

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

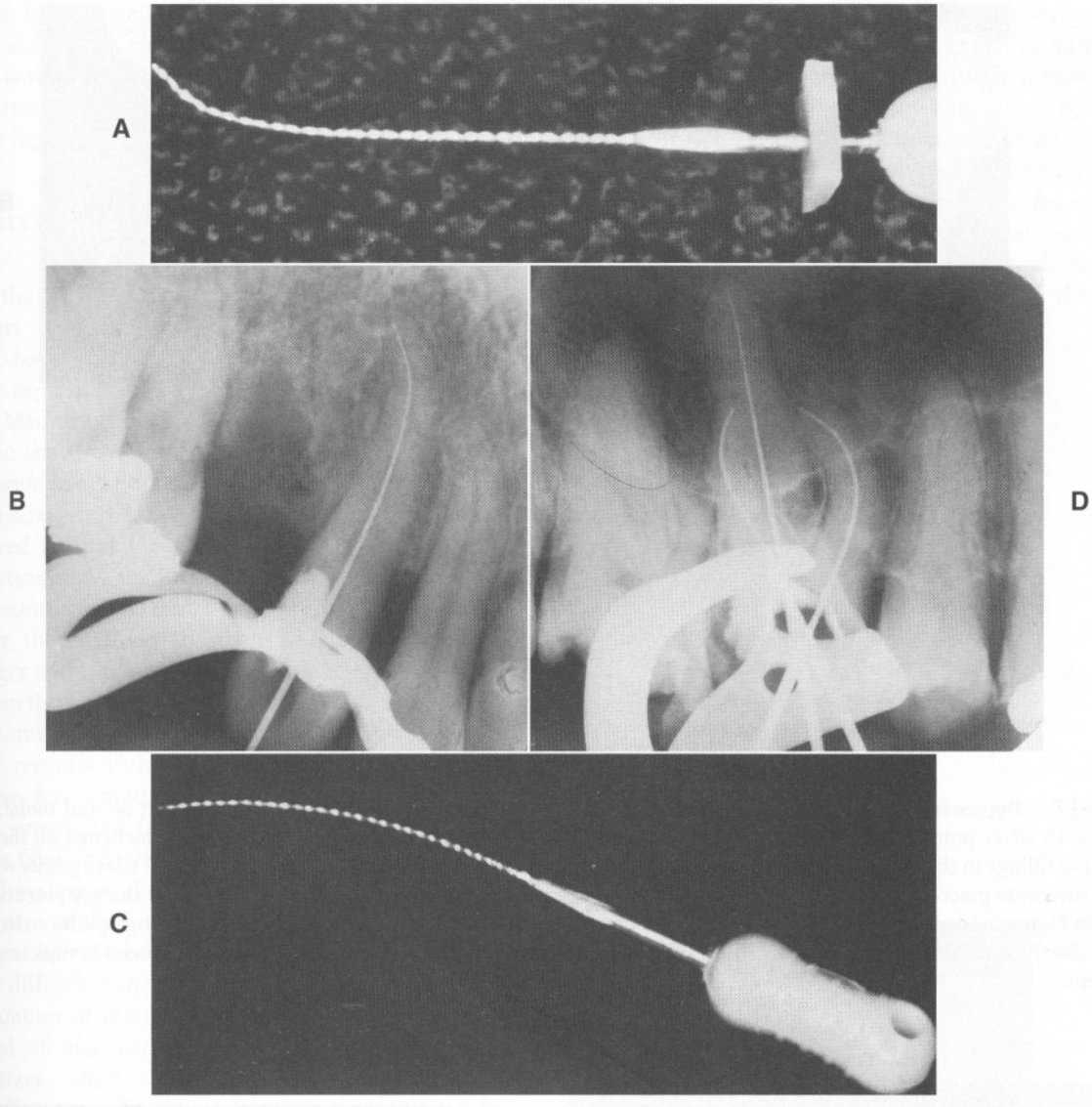


FIGURE 5-16 Sharp bend at tip of instrument **(A)** is used to explore and prepare a tooth with a dilaceration **(B)** or to bypass an obstruction. A gradual bend **(C)** is given all other instruments. Use of straight instruments would make exploration of teeth similar to this maxillary molar **(D)** 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

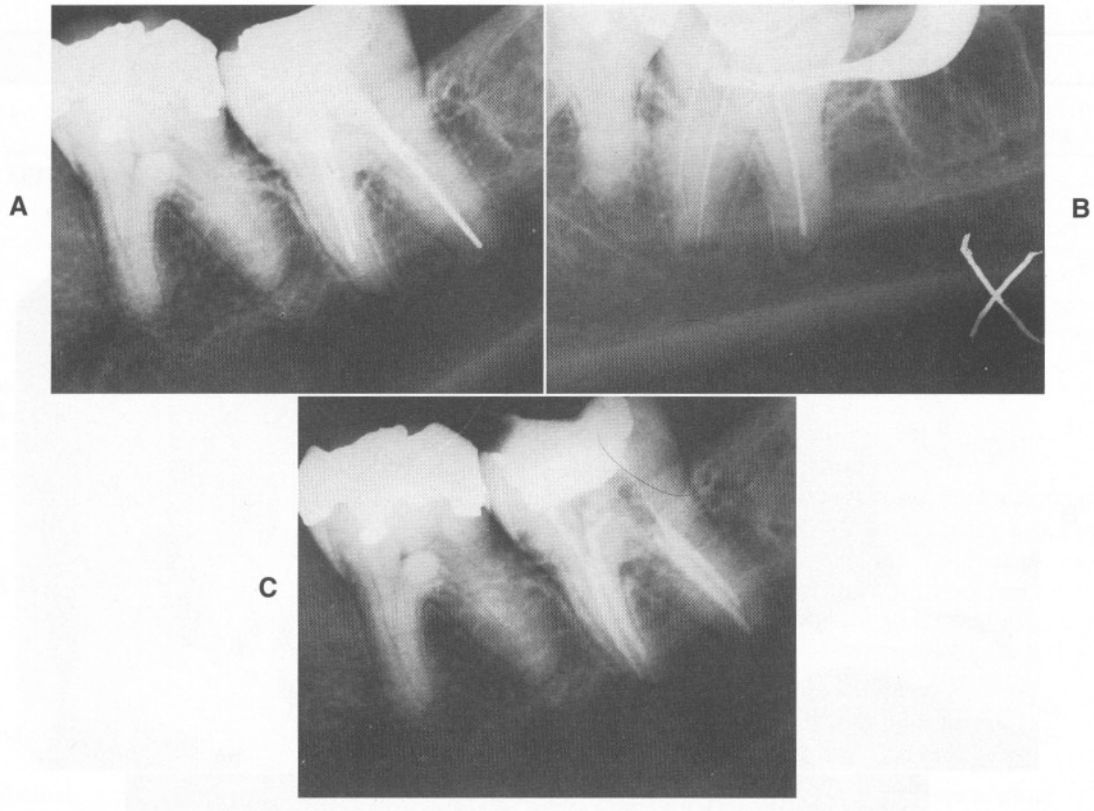


FIGURE 5-17 Bypassing ledged canal by precurving files. A, Preoperative radiograph of mandibular second molar, 1 year after treatment with silver points. The tooth was tender to percussion, and the periodontal ligament space is thickened on the mesial root. Note that the fillings in the mesial root are 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.

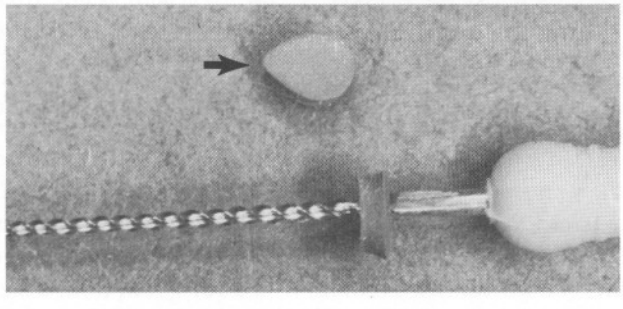


FIGURE 5-18 Teardrop stop will aid in using the precurved file. Point of the stop *(arrow)* indicates direction of curve even when instrument is within canal. (Courtesy Dr. Arthur Rybeck, Jr., Wheeling, W. Va.)

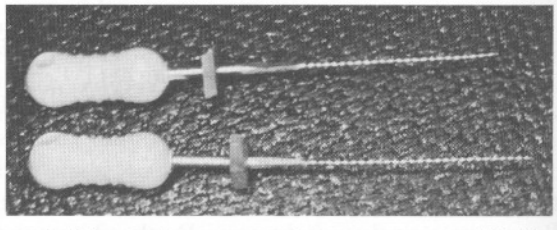


FIGURE 5-19 Making intermediate sizes. Size 10 file *(bottom)* is compared to an instrument of similar size in which 1 mm has been removed from tip to produce a size 12 instrument *(top)*. Note that stop has been moved toward handle of size 12 file to retain correct working length.

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

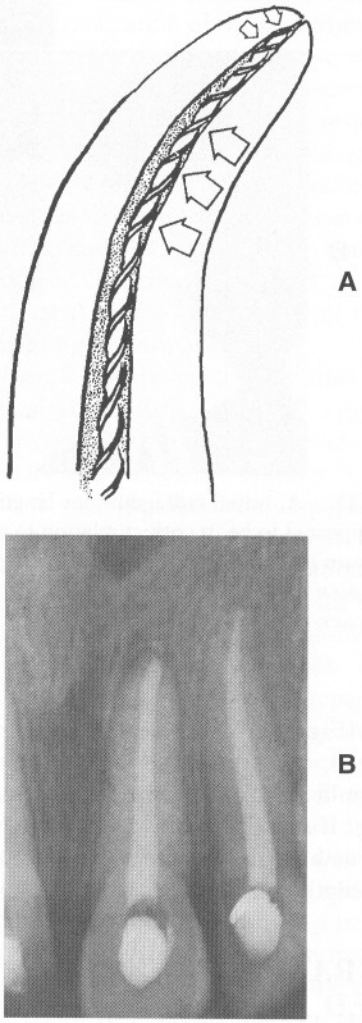


FIGURE 5-20 **A,** When curved canal is being enlarged, flutes of enlarging instruments rasp more against inner border of curve *(large arrows)* and thus decrease working length. Because curved instrument tends to straighten, some pressure is also forced against opposite wall near apex *(small arrows)*. 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.

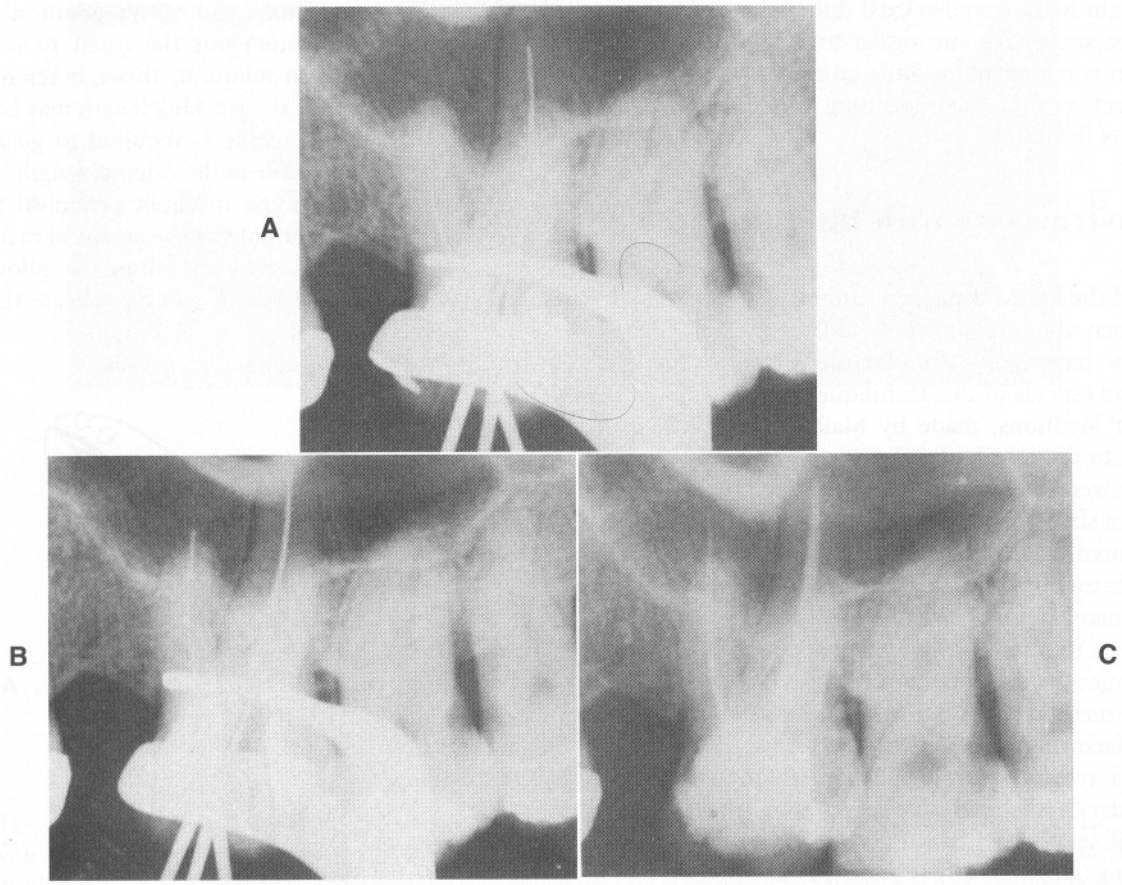


FIGURE 5-21 **A,** Initial radiograph for length determination. Size 10 file in mesiobuccal canal measured 18.5 mm from mesiobuccal cusp and appeared to be in correct relation to apex. **B,** Verification after some canal enlargement. Size 25 file in mesiobuccal canal still 18.5 mm from mesiobuccal cusp. 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

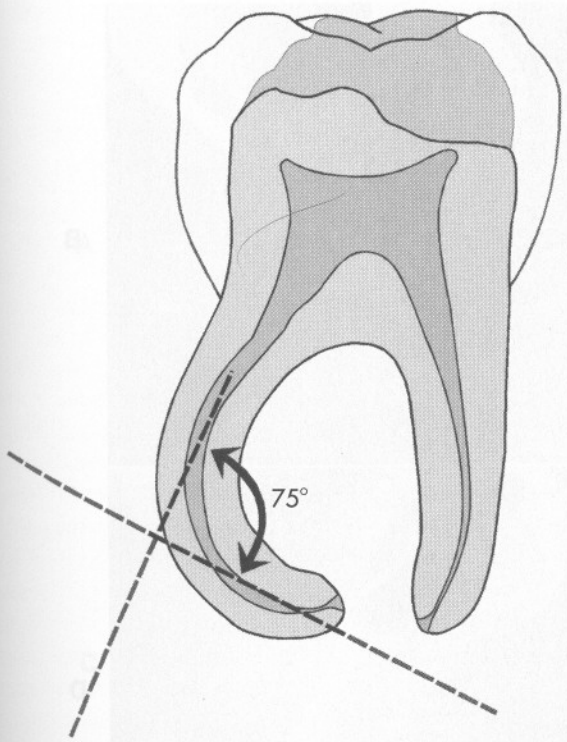


FIGURE 5-22 To estimate degree of curvature, imagine a straight line from orifice through the coronal portion of the root and another straight line from apex through apical portion of curve. The interior angle formed by intersection of these lines is the degree of curvature. Such an estimate is of mesiodistal 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.

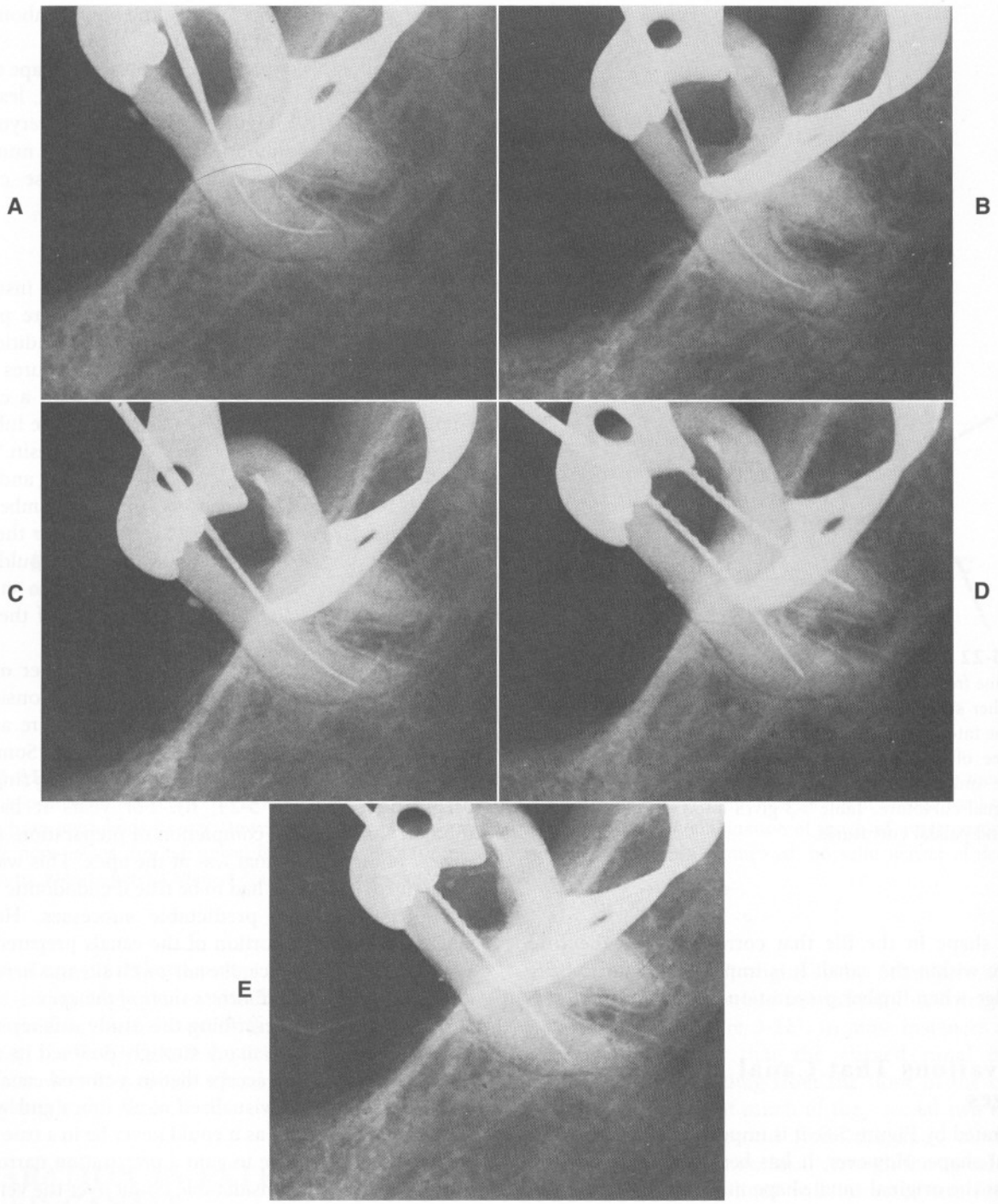


FIGURE 5-23 Mandibular second molar with well-placed size 10 file in the single mesial canal. A, Shape is excellent, and working length perhaps slightly too long. **B,** Size 15 file in place at 0.5 mm shorter than working length in *A*. Still looks good. **C,** Size 20 file in place starting to deviate. 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

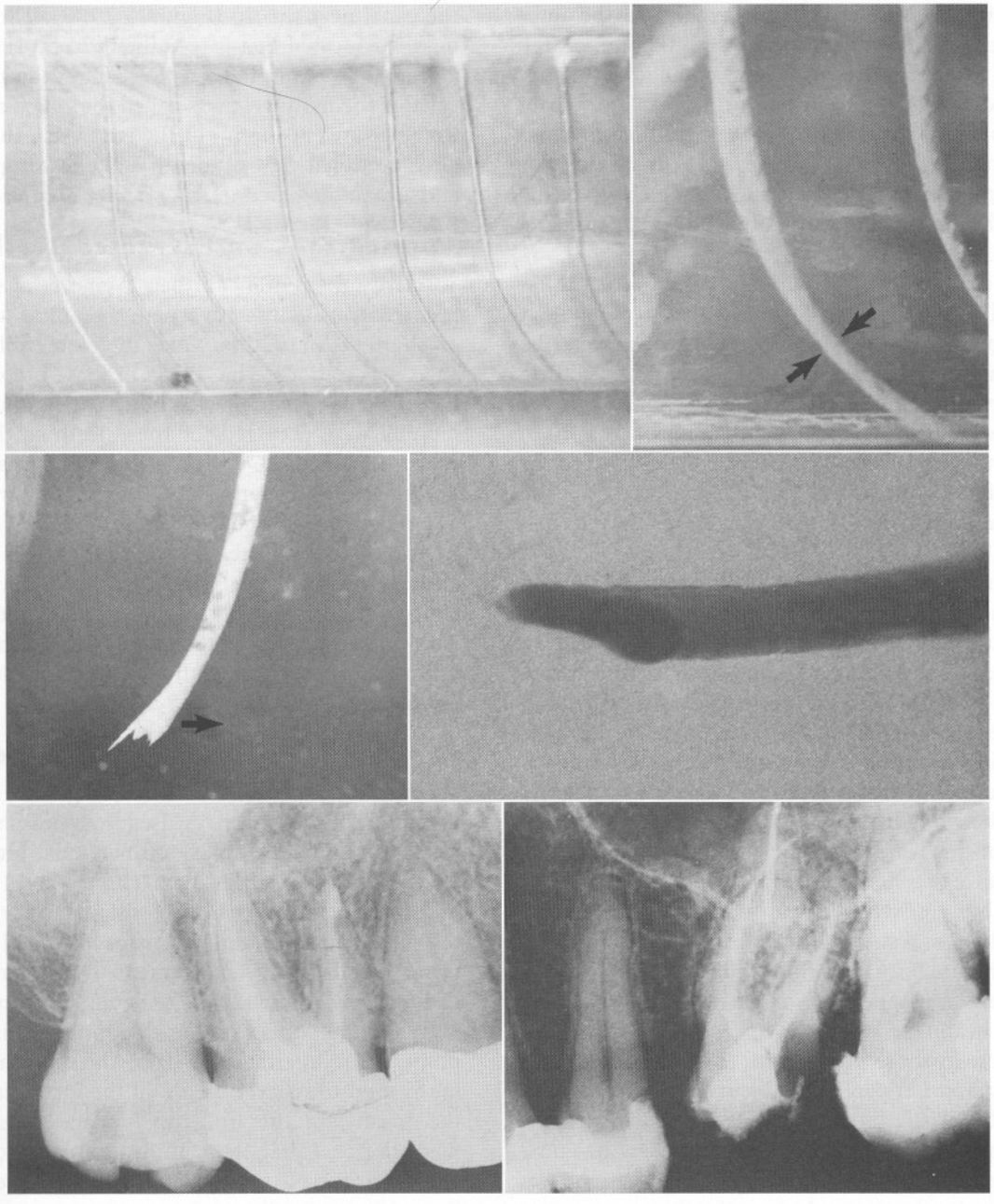


FIGURE 5-24 **A,** Plastic block made to simulate curved canals prepared by curving silver points and pouring acrylic casting resin. **B,** Typical canal preparation *(left),* which is not narrowest at apex but rather several millimeters from the apex *(arrows),* illustrates hourglass shape. **C,** Canal 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.

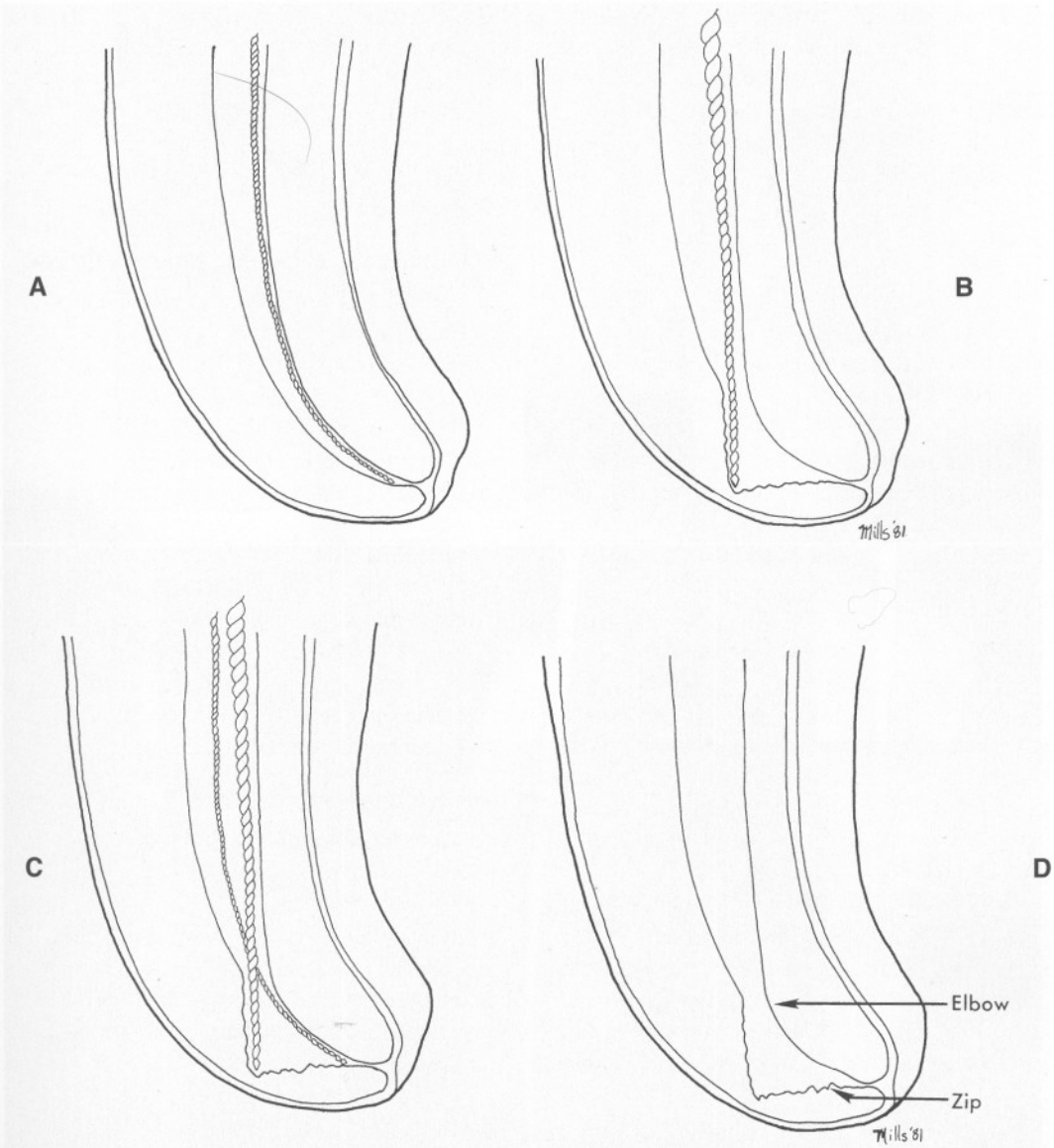


FIGURE 5-25 **Schematic drawing of subtle changes in canal shape that cause zipping and the elbow. A,** Small files are flexible and able to traverse the curve with minimal difficulty. Virtually no alteration in canal shape results. **B,** As wider, stiffer files are used, each opens up away from curve 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