillary second primary molar, the curve of the mesiobuccal root first to the mesial and then to the distal is readily seen on the radiograph, as is the curve of the distal root first to the distal and then to the mesial (see

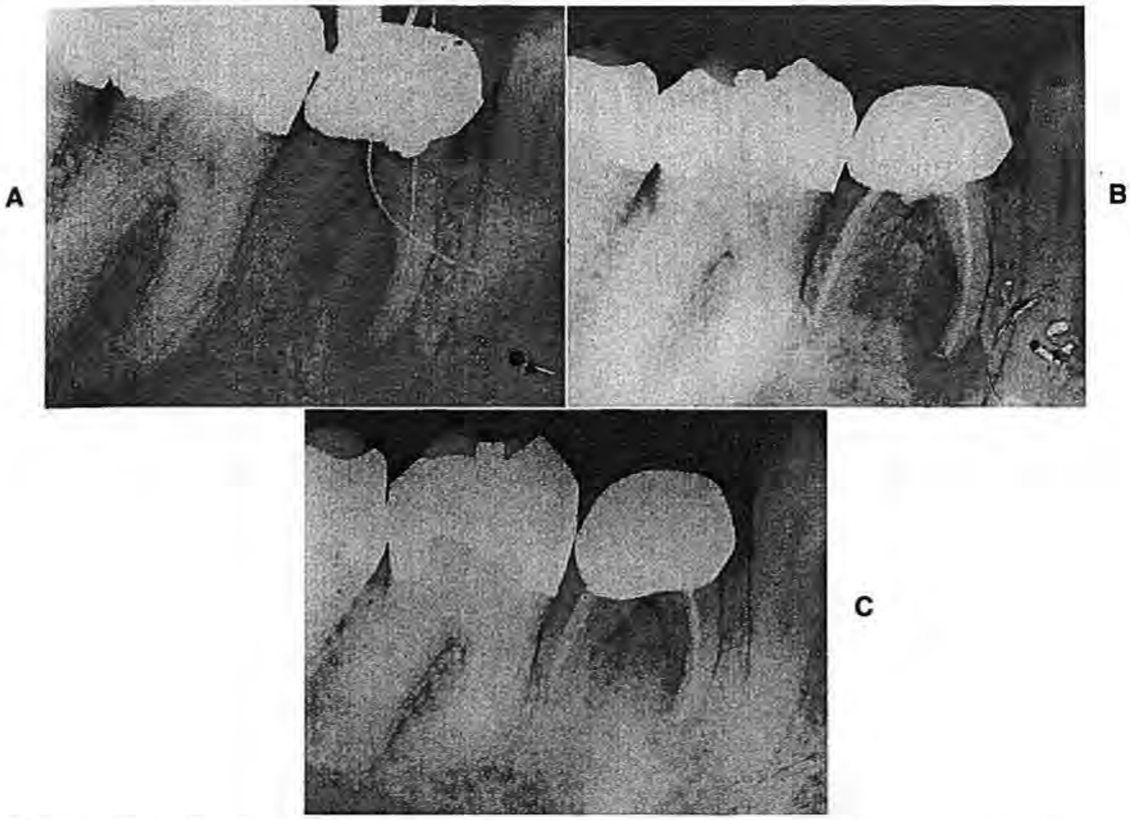


FIGURE 5-50 **A,** Radiographs of initial files in place after referral from a general dentist for treatment of primary second molar without permanent successor. Perforation into furcation and a large apical radiolucency of mesial root. **B,** Completed treatment. Canals filled with laterally condensed gutta-percha and furcation perforation sealed with ZOE. **C,** Excellent healing 2 years later. (Endodontics by Dr. Gene R. Palmer, formerly of Escondido, Calif.)

Figure 5-50, *B*). However, unseen on the film is the curve of the palatal root first to the palatal and then to the buccal and the buccal roots curving initially to the buccal and then to the palatal. These curves may be quite severe, and the chances of zipping at the apex and/or strip perforating in the center of the curves are always present.

To prepare these canals properly, the practitioner must use small increments of file clips and remove flutes to protect against the zip. Fortunately the roots are fairly short, so apical pressures on the files are minimized. Radiographs of the maxillary molars are quite difficult to evaluate because of the angles of the projections and the overlapping of radiopaque structures. Because of the strangely shaped canals, much irrigant is needed because it is doubtful whether the files themselves would be able to clean the canal sufficiently.

Lateral condensation of gutta-percha is suggested for filling (see Chapter 7), but vertical condensation should not be attempted because the roots are so thin and susceptible to fracture. Excess sealer and cones are common due to the frequency of unexpected apical resorption (Figure 5-52, *C*).

ULTRASONICS

History of Ultrasonics in Dentistry

Ultrasonic devices have been used in industry to remove unwanted materials and debris for many years. In 1957 Richman reported on the use of a barbed broach connected to an ultrasonic delivery system for use in canal preparation and apical resection. Other applications in endodontics were not reported for more than 20 years, but vibrations at ultrasonic levels (20 to 30 kHz) were used in medicine and dentistry for cleaning instruments during this period.

Then, beginning in 1980, Martin and Cunningham and their group in the Washington, D.C./Bethesda Naval Hospital area started to report studies on many aspects of ultrasonic treatment. At this same time, Miyahara and others in Japan evaluated ultrasonic use, most specifically in canal preparation and cleaning, but also with removal of unwanted items from the canal space and as a method for thermoplasticizing gutta-percha for canal filling.

These innovators sparked many additional investigations into newer techniques, wider ranges for use, and improved delivery systems. Research in the area of ultra-

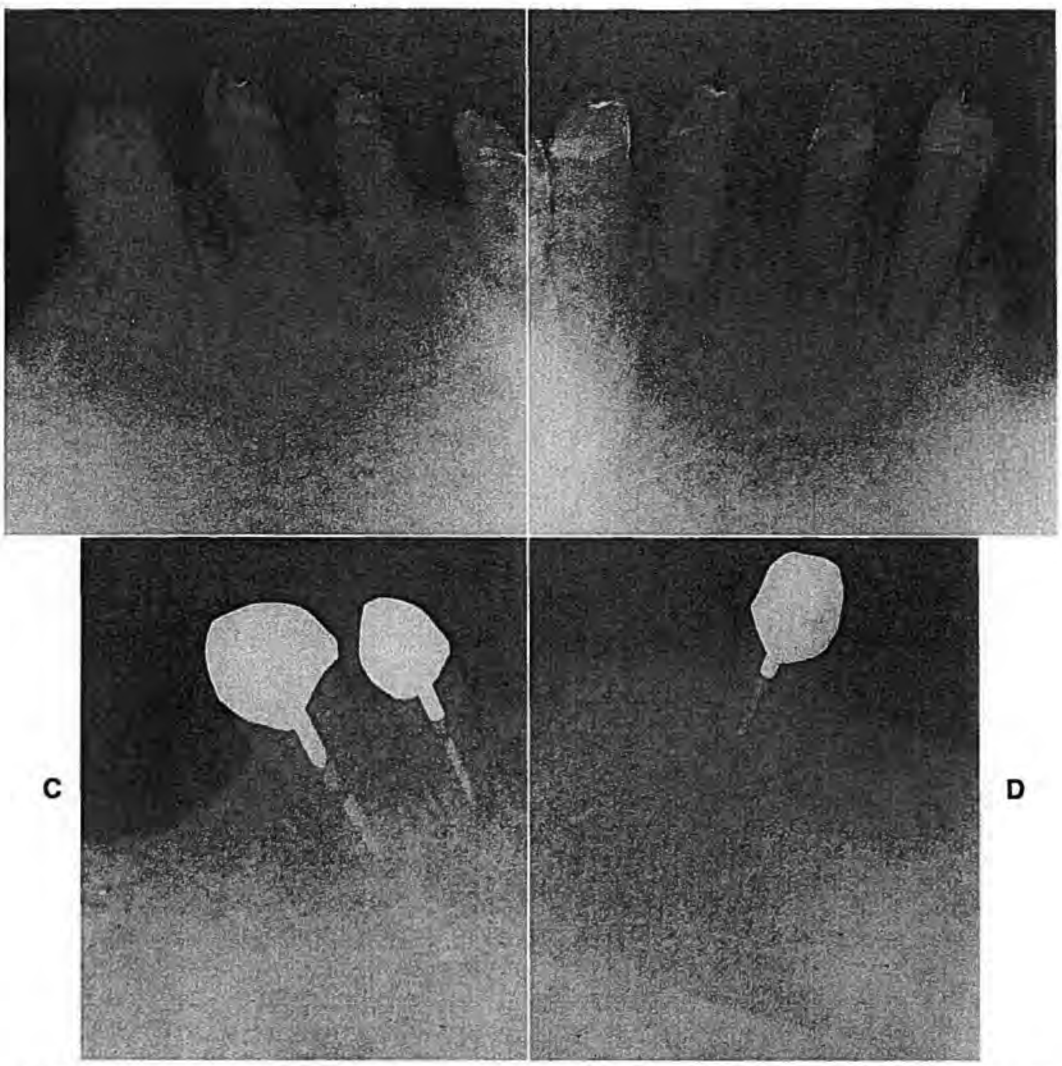


FIGURE 5-51 **Mandibular incisor area.** Although patient was 30 years old, only primary incisors were present without permanent successors. Because of the resorptive defect on one tooth and the large lesion on the other, two incisors were extracted. **A** and **B**, Preoperative radiographs. **C** and **D**, One year later, endodontics completed. Canals are filled with laterally condensed gutta-percha and Wach's paste; post rooms prepared. Teeth are supporting overpartial.

sonics has allowed for many teeth to be saved that could not be treated successfully otherwise. This is particularly true for many endodontic specialists who find much of their practice being devoted to re-treatments. Removal of canal fillings and posts from failing cases facilitates successful nonsurgical re-treatment in many instances where surgery had been the only choice. Even if surgery were ultimately necessary, the resection could be performed down to solidly filled canals, where the chance for success was higher than with apically placed fillings.

Recently, ultrasonic tips have been designed to facilitate surgical access to root tips. Because these tips are smaller than standard burs, the preparations are smaller, apt to remain well within the confines of the tooth (a problem on some occasions with burs), and provide a cleaner environment for the apically placed filling (see Chapter 9).

Method for Action

Martin and Cunningham have coined the term *endosonics* to refer to endodontic treatment by supersonic, sonic, or subsonic systems. They also have stated that the use of this equipment creates a *synergistic system* whereby canal preparation and cleaning, irrigation and disinfection, and canal packing and filling are all accomplished with the same group of devices.

Ultrasonic cleaning was described initially as *implosion* or *cavitation*. Cavitation occurs when the ultrasonic file vibrates in a liquid to produce alternating compressions and rarefactions of pressure. A negative pressure develops within the exposed cells of the intracanal materials (pulp tissue, bacteria, debris, metabolites, substrates, etc.). This causes an implosion, or inward explosion, that breaks these cells apart inwardly and leads to their destruction. Because an irrigation/aspiration system is employed in the

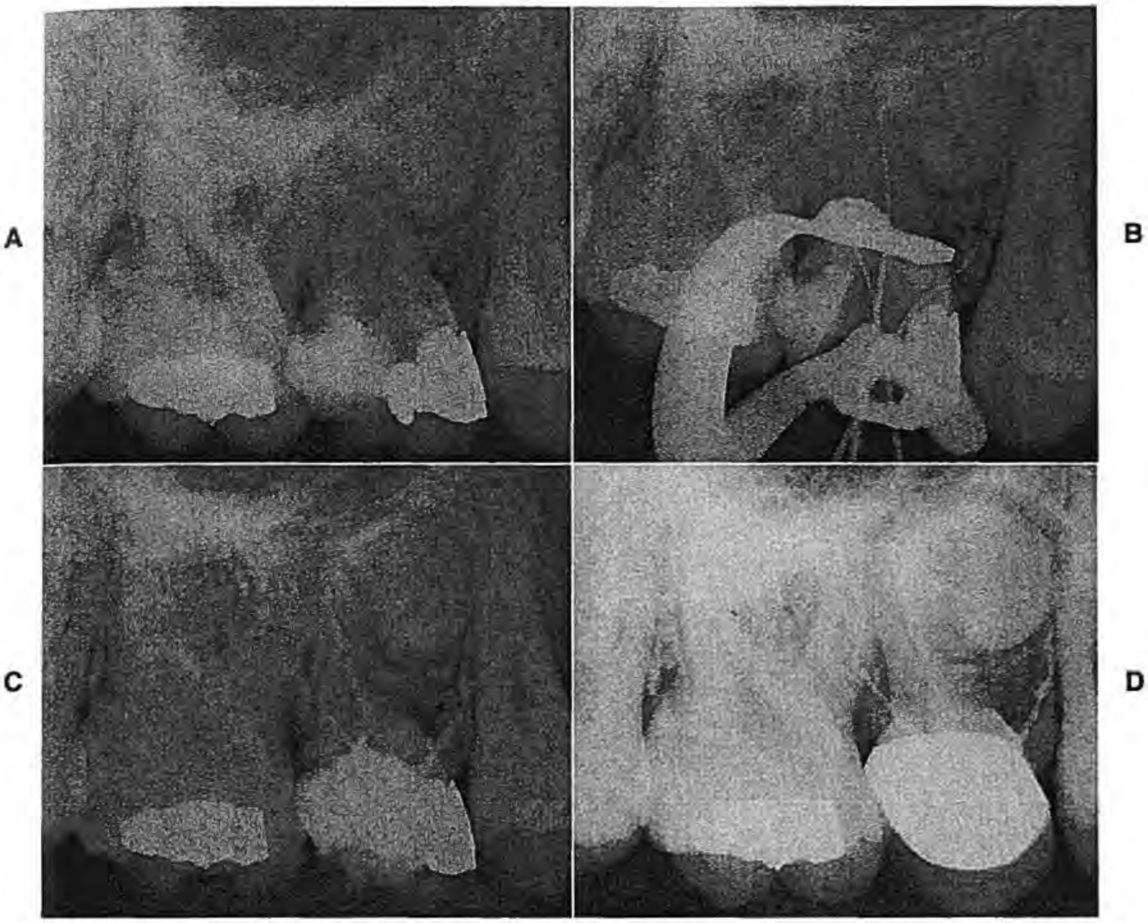


FIGURE 5-52 Maxillary posterior area of an 18-year-old patient with primary second molar and merely bud of the permanent successor. A, Preoperative radiograph. **B,** Files in place give some indication of mesiodistal curves but no sign of considerable buccolingual curvatures. **C,** Canals filled with laterally condensed gutta-percha and Wach's paste. Some excess sealer has been expressed. **D,** Eighteen months later.

endodontic equipment for ultrasonics, the broken cell parts are washed out and then removed from the canal system. The atomic bomb also works by the implosion principle, as do other methods for destruction and removal of materials.

Ahmad and her group from Guy's Hospital published papers that offered another mechanism for ultrasonic cleaning. They stated that the power setting used to energize the endodontic unit was too low to produce cavitation and that the width of the canal space was too small to allow for this condition. They suggested that the principle was that of *acoustical streaming,* a process by which the vibrating file generates a stream of liquid to produce eddies and flows of oscillation. The dimensions of these eddies and flows around the file are consistent and reproducible. Other studies have indicated that the dimensions produced will destroy or disrupt mammalian tissues.

Whichever of these principles is responsible, it seems that ultrasonics does work and will allow for many desirable and effective procedures. Removal of dentin for canal preparation, elimination of unwanted intracanal materials, and improved cleaning of the canal all may be accomplished, often in less time than by hand and with better efficiency than by other machines.

The energy from ultrasonic devices is derived from instruments vibrating at levels of 20 to 30 kHz by either electromagnetic or piezoelectric power sources. Both of these are power sources that convert other forms of energy into electric energy. Electromagnetic energy is produced by rotary generation and is typical of the electric power used in homes and industries. The most frequently used ultrasonic electromagnetic unit is the Cavi-endo,* the instrument used in the investigations by Martin and Cunningham. Piezoelectric energy is induced by subjecting crystals of certain materials, such as quartz or Rochelle salts, to physical force or pressure, as typically used in phonographs and microphones. For dental use, piezoelectric units (Figure 5-53, *A*) are much more powerful than electromagnetic units. Thus they are most

*Caulk/Dentsply, Milford, DE 19963.

A

B

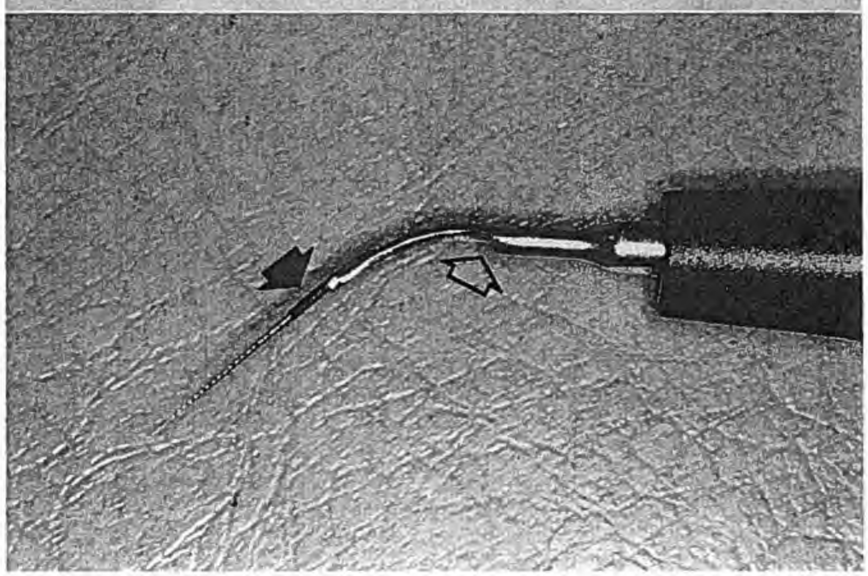


FIGURE 5-53 **A,** Ultrasonic unit powered by piezoelectricity. **B,** Ultrasonic tip with file attached to pictured unit. A plastic sleeve *(solid arrow)* has been placed to indicate working length because a rubber stop would prevent the movement of liquids from the unit *(open arrow)* into the canal. The plastic sleeve may lessen the effectiveness of acoustical streaming.

effective in removing unwanted items, such as silver points and posts, from the root canal space. The most frequently used piezoelectric unit is the Enac.* Lower levels of power are also available, in the so-called sonic or subsonic range, for handpieces.

Techniques for Use

The ultrasonic systems involve a power source (see Figure 5-53, *A*) to which an endodontic file is attached with a holder and an adapter (see Figure 5-53, *B*). Irrigants are emitted from cords on the power source and travel down the file into the canal to be energized by the vibrations. A wide range of files is available with varying abilities, including those with safe-ended tips and instruments of diamond particles. The latter reputedly have enhanced properties for conducting ultrasonic energy.

The irrigants may be either water or sodium hypochlorite. Sodium hypochlorite may cause a problem with these units because of clogging or corrosion. Evacuation devices must also be used to remove the irrigants and debris from the canal.

*Osada Electric, Tokyo, Japan.

Initial articles have indicated that ultrasonics give better canal debridement than does preparation by hand instruments. More recent papers have cast some doubt on those claims. Removal of the smear layer may be accomplished more readily with ultrasonics, but the sites where the tip actually touches the canal wall produce a new smear layer. No one knows the true significance of removing the smear layer, but Cameron recommends its elimination so that the filling material may enter into the superficial layers of dentin tubules.

Because the intracanal irritants are blown apart by the ultrasonic system and then removed from the canal by the evacuator, some claim that fewer noxious agents are pushed through the apex of the tooth into the periapical tissues. This decrease was found to lead to fewer postoperative flare-ups with the ultrasonic device than with routine therapy.

Removal of posts, silver points, cements, and other unwanted materials in the canal have been reported with the ultrasonic systems (see Chapter 8). The larger items (posts, silver points) are loosened with instruments usually involved with scaling and gross debris removal, whereas the cements require the endosonic files. Dentistry in eastern Europe often involves filling canals with cements that have no solvents. To re-treat failing cases, it becomes necessary to drill out the cement, which may lead to root perforation. The ultrasonic unit offers an extremely favorable alternative.

Canal Preparation

Some studies with the ultrasonic device have indicated minimal or no zipping when the instrument was used for preparation of curved canals. My initial investigations indicated that this was not consistently true (Figure 5-54,

A, B

C

D

E

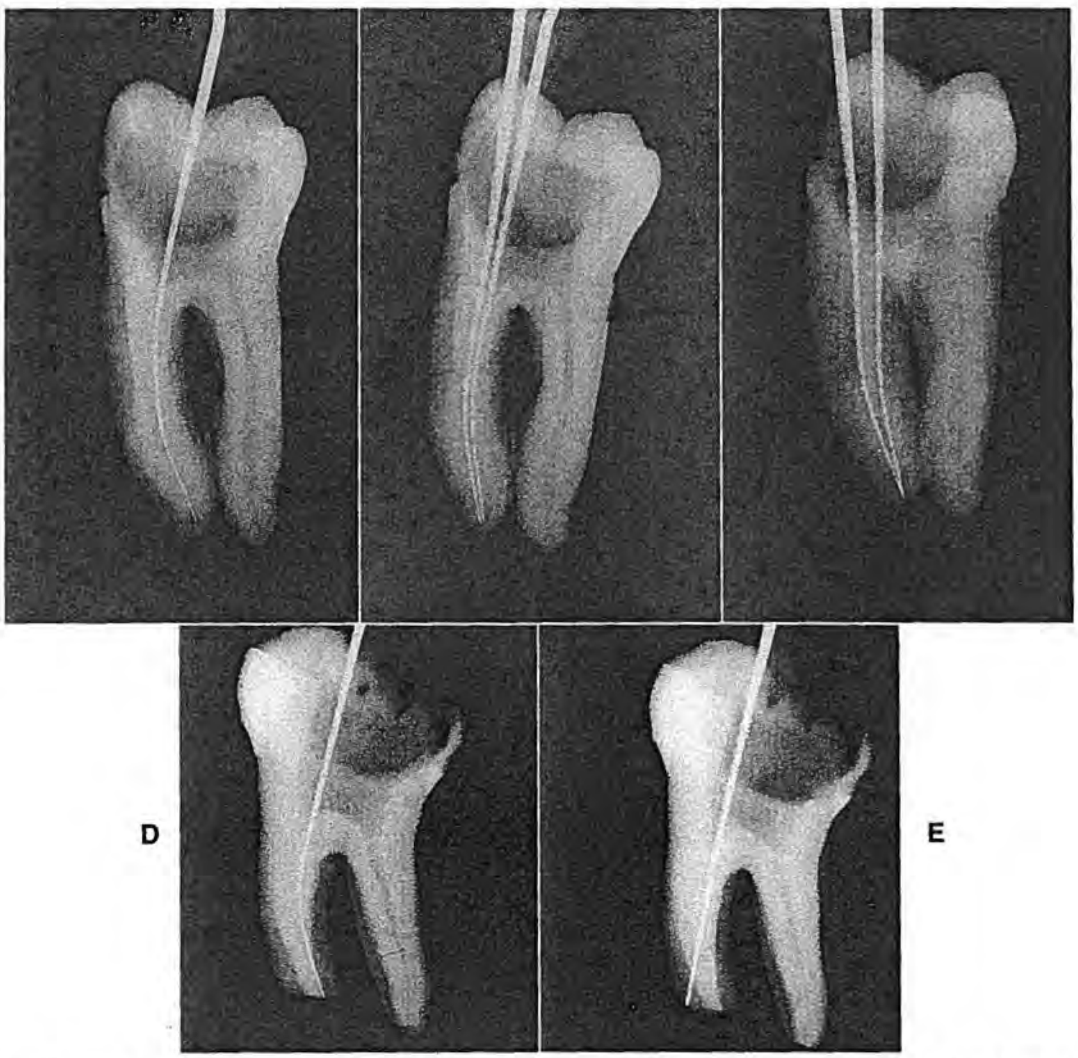


FIGURE 5-54 Initial studies on retaining original canal shape using a piezoelectric ultrasonic unit. A, Hand file in one of the mesial canals of an extracted mandibular molar to indicate original canal shape. **B** and **C,** Two views of size 30 files in place after only 1 minute of ultrasonic preparation. This was rated as an excellent preparation. **D,** Hand file in one of the mesial canals of another mandibular molar to indicate original canal shape. **E,** Size 30 file in place after only 30 seconds of ultrasonic preparation. This was rated as an unacceptable preparation.

D and *E*). In their first report in 1985, Chenail and Teplitsky stated that the instrument could safely prepare curved canals. However, they stayed with minimal sizes, and zipping rarely occurs at these small sizes. By 1988, when they had evaluated enlargement to size 30 and greater, they also found that zipping was a constant feature.

Schulz-Bongert et al recently described the use of a piezoelectric source* for preparation of curved canals alone and in combination with hand preparation, including flute removal, at the apex (Figure 5-55). They reported that when used alone in canals with curvatures of 30 degrees and greater, severe zipping occurred (see Figure 5-55, *A* and *B*). However, when the ultrasonic unit was used above the elbow only for reverse flaring and flaring, in combination with hand filing at the apex, minimal zipping resulted (see Figure 5-55, *C* and *D*). Stripping (see Figure 5-14, *C*) also occurred with ultrasonics alone, but not in the combination-treated cases.

It is impossible to use rubber stops for length control because they would interfere with the passage of irrigants up the files. Therefore length control can be a problem even when using miniature rubber sleeves that fit on the files (see Figure 5-53, *B*) or using the files with millimeter serration indicators on the shaft. Some of the sonic systems have wire length indicators for working length that come off the handpiece and thus allow for free passage of fluids in both directions.

Related Uses for Ultrasonics

The advent of ultrasonics has improved the ability of the dentist to treat successfully a wider variety of cases.

*Electro Medical Systems SA, Le Sentier, Switzerland.

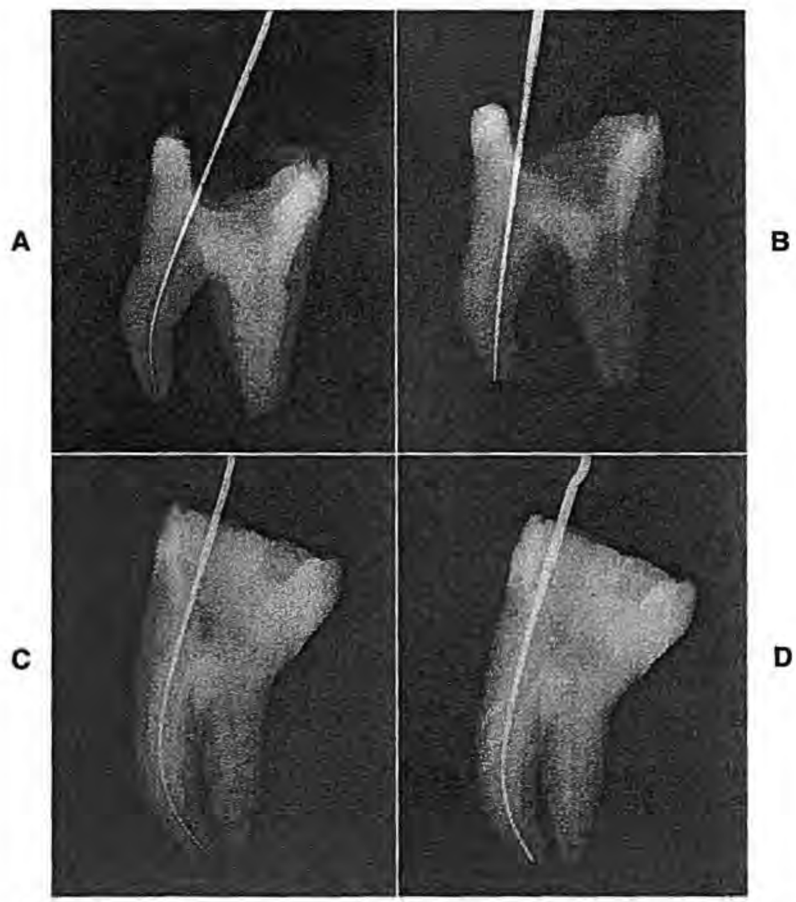


FIGURE 5-55 Use of the ultrasonic unit for preparation of curved canals. Extracted teeth were prepared with ultrasonic use only or with a combination of ultrasonics coronal to the elbow and hand filing with flute removal apical to the elbow. **A,** Example of use of ultrasonics only, size no. 10 file in place to the working length, indicating curvature of approximately 30°. **B,** After use of ultrasonic preparation only, size no. 30 file was placed, indicating complete straightening of the canal with apical zip. **C,** Example of combination of ultrasonics coronal to the elbow and hand filing with flutes removed apical to the elbow, size 10 file in place indicating curvature of approximately 50°. **D,** After completion of preparation, size no. 30 file in place in virtually the same position as was the no. 10 file, with minimal straightening or zipping. (Reprinted with permission from The Compendium of Continuing Education in Dentistry. From Schulz-Bongert U, Weine FS, Schulz-Bongert J: *Compend Contin Educ Dent* 16:270, 1995.)

Despite the lack of agreement as to the degree of cleaning ability compared with nonultrasonic use, I am impressed with the amount of debris removed by ultrasonic use in teeth with open apices and necrotic pulps (see Chapter 14), those with chronic lesions (Figure 5-56), and teeth that have been left open for long periods that need to be reclosed. After completing preparation of the walls and gaining the desired shape in such cases, either with or without the use of mechanical aids, I allow for several minutes of ultrasonic cleaning, leaving the tip centered in the canal during that time with the sodium hypochlorite passing freely within the canal.

The ultrasonic unit is quite useful in preparing teeth for re-treatment because of its ability to gain a cleaner environment (see Figure 5-56). Failing cases requiring the retrieval of silver points are particularly easier to re-treat since the advent of ultrasonics. Generally in these cases, some cements are on the chamber floor around the previous canal fillings. If a bur is used to clean the chamber, the portion of the points protruding from the canal is cut away, and re-treatment is severely hampered by inability to pull out the materials. However, if an endosonic file is used around and into the cement, the chamber contents are removed cleanly, and the protruding silver point segments remain in the same position that is favorable for removal. The entire floor is much cleaner, and unwanted debris is eliminated if locating an additional canal becomes necessary.

IRRIGANTS AND CHELATING AGENTS

Functions of Irrigants

Irrigants perform important physical and biologic functions during endodontic therapy. Their action is unquestionably more significant than that supplied by the use of intracanal medicaments. When there is a wet environment during canal preparation, the dentin shavings are floated to the chamber where they may be

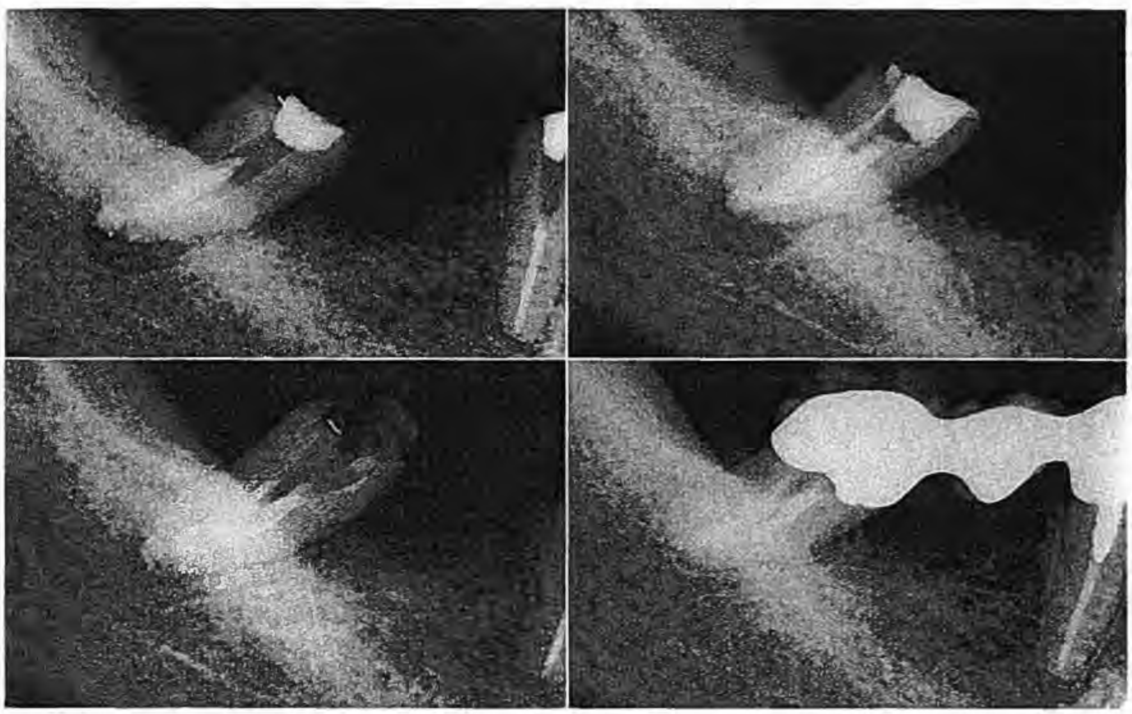


FIGURE 5-56 Improved cleaning ability by ultrasonic preparation. A, Preoperative radiograph of mandibular posterior area. The second molar had been treated 1 year earlier by another endodontist and had a vital pulp with no periapical lesion at that time. Now it is tender to percussion and slightly mobile, and a periapical lesion is present. The treatment seemed satisfactory, and I was reluctant to attempt re-treatment. Because the involved tooth was a posterior abutment and without it no fixed prosthesis could be placed, I agreed to attempt redoing the therapy but stressed to the patient the questionable prognosis. **B,** I discovered that the original treatment was performed at only one appointment, which is difficult on a C-shaped second molar. My repreparation included the use of a solvent to remove the old gutta-percha and ultrasonic cleaning, which had not been used earlier. At the second appointment, I filled the canals with laterally condensed gutta-percha and Wach's paste. My filling really appears to be no different than the original filling shown in *A.* I advised the referring dentist to place a temporary bridge to evaluate healing. **C,** Six months later, the periapical lesion has healed and the tooth is firm and comfortable. I advised the restorative dentist to go ahead with the permanent bridge. **D,** Two years later, a fixed bridge has been constructed and the posterior abutment is comfortable and functioning well. (Restorations by Dr. Kerry Voit, Chicago. Reprinted with permission from The Compendium of Continuing Education in Dentistry. From Schulz-Bongert U, Weine FS, Schulz-Bongert J: *Compend Contin Educ Dent* 16:270, 1995.)

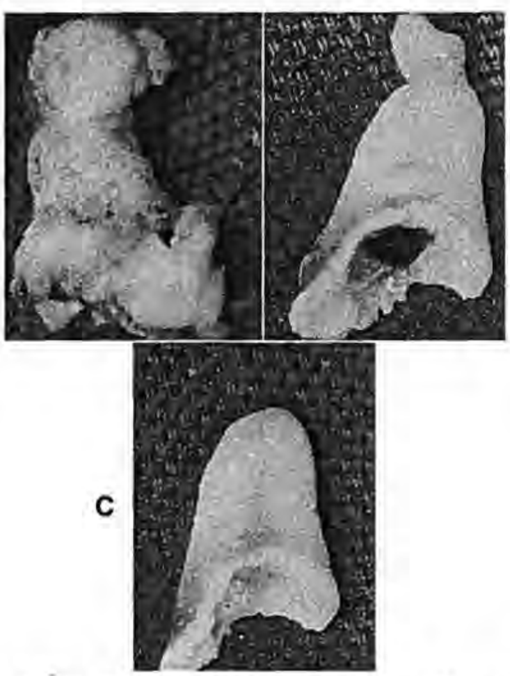
removed by aspiration with a suction device. Therefore they do not pack near the apex to prevent proper canal filling. Files and reamers are much less likely to break when the canal walls are lubricated by the irrigants.

Many liquids would provide these aids, but in addition the irrigants that are typically used have the function of being necrotic tissue solvents. When used with canal instrumentation, the irrigants loosen debris, pulp tissue, and microorganisms from the irregular dentin walls so that they can be removed from the canal. Because reamers and files are much too small to fit into accessory canals, it is the solvents' action that removes the tissue remaining there so that the subsequently used filling materials may be packed or pushed into these areas.

Most irrigants are germicidal but have further antibacterial effect by ridding the canal of the necrotic debris. With reduced substrate present, the microorganisms have less chance for survival. Irrigants also have a bleaching action to lighten teeth discolored by trauma or extensive silver amalgam restorations and decrease the chance of postoperative darkening.

The commonly used irrigants are capable of causing inflammation to periapical tissue. Therefore instrumentation must be confined within the canal to limit the forcing of irrigants through the apical foramen. Unquestionably, solution frequently does reach the periapical tissue, and some inflammation results. Because the stronger solvents produce greater inflammatory response, the strength of the solutions should be kept to the lowest level that will be effective in debridement.

A



B

C

FIGURE 5-57 Solvent action of 5% sodium hypochlorite solution. A, Maxillary bicuspid with granulomatous mass attached, shortly after extraction. **B,** After exposure to the NaOCl for 30 minutes, much of tissue has dissolved, leaving only a small portion of the lesion attached to the apex. **C,** After 60 minutes of exposure, all soft tissue has been dissolved.

Useful Irrigants

Sodium hypochlorite (NaOCl), NF, is the most widely used irrigant in endodontics and has effectively aided canal preparation procedures for many years (Figure 5-57). A 5% solution provides excellent solvent action but is dilute enough to cause only mild irritation when contacting periapical tissue. Household liquid bleach (Clorox, Linco) has 5.25% NaOCl and therefore requires slight addition of sterile distilled water to lower the incidence of periapical inflammation. For those who perform endodontic treatment frequently, these solutions are easier utilized than preparation of the irrigant by dissolving sodium carbonate and chlorinated lime.

Hydrogen peroxide solution (H_2O_2), USP, is also widely used in endodontics, with two modes of action. The bubbling of the solution, when in contact with tissue and certain chemicals, physically foams debris from the canal. In addition, the liberation of oxygen destroys strictly anaerobic microorganisms.

The solvent action of H_2O_2 is much less than that of NaOCl. However, many clinicians use the solutions alternately during treatment. This method is strongly suggested for irrigating canals of teeth that have been left open for drainage because the effervescence is effective in dislodging food particles as well as other debris that may have packed the canal.

Being less effective as a solvent, H_2O_2 is also less damaging to periapical tissues. Therefore, when procedural accidents have caused either root or floor of chamber perforation or when the apical constriction has been destroyed with severe pericementitis present, it is the preferred irrigant. However, peroxide should not be the last irrigant used in a canal because nascent oxygen may remain after access preparation closure and build up pressure. Therefore NaOCl should be used to react with the H_2O_2 and liberate the oxygen remaining; then the canal is dried with paper points and closed.

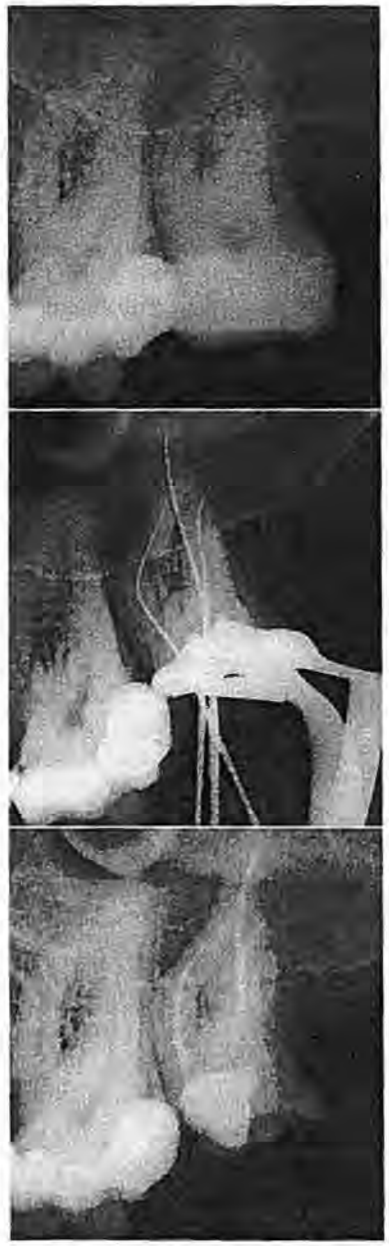
Carbamide peroxide is available in any anhydrous glycerol base (Gly-Oxide*) to prevent decomposition and is a useful irrigant. It is better tolerated by periapical tissue than NaOCl yet has greater solvent action and is more germicidal than H_2O_2. Therefore it is an excellent irrigant for treating canals with normal periapical tissue and wide apices, in which the more irritating solutions would cause severe inflammation when forced out of the canal. The best use for Gly-Oxide is in narrow and/or curved canals, utilizing the slippery effect of the glycerol. Whereas

*SmithKline Beecham Consumer Healthcare, L.P., Pittsburgh, PA 15230 chelating agents react with dentin and may cause root perforation or ledging in the softened walls, this action will not occur with Gly-Oxide, where only lubrication is enhanced. Because the canal walls are slippery, they are easier to prepare but are less likely to be gouged or perforated (Figure 5-58).

Method of Irrigation

Disposable plastic syringes of 2.5 or 5 ml capacity with 25-gauge blunted needles are useful for endodontic irrigation. Glass syringes with metal tips are also satisfactory but are much more expensive and more easily broken. A bend of approximately 30 degrees is made in the center of the needle so that the canals of both anterior and posterior teeth are reachable.

Irrigants must never be forcibly inserted into the periapical tissue but rather gently placed within the canal. It is the action of the intracanal instruments that distributes the irrigant to the nooks and crannies of the canal, rather than the injecting syringe. For relatively large canals the tip of the syringe is placed until resistance from the canal walls is felt, then the tip is withdrawn a few millimeters. The solution is expressed very slowly until much of the chamber is filled. In the treatment of posterior teeth and/or small canals, the solution is deposited in the chamber. The files will carry the irrigant into the canal, and the capillary action of the narrow canal diameter will retain much of the solution. Excess irrigant is carried away by aspiration with a small tip, of approximately 16 gauge, if available. Otherwise, a folded gauze pad (2 × 2 inches) is held near the tooth to absorb the excess. To dry a canal in a case where aspiration is not available, the plunger of the irrigating syringe may be withdrawn, and the bulk of the solution will be aspirated in that manner. Paper points are then used to remove residual liquid.



A

B

C

FIGURE 5-58 Typical case treated with carbamide peroxide (Gly-Oxide) as irrigant. (Gly-Oxide is available in $\frac{1}{2}$ and 2-ounce bottles and disposable plastic ampules.) **A,** Maxillary second molar with curved canals, verified by radiograph, **B,** with files in place to determine working lengths. **C,** By careful preparation, using precurved files, incremental instrumentation, removal of flutes, and lubricating properties of Gly-Oxide, canals were prepared sufficiently to fill with gutta-percha.

Recent Studies Concerning Irrigants and Their Clinical Implications

For many years intracanal irrigants were considered to be among the most mundane of the entities involved in endodontic therapy. Almost every case involved either NaOCl, H_2O_2, or both, and relatively little thought was given to their use. The medicaments were considered to have better antimicrobial action, and their names, formulae, and odors were more exotic.

Then, in the last decade or so, a plethora of articles investigating the actions and uses of irrigants has appeared, and some significant differences in endodontic therapy have resulted.

Baker et al studied the effectiveness of various strengths and volumes of saline, NaOCl, H_2O_2, Gly-Oxide, and chelates. They reported no irrigant better than any other in dissolving necrotic debris or making canals cleaner. Therefore these clinicians recommended that the most biologically acceptable material be used as an intracanal irrigant—physiologic saline. The study received considerable attention, and many clinicians switched to saline. However, these clinicians failed to analyze the study carefully. The canals were considered to be well prepared when clean white dentin shavings were produced—not a good criterion. Also, no canal flaring was performed. Thus the canals were not well prepared, and the conclusion of the study should have been that when canals are poorly prepared, no solution will do a superior job in irrigation.

Two years later Svec and Harrison, using better methods of canal preparation, found that the combination of 5.25% NaOCl and 3% H_2O_2 gave a superior preparation to one utilizing normal saline or either irrigant alone. The following year Harrison et al reported that in a study of 253 cases there was no statistical difference in incidence and degree of pain among groups irrigated with saline, 5.25% NaOCl, or NaOCl and H_2O_2.

Daughenbaugh and Schilder have reported a scanning electron microscopic study using various concentrations and combinations of irrigants. Their canals were widely enlarged at the orifices and flared. This change in preparation method alone gave generally much better results than those reported by Baker et al. The conclusion of the study was that 5.25% NaOCl alone produces clean canals, free of organic tissue, but that the walls have fewer open tubules than those prepared with a combination of 2.5% NaOCl and 3% H_2O_2 (Figure 5-59). The open tubules were considered to be desirable because they allowed for penetration by the medicaments and better adhesion for the sealers.

I believe that these studies make it clear that alternating irrigants gives a cleaner canal with less organic debris and more desirable walls. Considering the studies by Sundqvist (see Chapter 13) on the potentially destructive anaerobes, I find the additional value of liberated oxygen to be also quite appealing (Figure 5-60). One other study, by Senia et al, also enters in my choice of irrigants. They had reported that NaOCl does not reach the apex of small canals until the canals are enlarged to size 20 or greater. However, Gly-Oxide, being more viscous with a high surface tension, can be manipulated into very small canals and will liberate oxygen in even these deep recesses. Therefore I prefer to use Gly-Oxide as the major irrigant in small canals until size 20 is reached and then switch to NaOCl (Figure 5-61). In larger canals I merely alternate irrigants. In teeth with periapical lesions I make considerable effort to allow for free exchange between the irrigants so the oxygen will be liberated and will kill the anaerobes.

Function of Chelating Agents

The problems of enlarging very sclerotic canals nagged even the earliest practitioners in endodontics. Phenolsulphonic acid, reverse aqua regia, and other severely caustic chemicals were advocated to aid in the enlargement of canals with narrow diameter. These chemicals were nonselective and therefore destroyed anything in contact, including periapical tissue.

Chelating agents provide an excellent alternative because they act on calcified tissues only and have little effect on periapical tissue. Their action is to substitute

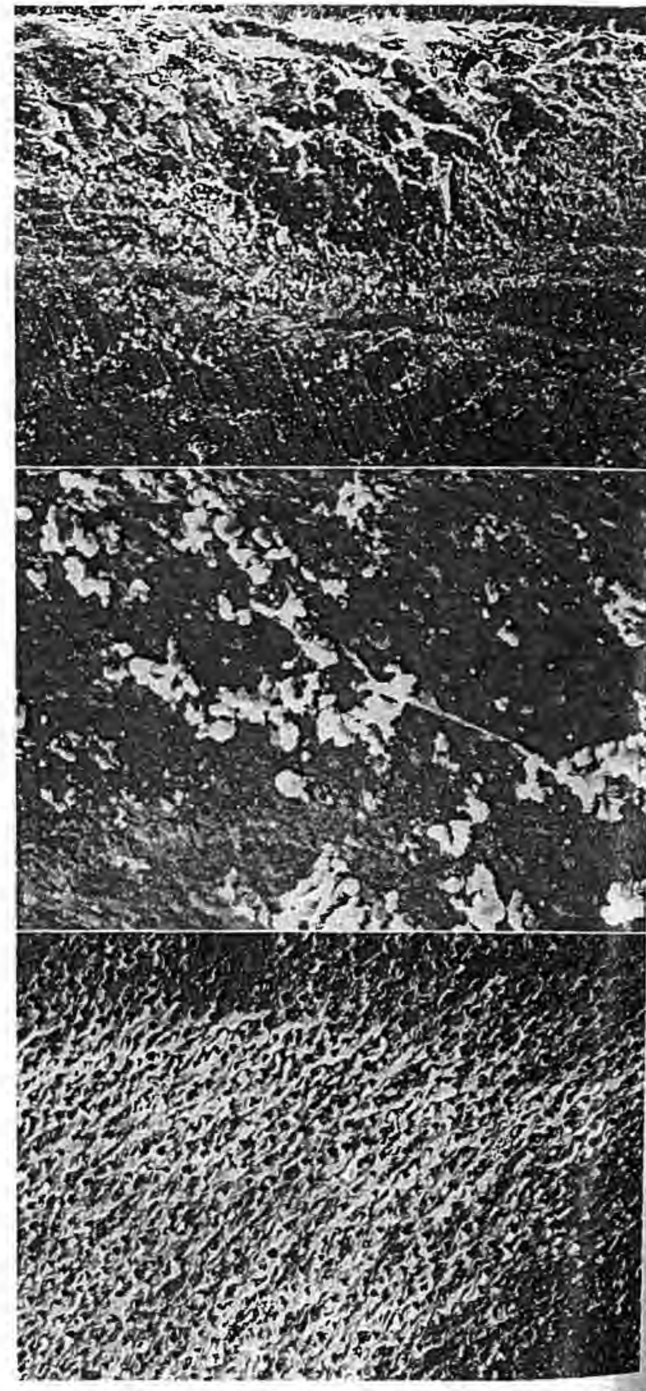


FIGURE 5-59 Photomicrographs of in vitro specimen prepared as follows. A, Saline irrigant. Much organic tissue present. (×6.) **B,** 1% NaOCl. Smearing of dentin surface, and organic debris present. (×60.) **C,** 2.5% NaOCl alternated with 3% H_2O_2. Beautifully clean and smooth canal. (×560.) (Courtesy Dr. Jeffery A. Daughenbaugh, Salinas, Calif.)

sodium ions, which combine with the dentin to give soluble salts, for the calcium ions that are bound in less soluble combination. The edges of the canal are thus softer, and canal enlargement is facilitated.

Chelating agents are placed in the orifice of a canal to be enlarged on the tip of the endodontic explorer or on the

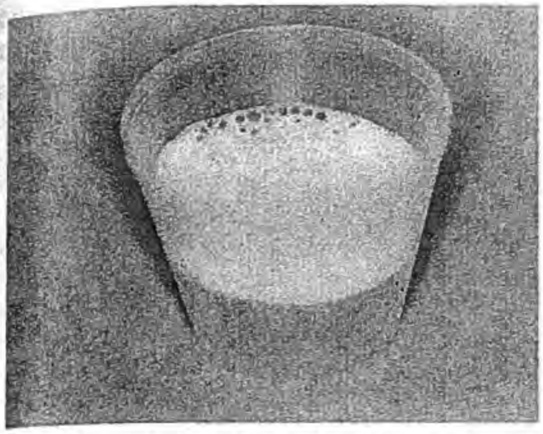


FIGURE 5-60 A few milliliters of NaOCl was placed in this dappen dish and then a few milliliters of Gly-Oxide were added. A bubbling and foaming reaction immediately took place. The same reaction occurs in the canal when these two chemicals are mixed. The bubbling is the oxygen escaping, which will kill anaerobes. The foaming helps to wash out unwanted debris.

flutes of the enlarging instrument if the agent is foamy (as is RC-Prep) or by plastic irrigating syringe if liquid (e.g., EDTA). EDTA reacts with glass, so syringes of that material may not be used.

Chelating agents may be useful in the location of a difficult-to-find orifice by sealing in the chamber between appointments. Because the orifices are less calcified than the surrounding dentin, sufficient softening may allow it to be located with the sharp tip of the endodontic explorer at the next appointment.

If misused, chelating agents may cause problems during endodontic therapy. They should not be used in a ledged or blocked canal to aid in reaching the apex. If a sharp instrument is forced or rotated against a wall softened by the chelate, a new but false canal will be started. The operator may erroneously believe that the canal has been located and continue the preparation, thus losing any chance for finding the true canal. Chelating agents are dangerous in curved canals once the larger-sized instruments (size 30 or greater) are being used. These instruments are not as flexible as the smaller sizes and, with the canal walls softened, may produce an elliptication of the apex or root perforation.

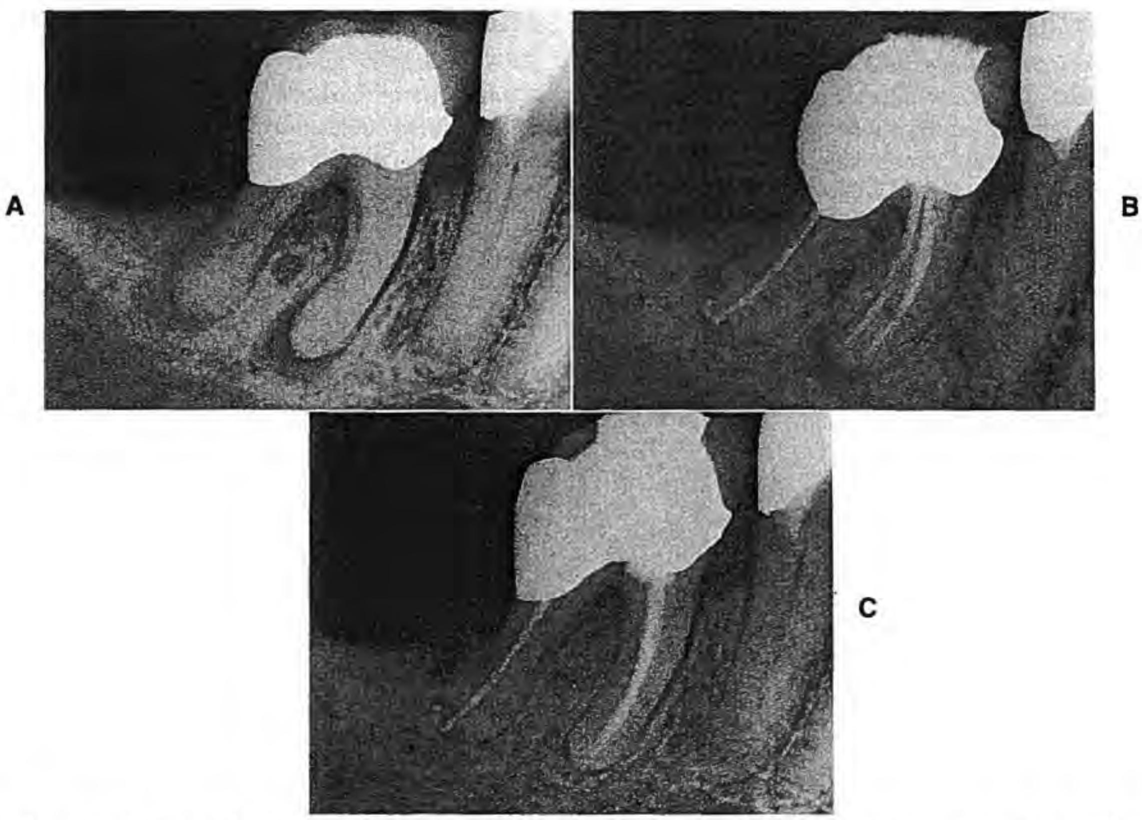


FIGURE 5-61 **A,** Radiograph of mandibular first molar with periapical lesions on both roots and extremely narrow canals, particularly in mesial root. Canals were enlarged to size 20 with carbamide peroxide and then alternated with NaOCl. **B,** Filled with laterally condensed gutta-percha and Kerr's antiseptic sealer. **C,** Excellent healing 3 years later.

The best use of these agents is to aid and simplify preparation for very sclerotic canals after the apex has already been reached with a fine instrument.

EDTA. Patterson did much research on the disodium salt of EDTA. He reported that a 10% solution lowered the Knoop hardness number of treated dentin to 7, from a normal reading of 25 near the dentinoenamel junction up to 70 at approximately one third of the distance from the dentinoenamel junction to the canal wall when untreated. Next to the lumen of the untreated canal, where canal instrumentation is initiated, the Knoop hardness number was found to be 42. Reduction to a reading of 7 significantly reduces the difficulty encountered in using the smaller-size instruments to begin canal preparation.

Patterson further states that a 10% solution of EDTA did produce bacteriologic inhibition comparable to that of beechwood creosote against alpha-hemolytic streptococci and *Staphylococcus aureus.* Injection of 0.1 ml of 10% EDTA in the back muscle of albino rats produced moderate inflammation, whereas injections of distilled water and eugenol produced inflammation described as slight.

EDTA will remain active within the canal for 5 days if not inactivated. If the apical constriction has been opened, the chelate may seep out into the tissue and damage the periapical bone. For this reason, at the completion of the appointment the canal must be irrigated with a sodium hypochlorite–containing solution, a small file being placed into each canal where EDTA was used to ensure penetration of the inactivator.

Some research seems to indicate that the use of EDTA in canal preparation aids in the removal of the smear layer on the dentin wall. This might allow for better surface contact between the canal filling and the dentin wall and better potential penetration of the sealer into the dentinal tubules.

RC-Prep.* As developed by Stewart, RC-Prep combines the functions of EDTA plus urea peroxide to provide both chelation and irrigation. The foamy solution has a natural effervescence that is increased by irrigation with NaOCl to aid in the removal of debris. RC-Prep may be placed in the canal on the flutes of a file by plastic irrigating syringe (Figure 5-62).

A

B

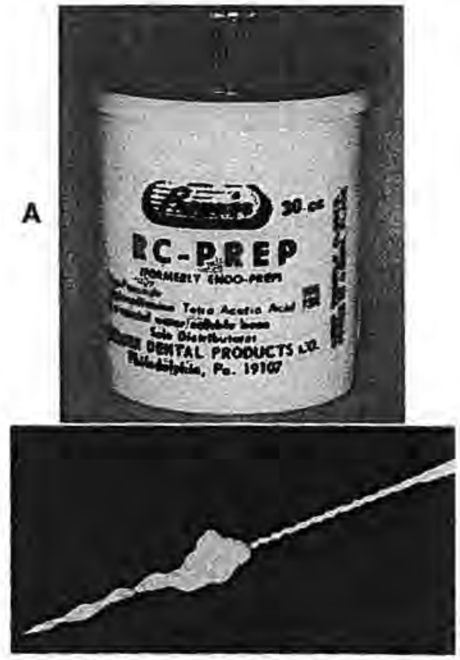


FIGURE 5-62 **A,** RC-Prep (developed by Stewart) provides for chelation and irrigation by using a combination of EDTA and urea peroxide. **B,** Because it is foamy, RC-Prep is placed on flutes of a file and carried directly to walls of canal being prepared.

INTRACANAL MEDICAMENTS

Originally endodontics was mainly a therapeutic procedure in which drugs were used to destroy microorganisms, fix or mummify vital tissue, and effect a sealing of the root canal space. The drugs used were generally caustics, such as phenol and its derivatives, and periapical tissues were frequently adversely affected.

Gradually the reliance on drugs has been replaced by emphasis on debridement. It cannot be argued that what is removed from the canal has a greater significance in endodontic success than what is placed in the canal. Even so, drugs are still used as intertreatment dressings, although an ever-increasing number of endodontists use them only for symptomatic cases.

Function of Intracanal Medicaments

Most medicaments are effective antimicrobial agents. With the number of microorganisms reduced by irrigation and instrumentation, the medicament destroys those remaining and limits the growth of any new arrivals.

Corticosteroid-antibiotic combinations are useful in treating apical periodontitis, occurring either as a pretreatment symptom or as a result of overinstrumentation.

Volatile medicaments should never be used to determine, through retention of their scent on the cotton pellet taken from the chamber, whether the material used to seal the access cavity has been effective. Culturing is a much more reliable indicator, although many practitioners cannot resist the opportunity to sniff the dressing after opening the access cavity at the start of each appointment.

*Premier Dental Products, Norristown, PA 19401.

Phenol and Related Volatile Compounds

Phenol was used for many years for its disinfectant and caustic action. However, because it has strongly inflammatory potential, at present it is rarely used as an intracanal medicament. Phenol may be used for disinfection before periapical surgery (see Chapter 9) and for cauterizing tissue tags that resist removal with broaches or files.

Eugenol also has been used in endodontics for many years. It is a constituent of most root canal sealers and is used as a part of many temporary sealing agents. Although the compound has a high irritating potential when evaluated histologically, it seems to be extremely soothing clinically to vital tissue, probably from some type of caustic action to irritated nerve endings. It is used as an intracanal medicament after partial or complete pulpectomy.

Camphorated monoparachlorophenol (CMCP) was the most widely used medicament in endodontics for many years, but recently its use has waned tremendously.

Formocresol, a combination of formalin and cresol, is used as a dressing for pulpotomy to fix the retained pulpal tissue. It may also be used as an intratreatment medicament when a pulpotomy is performed as emergency treatment to relieve pain, in situations where pulp inflammation is confined to the pulp chamber.

The efficacy of medicaments in endodontic therapy has undergone many changes. In recent years there has been a strong impetus to use the best-tolerated medications regardless of their antimicrobial efficiency. An extremely impressive series of studies by Makkes et al in Amsterdam has further weakened the position of the pro-medication faction among endodontists, particularly when treating teeth with nonvital pulps. They studied the tissue response to sterile dead muscle and necrotic muscle tissue treated by fixation. The two groups are analogous to pulp tissue that became necrotic by physical or chemical trauma and necrotic tissue onto which chemical fixative medicaments had been placed.

For many years it was assumed that the necrotic pulp tissue was a source of serious irritation to the local area, even without ingress by microorganisms, and that this reaction was responsible for the initial development of a granuloma. On the other hand, many practitioners believed that treatment of this necrotic tissue with fixatives such as formaldehyde will render the pulp remnants harmless. However, Makkes et al reported a very contrary finding. Tissue reaction to the sterile dead muscle was minimal and self-limiting, whereas the response to fixed muscle tissue by formaldehyde or glutaraldehyde was a severe chronic inflammation, even in the absence of microorganisms.

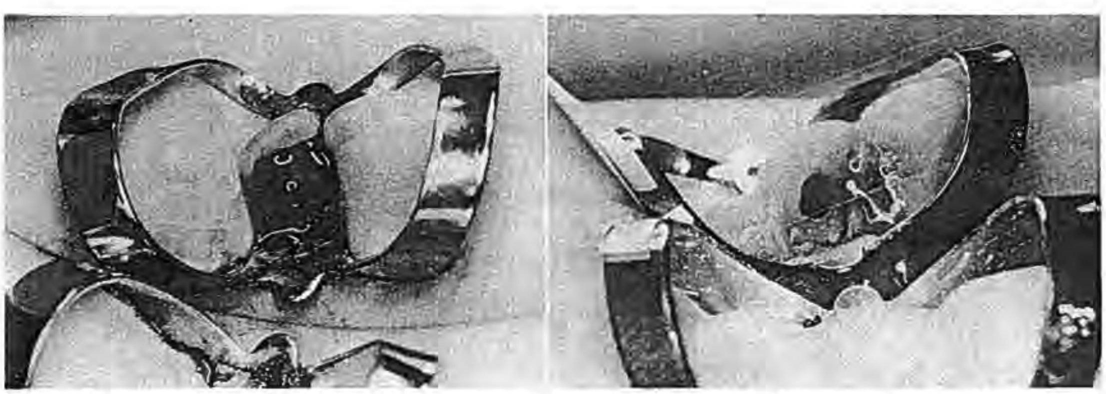
I believe that proper canal debridement with heavy irrigation and alternation is best treatment, and the medications are unimportant. In fact, more than 90% of the cases illustrated in this textbook were managed without any intracanal medicament.

My use of formocresol is limited solely to pulpotomy dressing as emergency treatment (see Chapter 3) when there is no apical spread of inflammation or infection, so the medicament is placed on vital tissue a long distance from the periapical tissues.

Calcium Hydroxide as a Medicament for "Weeping" Cases

One of the most perplexing conditions to treat is the tooth with constant clear or reddish exudation associated with a large apical radiolucency. The tooth often is asymptomatic, but it may be tender to percussion or sensitive to digital pressure over the apex. If cultured, the drainage generally will not support bacterial growth. When opened at the start of the endodontic appointment, a reddish discharge may well up, whereas at a succeeding appointment the exudate will be clear (Figure 5-63). Some

A



B

FIGURE 5-63 **A,** Maxillary lateral incisor with large periapical lesion opened for drainage, allowing heavy bloody exudate to discharge. **B,** Several appointments later, a clear exudate (shiny area to right of access cavity) discharged.

pressure is present, but not nearly as much as with an acute periapical abscess. If the tooth is left open under a rubber dam for 15 to 30 minutes, it may be closed up by absorbing the exudate with an aspirator and paper points; however, a similar condition will still be present at the next appointment. The canal has already been enlarged to a more than acceptable size. This is referred to as a *weeping canal.*

One is always in a quandary as to the correct method for treating such a canal. Classically those with exudates were not considered to be ready for filling (see Chapter 7). Should surgery be performed to curette the area of pathosis at the same appointment at which the canal is filled? Perhaps it would be best merely to fill the canal and see whether surgery could be avoided. The problem with this regimen is that because of the apical oozing, it is very difficult to fill weeping canals adequately. Prescribing antibiotics for the patient seems foolish because of the frequency of negative cultures.

The answer to this recalcitrant problem is to dry the canal with sterile absorbent paper points and place calcium hydroxide paste in the canal, similar to what is done to gain apexification in teeth with open apices and nonvital pulps (see Chapter 14). It is absolutely astonishing to see a perfectly dry clean canal at the next appointment that is simple to fill after minimal further preparation (Figures 5-64 and 5-65).

The exact mechanism for the action of calcium hydroxide in this type of case is an object of much conjecture. I believe that it is closely related to the pH of the periapical tissues, which must be acidic in the weeping stage. The pH is converted by the paste to a more basic environment. Others believe that the calcifying potential of the medicament starts to build up bone in the lesion. Still others suggest that the caustic action of the calcium hydroxide burns residual chronic inflamed tissue.

Whatever the reason, I have used this technique in several cases that healed magnificently and were followed up for significant time periods (Figure 5-66; see also Figure 5-65).

Many dentists presently select calcium hydroxide as the intracanal medicament of choice for routine cases, replacing the phenolic derivatives. This is particularly true in the Scandinavian countries, where a considerable amount of research on this material has been reported. It has advocates in the United States as well.

Because of its pH, few microorganisms can survive in calcium hydroxide's presence. The material has an excellent record of helping to heal radiolucencies. Unlike the phenolic derivatives, calcium hydroxide leads, at worst, to a minimal number of immunologic reactions.

I still believe that the functions of medicaments should be sublimated to use of excellent debridement and that they should be employed only in those few cases where other aspects of therapy have not worked. Ultrasonic use has given us cleaner canals; healing of radiolucencies will occur without employing calcium hydroxide; and using no medicament is even more likely to avoid an immunologic reaction.

SEALING AGENTS FOR INTERTREATMENT DRESSINGS

Need for Sealing Agents

If the endodontic treatment will take two or more appointments, some type of temporary sealing agent is needed to close the access cavity between visits. The material selected must provide for effective closure against microorganisms and salivary contamination, which would bring irritants to the periapical tissue if allowed free passage. The access-sealing agent must also retain the

Figure 5-64 Case similar to that shown in Figure 5-63. Maxillary lateral with large periapical lesion. **A,** Preoperative radiograph. First time canal was opened, a large bloody exudate welled up; at subsequent appointments and after several negative cultures, calcium hydroxide paste was placed. **B,** Exudates ceased by the next appointment, and the canal was filled. **C,** Excellent healing 6 months later.

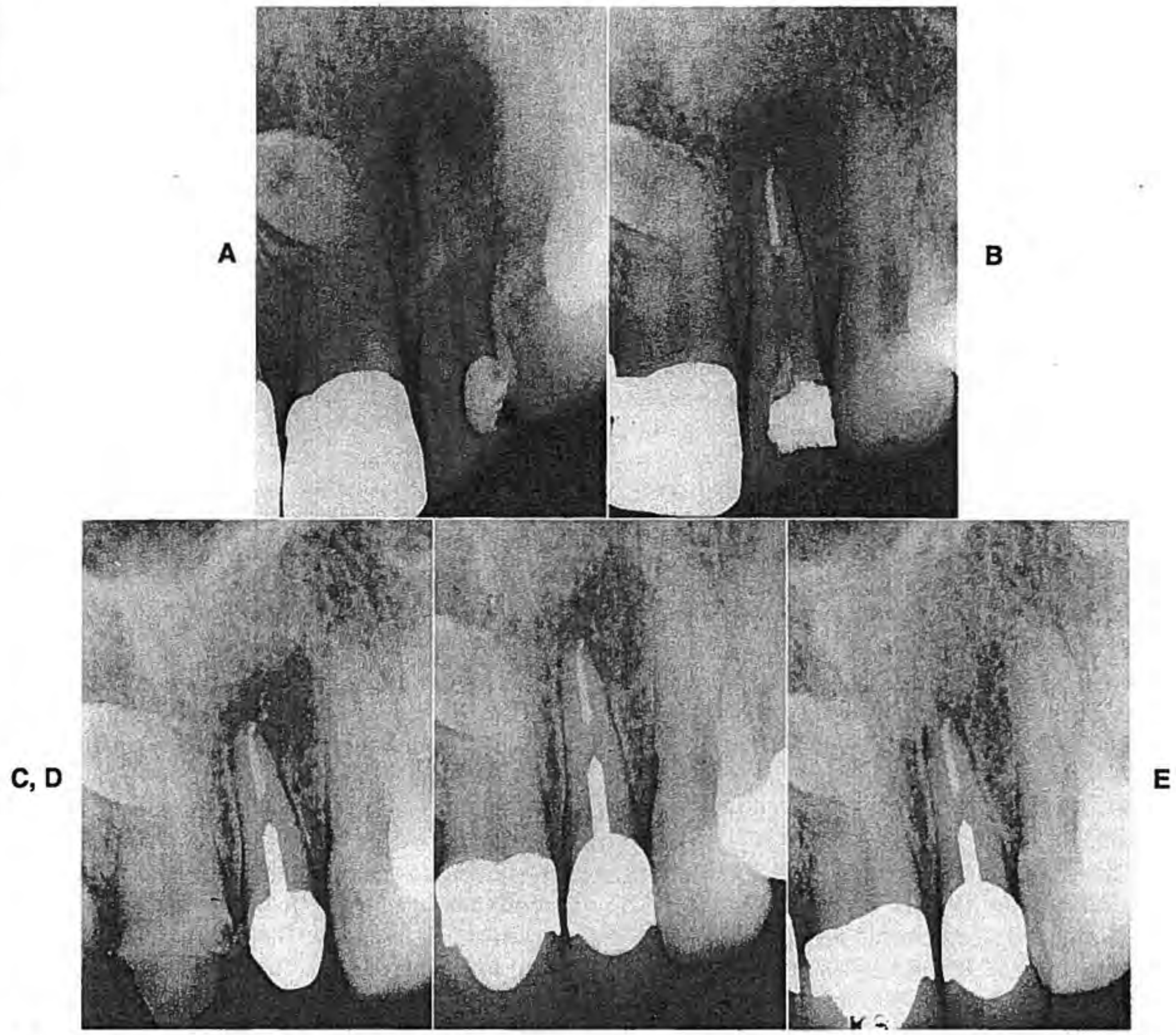


FIGURE 5-65 **A,** Preoperative radiograph of lateral incisor with large periapical lesion and acute periapical abscess. At emergency appointment a bloody exudate, similar to that shown in Figure 5-63, *A,* drained. **B,** After several appointments of persistent drainage, calcium hydroxide paste was injected to stop exudation, and canal was filled at the next appointment. **C,** Six months after treatment. **D,** Eighteen months after treatment, lesion healing well. **E,** Three years after original treatment, only a faint sign of the lesion is apparent. (Restoration by Dr. Sherwin Strauss, Chicago.)

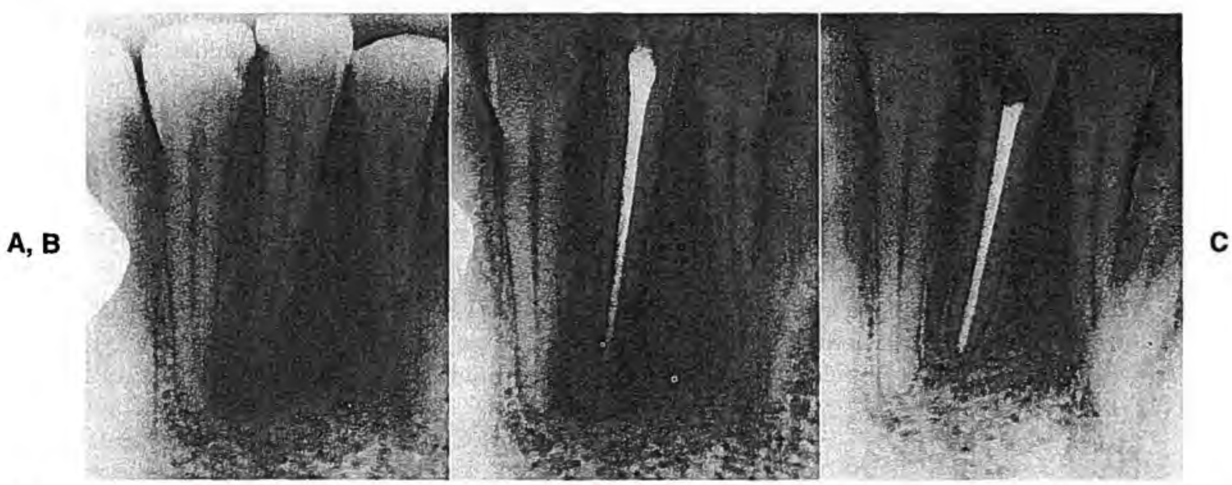


FIGURE 5-66 **Mandibular incisor with large periapical lesion and persistent discharge, treated with calcium hydroxide.** **A,** Preoperative radiograph. **B,** Canal filling with gutta-percha after using calcium hydroxide paste. **C,** Six years after original treatment. (Restorations by Dr. R. Ceisel, Evanston, Ill.)

intracanal medicament, if used, within the tooth to allow effectiveness for the drug.

Types of Available Sealing Agents

According to radioisotope studies, silver amalgam plus cavity varnish is the most effective sealant available in dentistry. Unfortunately, it would be difficult and time consuming to use those materials at the conclusion of each appointment and then have to drill everything out at the next visit.

Fortunately, zinc oxide powder with eugenol (ZOE) provides an excellent seal and is much easier to place and remove than amalgam. The addition of zinc acetate crystals speeds the set of ZOE without decreasing the sealing properties.

A large, thick mix of ZOE may be prepared each morning by the dental assistant and placed into the well of an empty ink bottle. A desiccating chemical, such as those included in bottles of medicines that may be altered by moisture, is placed in the bottom of the jar to retain the ZOE in usable condition for the entire day (Figure 5-67). Placement of the jar in the refrigerator will further retain the properties of the temporary sealer in workable form for a few additional days. When the temporary seal is needed, a suitable amount is removed from the jar and the acetate added.

Recently a light-cured material, TERM (Temporary Endodontic Restorative Material),* has been introduced. Its major advantages are the ease with which it may be used because it may be placed with a syringe from sterile prepacked compules, and it is set by exposure to visible light for 20 seconds.

The leakage studies have indicated a variety of results, from superior to poor. However, even the manufacturer advises that TERM be used only for 1 month or less because of several reports that its sealing ability decreases rapidly after 2 months.

TREATMENT OF OPERATIVE PERFORATIONS

Endodontic cases are increasing in complexity to a considerable degree. Cases are managed now that only a decade ago would have been thought to be hopeless. This has encouraged dentists to undertake therapy in more and more complicated cases, and unfortunately, some of the teeth become involved in procedural misadventures—one of the most aggravating of which is the operative perforation. Adding to the problem is that the average age of the population is increasing, and septuagenarians and octogenarians often display canals of extremely small size.

*Caulk/Dentsply, Milford, DE 19963.

FIGURE 5-67 Empty ink bottle is used to store zinc oxide–eugenol cement for use throughout the day. ZOE is mixed in morning and placed in well *(arrow)*. Bottom of jar has desiccating crystals to inhibit set of cement. One mixing will provide cement for as long as a week if jar is kept in refrigerator.

Operative perforations are defined here as a procedural accident whereby an artificial opening is created in a tooth so that a communication exists between the pulp canal space and the periodontal tissues. They may occur during an attempt to locate or enlarge a canal or when preparing room for a post or similar retentive device. Perforations may be due to trauma or to an altered state of pulpal or periodontal ligament tissue. These are inflammatory, not operative, perforations; their treatment is discussed in detail in Chapter 14, and to a lesser degree in Chapter 9. Many inflammatory perforations are treatable with calcium hydroxide pastes as an interim dressing, but our experience with that medicament in operative perforations is rather poor.

The indication of a perforation is generally a slow but steady seeping of blood. Because this symptom also often occurs during the extirpation of a vital pulp from a small canal, it may not immediately inform the operator of the procedural problem. However, as the false canal is enlarged, the seepage does not diminish but may increase. Drying attempts with paper points are futile. Ultimately a radiograph from at least two directions will confirm the problem.

General Rules for Treating Operative Perforations

The dentist always feels some guilt when an operative perforation occurs. Although I readily sympathize with that attitude, it should be put in the correct frame of reference. If the tooth did not need endodontics, the perforation would not have resulted. Therefore the etiology of the perforation transcends the appointment when the accident occurred. This may seem simplistic, but there is a very good reason for what I say. For the best prognosis *a perforation must be sealed as quickly as possible* (Figure 5-68). The chances for success diminish greatly when the perforation is closed at an appointment subsequent to the occurrence. When a perforation occurs, the operator must stay calm and make the repair immediately, hoping for the best.

Even in the best circumstances a perforation does limit the degree of success for an endodontic case. Although I have had some perforated teeth remain normal and asymptomatic for years, some suddenly develop serious periodontal lesions. Therefore I prefer to retain perforated teeth when they are surrounded by sound adjacent teeth. If the treated tooth goes bad, it may be extracted and a fixed bridge used as a replacement. Attempting to use a perforated tooth as a bridge or splint abutment is very hazardous. If the treated tooth develops further problems, the complex restoration will have to be seriously compromised or scrapped. It is not worth the chance. It is better to face the music, extract the perforated tooth, and utilize other abutment teeth.

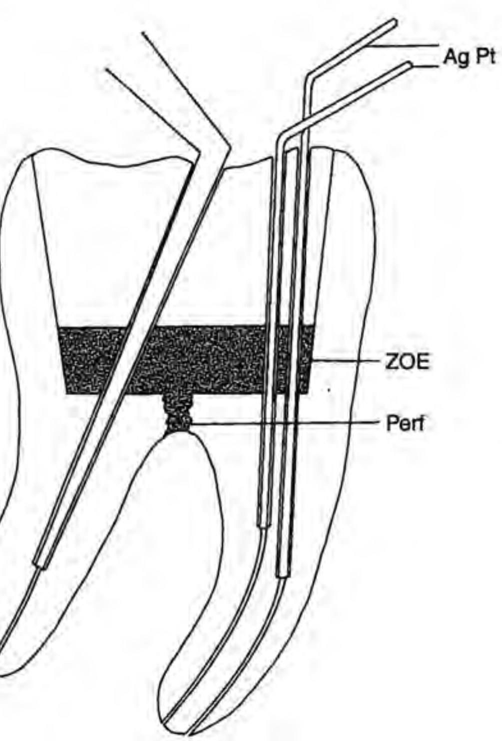


FIGURE 5-68 Diagram of perforation repair. Following perforation the true canal must be found. Silver points (or endodontic files) are placed well into the canals, protruding through the access cavity, to keep patency during the packing procedure. A heavy mix of ZOE is prepared and packed into the defect with a cotton pellet or cotton-tipped swab. Several more millimeters of ZOE are packed over the floor to provide a bulk of material for the closing of the perforation. When the cement has set, the silver points (or files) are removed, patency verified, and treatment completed (see Figures 5-69, *E*, and 5-70, *E*).

Inform the patient what has transpired. Perforations occur during the course of treating complicated teeth. The patient must be informed for legal purposes and also to understand the further choices of therapy available. Sooner or later the patient will discover what has happened; it is far better to learn it from you at the time of the occurrence.

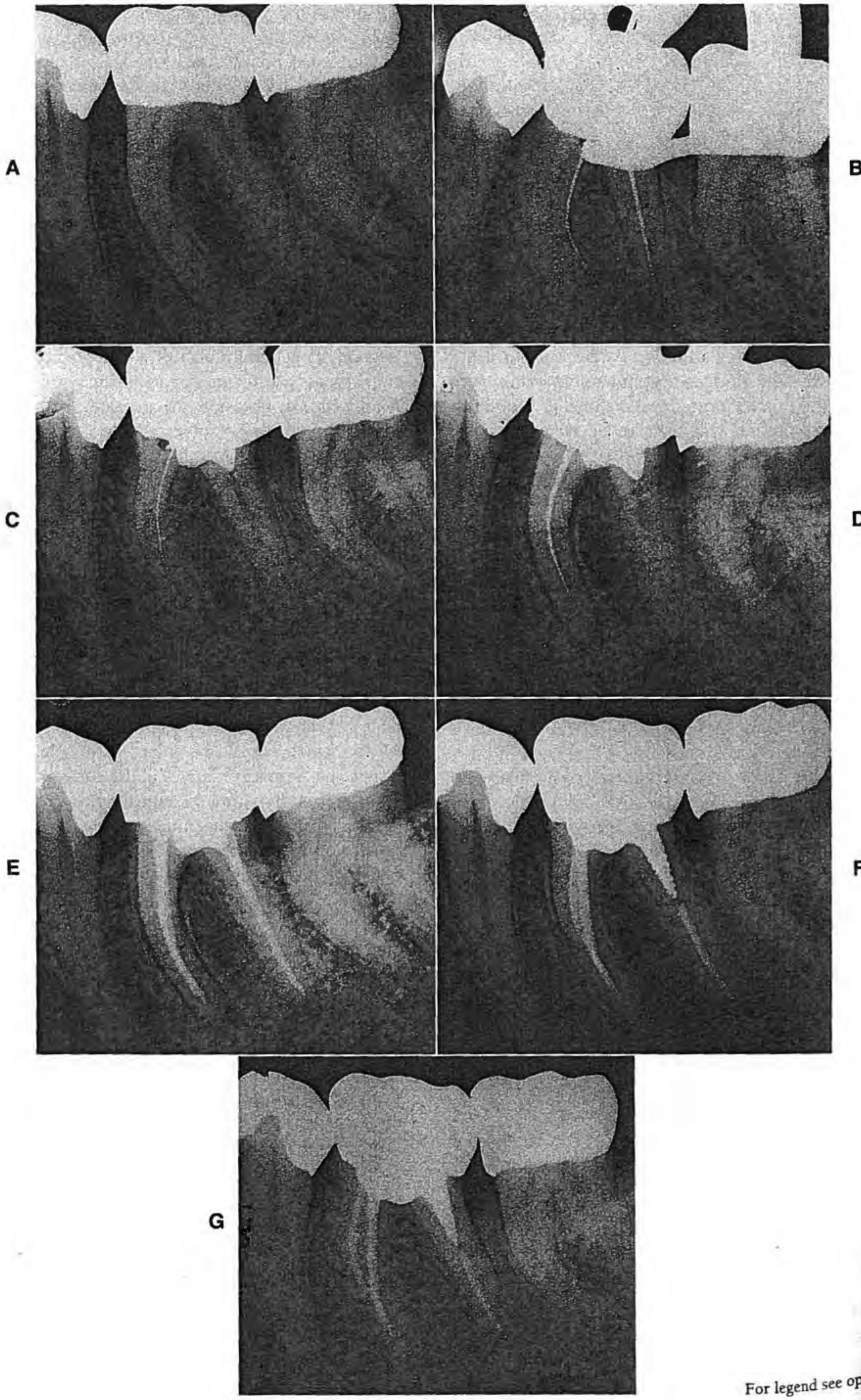
Treatment of Furcation Perforations by Packing the Chamber

This type of perforation is very common and has a fairly good prognosis when the perforation is sealed off immediately and when the patient's periodontal condition is good. It generally occurs when searching for a small canal that is diminished by irritation dentin (Figure 5-69, *A* and *B*). On occasion the operator will think that the missing canal has been located. However, the telltale sign of seeping bleeding may be verified by the placement of a file and taking of a radiograph (see Figure 5-69, *B*) from two angles.

The correct course of action at this point is to continue to search for the missing canal. If it cannot be located, an extraction or root amputation is indicated, and there is no need to take the time to make the repair. Very frequently the true canal will be located (see Figure 5-69, *D*) immediately after the perforation is verified by radiograph. The x-ray film will indicate the relationship between the true canal and the perforation, and the operator has another reference point to use in making the corrected location. All the canals should be enlarged to at least a minimum degree (i.e., size 25 or larger) at the correct working length. Use the least irritating irrigant for this procedure—saline would be fine—because there must be minimal irritation to the injured periodontal ligament adjacent to the perforation. A small inverted cone bur is used to slightly widen the most occlusal portion of the perforation. This also creates a somewhat retentive lock for the sealing material.

A silver point (or endodontic file) is placed in each canal. It need not bind at the apex but should bind several millimeters short of the apex and protrude through the access opening. These points will keep the filling material from going into the canals during packing of the chamber. Then a heavy mix of ZOE is prepared. A small portion of the cement is placed over the perforation and gently but firmly packed down. A larger portion of ZOE is placed over this area and again packed down (see Figure 5-68). Once the cement is hardened, the silver points are removed from the canals. A slight amount of enlargement of these canals is performed to verify their patency.

The case is then completed in the routine manner (Figure 5-70, *E*; see also Figure 5-69, *E*). The patient should be recalled initially at 6-month intervals. In addition to radiographs, the area of repair should be examined



For legend see opposite page.

FIGURE 5-69 Mandibular first molar with periapical lesions and large restoration. A, Preoperative radiograph. **B,** I thought that I had found the mesiobuccal canal, but the angled view indicated a perforation into the periodontal ligament. **C,** Canal located and perforation repaired. **D,** Both mesial canals located. **E,** Canals enlarged and filled with gutta-percha. Note perforation repair with ZOE. **F,** Three years later, periapical lesions have healed and furcation has remained normal. **G,** Fourteen years after original treatment, perforation repair still present, furcation area still closed, and all tissues appear normal. (Restorations by Dr. Sherwin Strauss, Chicago.)

for any periodontal defects and the presence of mobility. One hopes that the repair will remain as a tight seal against leakage and that the periodontal structures retain a normal condition (see Figures 5-69, *F* and *G*, and 5-70, *F* and *G*).

Treatment of Perforations by Enlargement and Filling as an Additional Canal

The disadvantage of sealing perforations by packing is that the operator has no true control over the movement of the ZOE cement. Some perforations may be overpacked and may cause extreme inflammation to the periodontal ligament, which is what we are trying to keep in a healthy state. On the other hand, if the cement is not packed to seal off most of the defect, the empty space will be an area to harbor bacteria and tissue breakdown products.

Accordingly, if the distance between the pulp canal space and the periodontal ligament is quite long and consequently difficult to pack off, the perforation may be enlarged and filled as an additional canal. There are some serious difficulties encountered in this technique as well. Many perforations extend to the buccal or lingual rather than proximal, however, and it is difficult to judge the exact site at which the defect reaches the periodontal ligament. Those that extend to the proximal can be measured with greater accuracy.

Again, it is wise to attempt to complete the sealing of the perforation as soon as possible after the misadventure is discovered. A measurement film is taken (Figure 5-71, *C*) and the canal prepared as in a routine case. The canal is filled with gutta-percha and lateral condensation. The periodontal ligament area should then remain in a relatively normal state (see Figure 5-71, *E*, and Figure 5-72).

Perforations Treated Surgically or Orthodontically

These entities will be described in Chapters 9 and 12, respectively.

New Materials for Perforation Repair

Many studies on perforation repair have investigated the use of amalgam. I have found this material deficient for this use, particularly if any excess material is expressed into the periodontium. If that occurs, a defect results almost immediately. Excess ZOE, on the other hand, usually is resorbed without the creation of a defect.

Recently, Torabinejad and his group from Loma Linda University have investigated the use of mineral trioxide aggregate (MTA) for use as a repair material for perforations, as a reverse filling material in periapical surgery, in apexification, and in several other endodontic areas.

The material is used similarly to that described for ZOE and has been reported to be very easy to apply. A recent study by Weldon et al used MTA and Super-EBA in furcation repairs, and the two materials had similar, positive results. Even though initial reports seem very favorable, more time is needed for evaluation.

NONINSTRUMENTATION TECHNOLOGY (NIT)

Lussi and associates from Berne, Switzerland, have written several papers which they called "a novel noninstrumentation technique" for cleaning out canal contents, including debris, and even to facilitate canal filling with a paste. The technique employs a vacuum system placed in the canal chamber with a malleable tube to remove the canal contents in a few seconds. Obviously the tooth must have fully developed apices but not so much reparative dentin that obliterates the chamber. If the operator needs to further prepare the canal, this may be performed as with a routine method. For filling, the vacuum is reversed to move the paste filling through the canal system.

Several manufacturers in the United States have evaluated this machine with mixed reviews. At the time of this writing, it still is not commercially available in the United States, but it is used by some Europeans. This could be an effective instrument to aid in obtaining a very clean canal prior to any instrumentation—a valuable addition to our armamentarium. Or, it could be a total flop, just as other promising ideas have been.

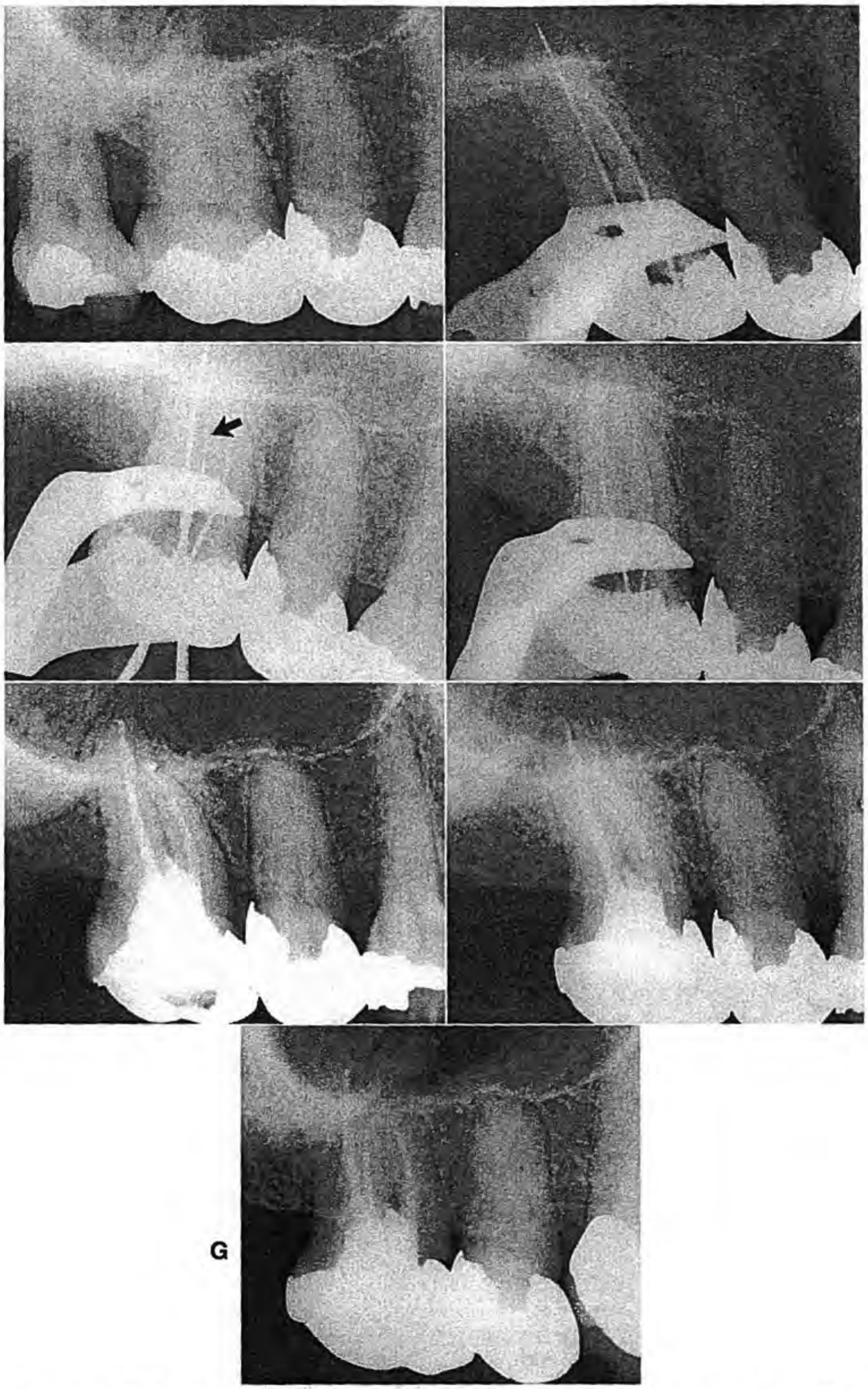


FIGURE 5-70 Perforation of chamber floor repaired with ZOE. A, Preoperative radiograph of maxillary molar area. Patient complained of severe pain to both hot and cold temperatures, and it was impossible to tell which molar was causing the problem. Because of the severe periodontal condition of the more posterior tooth, it was decided to have that tooth extracted in the hope it was responsible. After the extraction the pain persisted, so the other molar was scheduled for endodontic treatment. **B,** The palatal canal was located first, and then one buccal canal was found, indicated by this film of files in place in the palatal and mesiobuccal canals. More preparation was performed to locate the distobuccal canal. **C,** I thought that I had located it, so I placed files and took this radiograph. The file with the arrow had perforated the floor of the chamber rather than being placed in the distobuccal canal. **D,** The distobuccal canal was located slightly more to the distal. Files were placed into the canals to keep them patent during the repair. The orifice portion of the perforation was slightly widened with an inverted cone bur. Then the entire chamber floor was packed with ZOE. When the cement had set, the files were removed and patency verified. **E,** Treatment was completed, with canals filled with laterally condensed gutta-percha. **F,** Three years after original treatment. The tooth is comfortable, no pocket can be probed, and the area has retained a normal condition. **G,** Thirteen years after original treatment, all tissues appear normal.

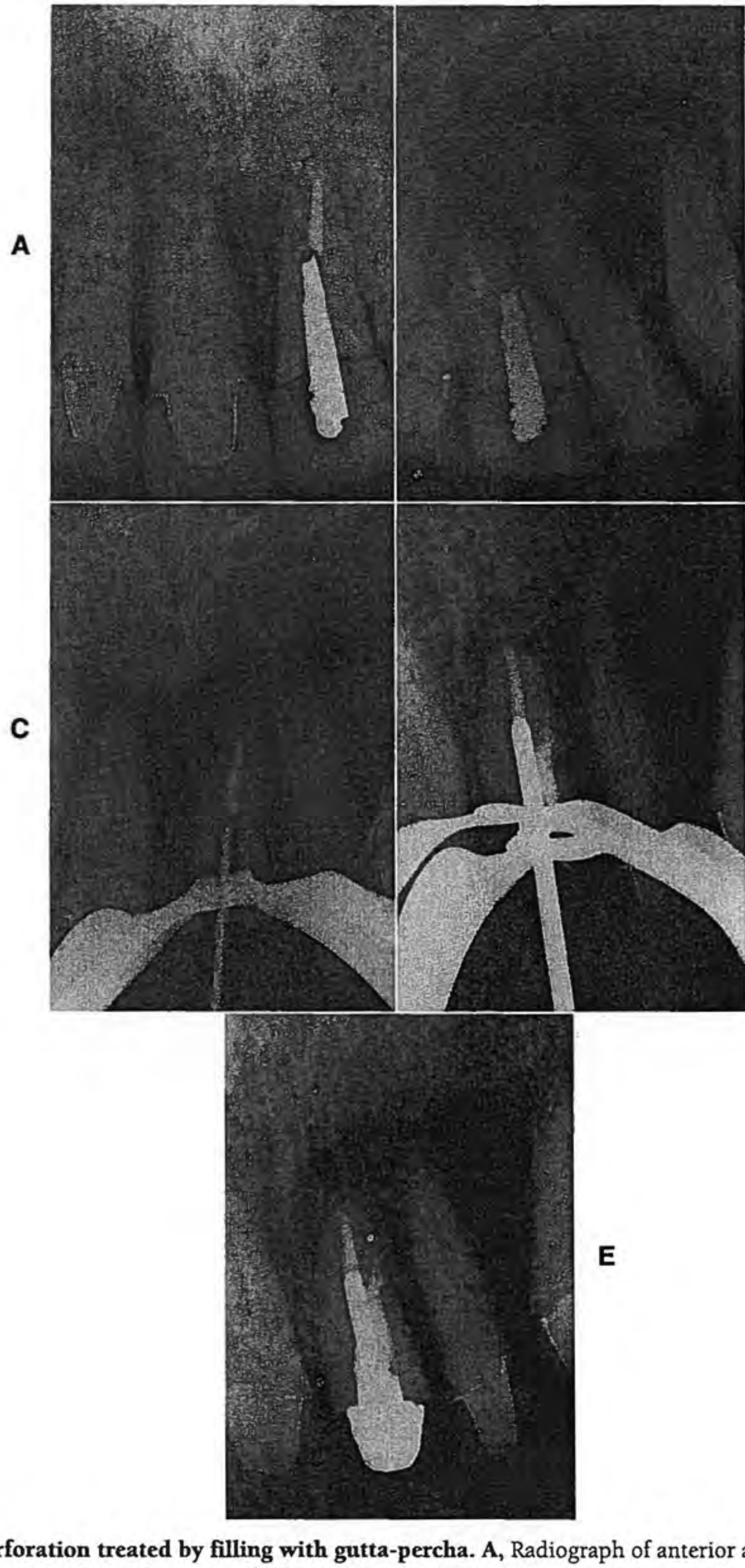


Figure 5-71 Tooth with perforation treated by filling with gutta-percha. A, Radiograph of anterior area with post and porcelain jacket crown. Post appears to be in canal, but the patient had a sinus tract on the palate, and I suspected a perforation. **B,** Angled view from distal verifies perforation to the palate. **C,** Crown and post were removed, and distance to perforation was measured with a file to slightly short of sensitivity by the patient. **D,** That false canal was filled with laterally condensed gutta-percha and Wach's paste, and an Endopost measured adjacent to it. **E,** Two years later the tract has not returned, and the tooth is comfortable. (Restorations by Dr. Don Hackman, formerly of Chicago.)

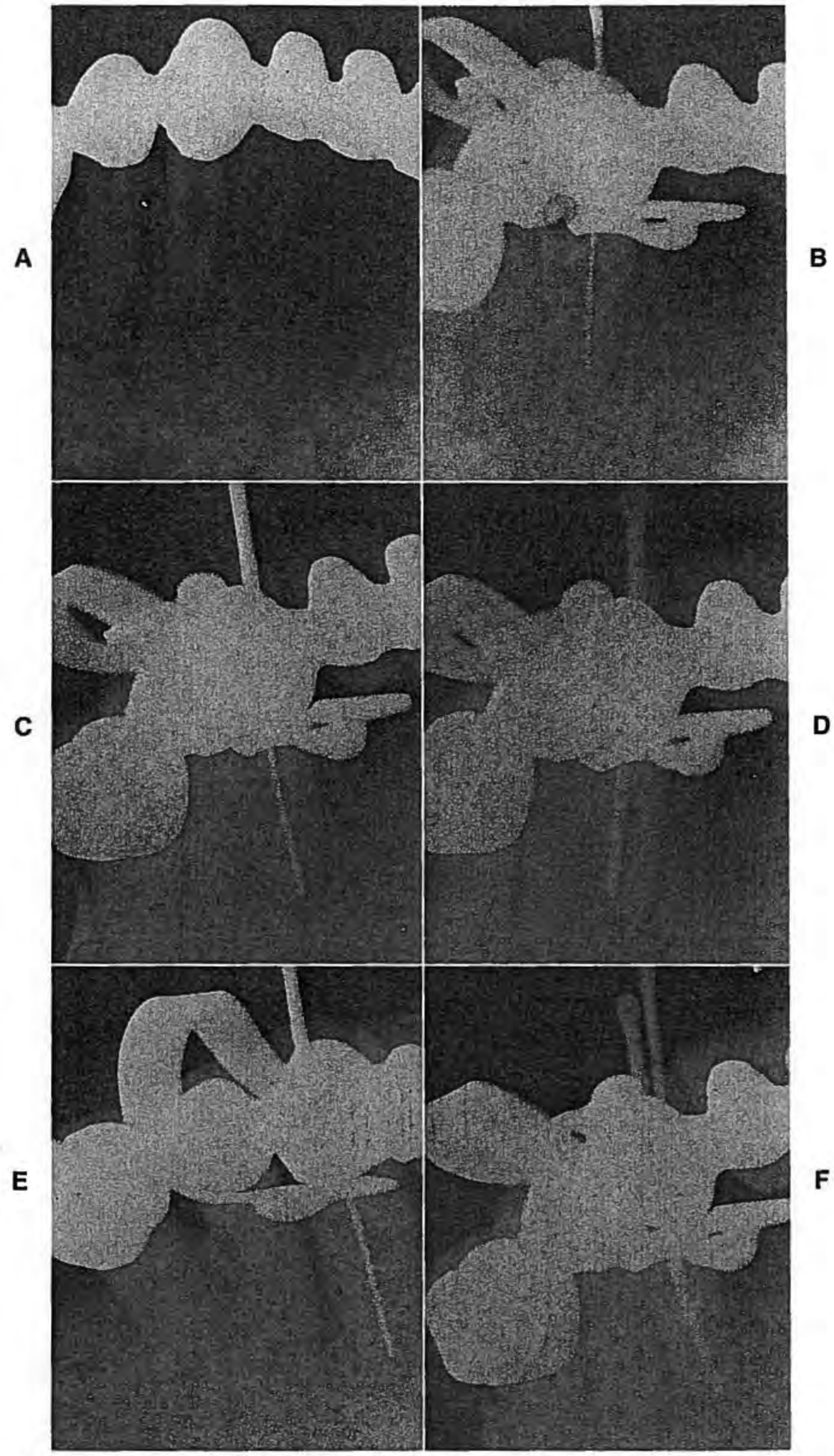


FIGURE 5-72 Mandibular cuspid with operative perforation by originating dentist. A, Preoperative radiograph. **B,** True canal located. **C,** Enlarged to size 50 and flared. **D,** In the attempt to gain a customized master cone, the perforation was again penetrated. **E,** Canal relocated, enlarged further, and closed to fill at next appointment. **F,** Master cone and one auxiliary cone placed, indicating that all are in the true canal.

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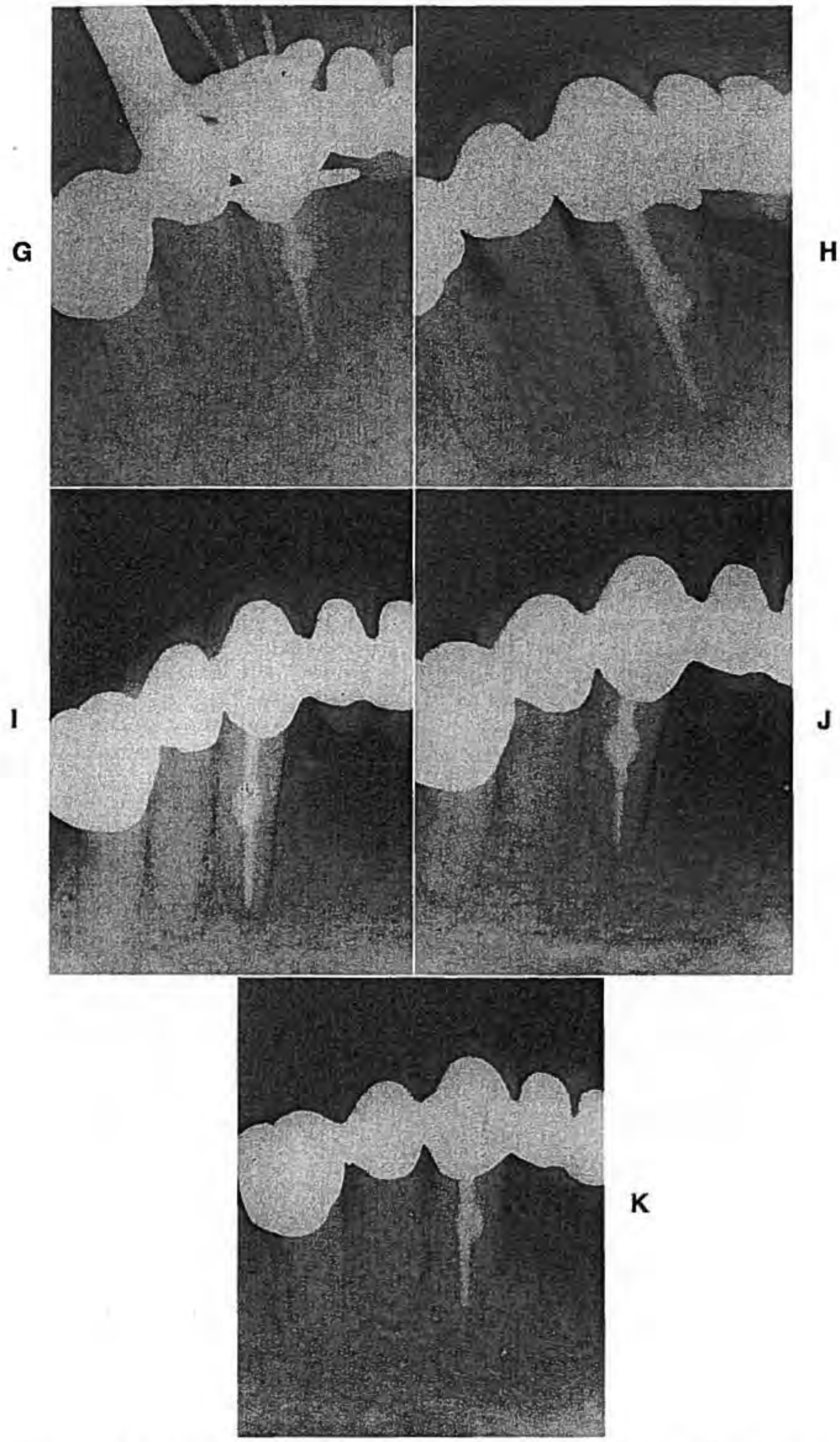

FIGURE 5-72, cont'd **G,** Several auxiliary cones later. **H,** Angled view of filled canal. **I,** Immediately after completion of canal filling, straight view. Notice that canal is filled very close to the radiographic apex. **J,** Two years after treatment, area looks excellent. **K,** Twelve years after treatment, canal filling appears to be several millimeters short of radiographic apex due to deposition of cementum. Tooth is firm and comfortable.

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