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Instrumentation and Obturation of the Apical Third of Root Canals: *Addressing the Forgotten Dimension*

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Abstract

Modern developments in instrument design and obturation techniques have greatly improved the efficiency of conventional endodontic therapy. Nickel titanium rotary instruments allow the practitioner to prepare canals more quickly and predictably. However, apical preparations by such instruments fail to address the anatomical complexity of the root canal system. Morphologic studies consistently show that canals are mostly oval or irregular in shape; therefore, round preparations by instrumentation result in uninstrumented areas of the root canal system. This is of particular importance in the apical third and in cases of preexisting periapical pathology, where residual bacteria may reside and cause persistent infections. How beneficial are these new instrumentation and obturation techniques to the basic purpose of root canal therapy in eradicating bacteria? This article presents the shortcomings of current instrumentation and obturation techniques and offers possible solutions to improve the outcome of endodontic therapy.

Learning Objectives

After reading this article, the reader should be able to:

- explain the presence of oval root canal configurations in most teeth.
- discuss the instrument designs and why they do not allow complete cleaning of the canals.
- describe techniques that can better clean and fill these canals.

The primary goal of root canal therapy is to eliminate bacteria to treat or prevent apical periodontitis. However, primary endodontic therapy is not always successful and may require subsequent conventional or surgical endodontic intervention. Long-term studies show that a direct relationship exists between the presence of bacteria at the time of obturation and endodontic failures.[1,2] The efforts made toward improving instrumentation and obturation techniques have made endodontic treatment faster and less fatiguing to the clinician. However, such advances have not proved to increase bacterial reduction.[3,4] This oversight is of particular importance in cases involving apical periodontitis, where bacteria already have invaded the apical area. By evaluating current instrumentation and obturation techniques in terms of their ability to adapt to the root canal anatomy, the authors discuss their limitations and offer suggestions to improve the practice and success of endodontic therapy.

Endodontic Challenges in the Apical Third

Anatomic Challenges

Perhaps the most critical challenge to endodontic therapy is recognizing the complexity of the root canal anatomy. The term "root canal" can be misleading because it inaccurately de-

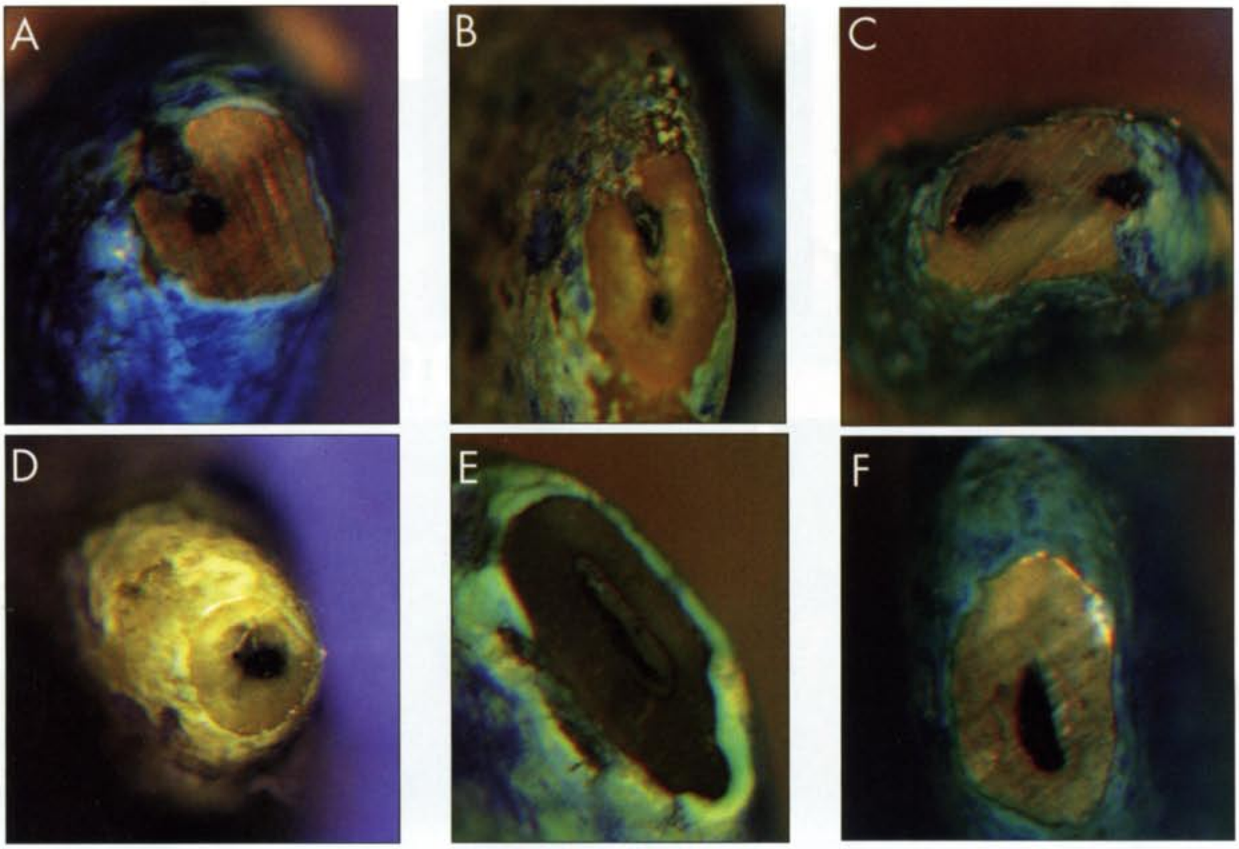


Figure 1—Cross sections of various root canals at the apical third; not all root canals are round.

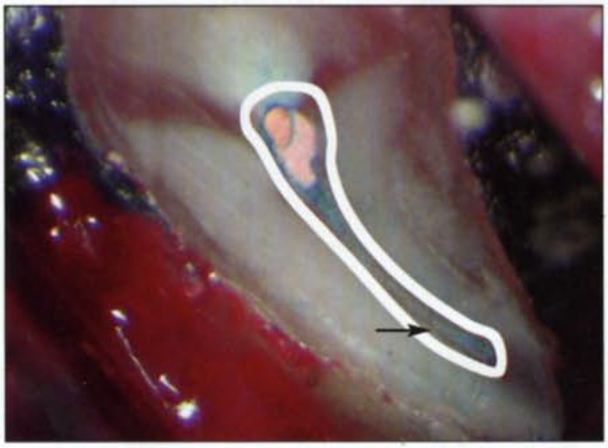


Figure 2—A clinical picture of mesiobuccal root apex after apicoectomy. Note the presence of a long isthmus and the presence of a missed canal (arrow).

scribes the actual internal morphology of the root. (For purposes of simplicity, the term will be used throughout this paper.) The word "canal" is derived from the Latin word "canalis," which means a pipe or a channel.[5] These definitions, in addition to the 2-dimensional radiographic depictions, create a sense that root canals are analogous to round tunnels. However, most root canals do not end at the apex as a rounded opening (Figure 1). Several morphologic studies have shown that as many as 75% of root canals in the apical third are actually irregular or oval shaped.[6-8] In a study that examined teeth of all groups, oval canals were detected in 25% of the sections investigated, and, with the exception of the palatal roots of maxillary molars, the buccolingual diameter was longer than the mesiodistal diameter.[9]

Other anatomical variations that complicate the instrumentation of the apical third include the lateral canals and isthmuses, which are often found in failed endodontic cases that require apical surgery (Figure 2). Morphologic studies as early as the 1920s showed that the root canal system consists of many branching systems, cul-de-sacs, and lateral and accessory branches.[10] It has been shown that the incidence of isthmuses in the apical 3 mm to 4 mm of roots is 45% in mesiobuccal roots of maxillary first molars, almost 30% in maxillary and mandibular molars, and 70% to 80% in the mesial roots of mandibular first molars.[11] These findings have been confirmed with microcomputed tomography.[12]

Instrumentation—Clinical Challenges

There are many clinical challenges brought about by oval-shaped canals. First, the long diameter of oval canals in the buccolingual dimension cannot be detected radiographically. Second, round preparations made by endodontic files do not allow access to the long dimension, remaining incompletely instrumented and obturated, serving as a possible source of future endodontic failure (Figure 3). Creating a circular preparation that would take these areas into account would most likely result in perforation of the root in the shorter dimension of the

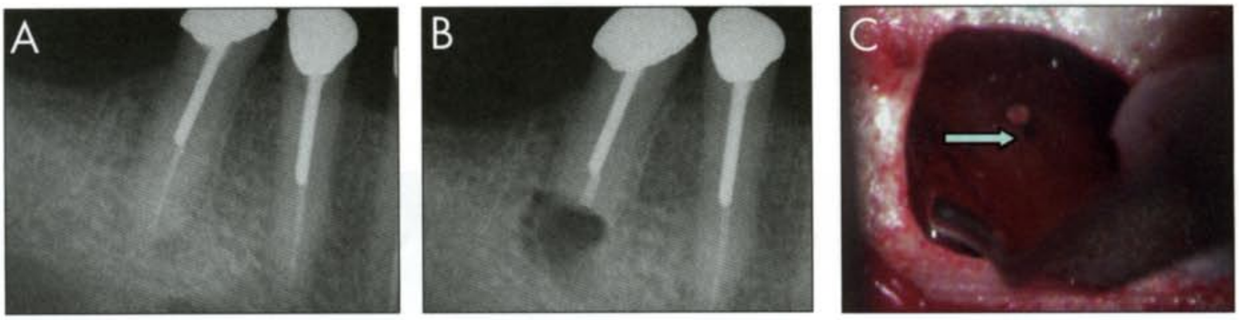


Figure 3—Root canal failure because of inadequate apical enlargement. (A) Preoperative radiograph showing a thin root canal filling. (B) Postoperative radiograph showing a well-condensed retrograde filling with MTA. (C) Inspection of apex after root resection indicates the presence of an inadequately filled oval root canal.

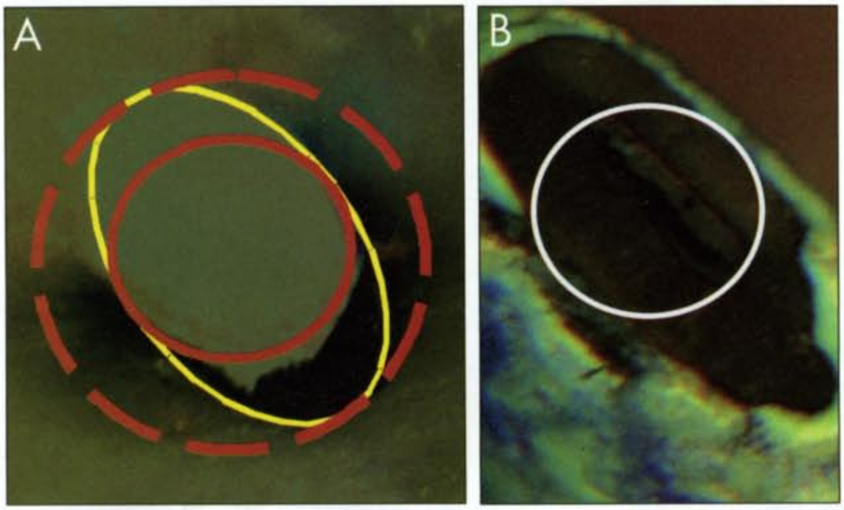


Figure 4—(A) Cross section of an obturated root canal at the apex. The yellow oval represents the original geometry of the root canal. The solid red circle represents the final root canal preparation and filling, which failed to completely encircle the original geometry. The dashed red circle represents the ideal size of the final preparation that completely encircles the unprepared root canal. (B) For canals that are buccolingually a thin oval in cross section, a circular preparation would require instrumentation to a size (white circle) that may perforate or significantly weaken the roots in a mesiodistal direction.[29,30]

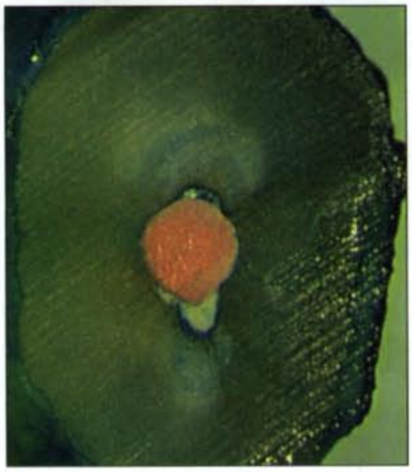


Figure 5—Cross section of a root canal instrumented with the rotary technique. Only the central part of an oval canal is instrumented, as a large round canal space, with long or short narrow wings extending buccolingually.

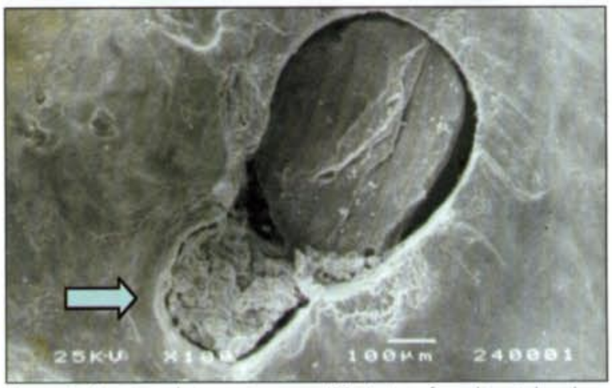


Figure 6—Scanning electron microscope (SEM) view of an obturated oval root canal. The debris in the lingual extension did not allow for complete obturation of the root canal and may lead to root canal failure in a clinical setting.

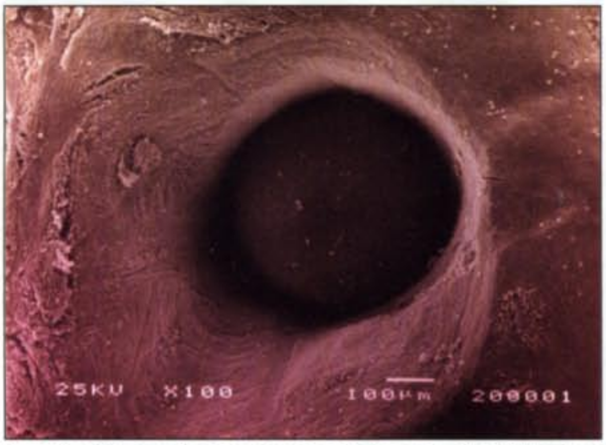
root canal (Figure 4). Finally, no instrumentation technique to date has succeeded in compensating for uninstrumented apical areas.

Design and Circular Preparations

The advent of rotary nickel titanium (NiTi) instruments has improved the efficiency of root canal preparation by decreasing chair time and causing less fatigue for the clinician. However, the same superelastic property that allows NiTi files to better negotiate curvatures, when compared with stainless-steel hand files, also functions as a disadvantage when instrumenting the apical third of oval canals. NiTi files apply little pressure against the buccal and lingual extensions of oval canals in the apical area, resulting in preparations that are essentially circular outcrops surrounded by unprepared areas toward the buccal and lingual (Figure 5).[13,14] Root canal cleanliness has been found to be poor in these cases with much remaining debris and smear layer in the unprepared extensions (Figure 6). Similar results are found with hand instruments.[15]

Instrumentation Techniques

Studies have shown that thorough instrumentation is hindered by anatomic variations such as oval canals.[13,16]



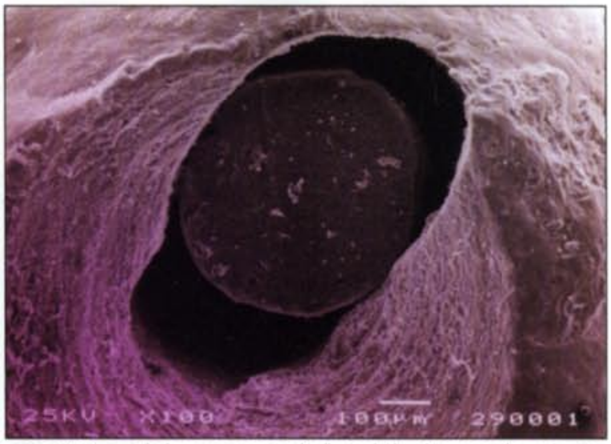


Figure 7—SEM view of apices of root canals obturated with cold lateral condensation. (A) A rounded preparation is ideally sealed with a cone-shaped gutta-percha master cone. (B) The use of a similar gutta-percha shape shows inability to produce an apical seal.

Given the restriction of round preparations made by rotary NiTi files, various hand-filing techniques have been revisited to better treat oval canals. Circumferential filing has been suggested as a way to overcome this problem.[17] However, it is believed that the effectiveness of this technique applies only to the coronal portion of the canal. Any canal curvature forces the apical part of the file to behave quite independently of the operator control. The manual crown-down technique also has been shown to be more effective in cleaning mesiodistal flattened root canals than the rotary technique, but neither completely cleaned the root canal.[15] When comparing different hand instrumentation techniques, Wu and colleagues found that circumferential filing was better at removing the inner layer of dentin compared with the balanced force method.[13] Still, the difference was not significant; both left large portions of the canal wall uninstrumented.

Current applications of microcomputed tomography have been groundbreaking, enabling researchers to accurately evaluate and compare the effectiveness of different instrumentation techniques. Peters and colleagues found that over 35% of root canals were left untouched after using hand and rotary systems.[12] However, it has not proved to enhance the ability to clean the canals compared with other hand instruments.[3,12]

Obturation Challenges in the Apical Third

The goal of obturation is 2-fold: the first goal is to keep microorganisms from entering and reinfecting the root canal system; the second is that good obturation of the instrumented canal will prevent tissue fluids from entering the root canal system and providing sustenance for residual bacteria. Both can be achieved by using an obturation technique, which allows the material to adapt to the apical preparation. As a measure of adaptation, density and flowability of the obturation material into canal irregularities are often evaluated.[18-21]

Wu and colleagues found that leakage may depend more on the dimension of the debris-filled portions, and the canals with very long buccolingual diameters and short mesiodistal diameters may be more difficult to clean.[22] Lateral condensation can be applied predictably in round canals; obturation of oval canals may leave unfilled areas (Figure 7). Oval canals present a particular challenge in creating a seal[23,24]; however, bacteria remaining after instrumentation can be inconsequential if they are entombed within a tight apical seal.[25] In a study evaluating cold lateral condensation, an adequate seal was achieved when the tip of the spreader was inserted 1 mm short of the working length.[26] A probable explanation for this effect is that a deeper penetration of the spreader was able to deform the gutta-percha cone into an oval-shaped canal. However, spreader penetration to this depth cannot always be achieved in situations of curved canals.

Obturation of oval canals using the warm vertical compaction (WVC) technique has shown more promising results (Figure 8). In particular, the WVC technique has shown greater ability to flow into canal irregularities.[27,28] A study comparing cold lateral with WVC and their ability to adapt to oval canals found that WVC produced significantly higher gutta-percha adaptation.[29] The same investigators also found that gutta-percha could penetrate into small clefts that were too thin to be mechanically instrumented when using the WVC technique. Jung and colleagues found that good adaptation of gutta-percha in the apical third depended not on the temperature of the System B plugger, but on the depth of penetration by the plugger vertically condensing.[23]

Suggestions for Treating the "Forgotten Dimension" in Oval Canals

Need for Apical Enlargement

Traditional guidelines for apical enlargement and instrumentation should not be used for oval canals. Weine proposed that enlarging the apical area to 3 sizes larger than the initial binding file was sufficient to debride the canal.[17] However, studies have shown that the first file to bind clinically is usually smaller than the shorter diameter of the canal.[29,30] As a clinical example, if

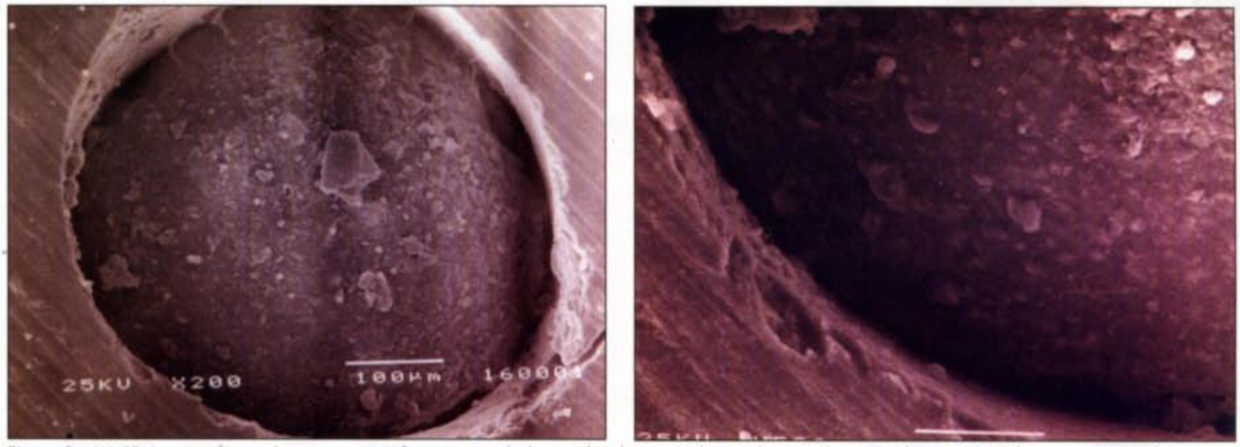


Figure 8—(A) SEM view of apical cross section of a root canal obturated with a pure thermoplastic technique (Obtura). (B) A closer inspection of the area shows close adaptation of gutta-percha with root canal walls. (No sealer cement was used.)

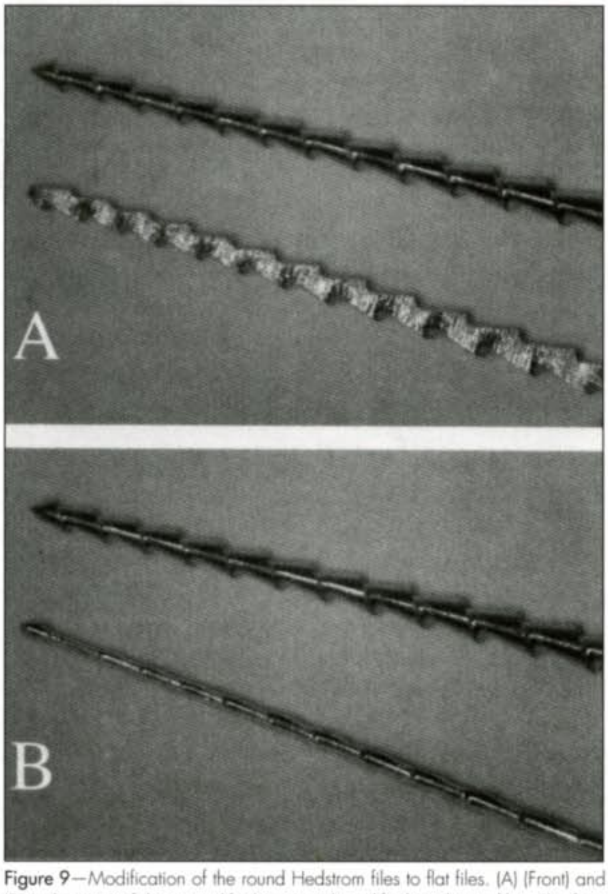


Figure 9—Modification of the round Hedstrom files to flat files. (A) (Front) and (B) (side view) of the unmodified (top) and modified Hedstrom files. The front and back of the Hedstrom file were flattened with a diamond bur. Cutting edges can only be seen on the sides of the file.

the shorter diameter of a canal were 0.25 mm and the larger diameter 0.50 mm, enlarging an initial binding file of 0.25 by 3 sizes would only create a master apical size of 0.40, which leaves remaining debris and infected dentin untouched. In a 2005 review by Baugh and Wallace, the authors examined studies related to apical morphology and instrumentation effectiveness.[31] Their conclusion was that apical preparations needed to be enlarged.

Bacterial Reduction

The main purpose of apical enlargement, particularly in necrotic cases, is to disinfect the root dentin. Bacterial reduction by apical enlargement had been proved in many studies.[32,33] In 2001, Peters and colleagues collected root dentin from teeth with apical periodontitis and identified the bacteria left in the root dentinal tubules.[12] They found bacteria to be present in the outermost layers of dentin in 62% of the dentin sample. Therefore, enlargement of root canals may lead to a greater probability of producing round finished root canals. This concurs with Kerekes and Tronstad who found that a size #70 would obtain round canals in almost all the mandibular incisor samples at 1 mm to 3 mm from the apex.[29]

Irrigation Penetration

The role of irrigation is critical for achieving satisfactory debridement and asepsis in root canal therapy by removing organic material, microorganisms, and their toxins.[4,34,35] However, irrigation solutions are only as effective as their depth of penetration. Instrumentation with smaller files limits the access of irrigating solution to the apex; therefore, it also prevents removal of debris in that area. Studies since the early 1970s have shown that canals must be prepared to at least size #40 for irrigation to reach the apical third of the canal.[36] Larger apical sizes also confirmed the need for apical enlargement to enable irrigating solutions to reach the apical third.[37]

Instrumentation

LightSpeed

LightSpeed instruments[a] have the advantage of attaining apical enlargement without compromising loss of tooth structure in the middle and coronal thirds. The football-tip design also creates an apical stop that assists in obturation. Studies have shown significantly better instrumentation in the apical area when using LightSpeed compared with hand instrumentation in cases of oval canals.[38] Another clinical study examined the effec-

[a] Discus Dental, Culver City, CA 90232; www.discusdental.com

tiveness of apical enlargement to bacterial reduction in patients with apical periodontitis. The authors found that apical enlargement with the use of LightSpeed after rotary instrumentation decreased bacteria by 80% in mandibular molar canals. They suggested that this regimen could substitute for 2-visit root canal treatment.[39] LightSpeed instrumentation allowed greater apical enlargement with significantly cleaner canals, less apical transportation, and better canal shape than both hand instrumentation groups at both levels ($P<.05$).

New Possibilities in Instrument Design: the IqFile

Although an effective irrigation regimen is indispensable for dissolving organic tissue in uninstrumented recesses, a change of instrumentation design for flattened root canals should be considered. One study looked at modified Hedstrom files (IqFiles) to instrument premolars with oval-shaped canals. The IqFile was prepared by flattening 2 opposing cutting surfaces of a Hedstrom file to make a pill-shaped cross section.[40] This modification produced a file with 2 sides of cutting flutes and 2 flat, noncutting sides (Figure 9). They found that when compared with the use of ProFile[b] instruments alone, the combination of ProFile instruments and IqFiles was associated with a significantly greater percentage area of final instrumentation at both 1-mm and 3-mm levels from the working length. The authors concluded that files that are pill shaped in cross section will perform significantly better in instrumenting oval canals than files with circular cross sections.

Ultrasonics

The inherent complexity of the root canal system can harbor bacteria in areas inaccessible to hand and rotary instruments. The use of an ultrasonically activated file after hand and rotary instrumentation has shown greater canal and isthmus cleanliness values in the apical 1-mm to 3-mm levels.[41,42]

In 2005, Gutarts and colleagues introduced an ultrasonically activated irrigation needle to be used for 1 minute after hand or rotary instrumentation.[41] Their results showed significantly cleaner canals and isthmuses in the mesial roots of mandibular molars.

Controversy in Enlarging Apical Size

Fracture

A common argument against enlarging the apical size is that it leaves the root canal–treated tooth more susceptible to root fracture because of the loss of remaining dentin thickness of the root. Although this may be based on clinical experience, no scientific data exist to support this argument. Zuckerman and colleagues examined the residual dentin thickness in mesial roots of mandibular molars prepared with LightSpeed rotary instruments and Gates-Glidden[c] reamers.[43] They found that instrumenting to LightSpeed #50 does not significantly decrease the residual dentin thickness.

[b] Dentsply Tulsa Dental, Tulsa, Okla; www.tulsadental.dentsply.com
[c] Essential Dental Systems, South Hackensack, NJ; www.edsdental.com

Conclusion

Evaluation of instrumentation and obturation techniques should focus on their ability to reduce or entomb bacteria in the root canal system. Many advances have been made to improve the efficiency of root canal treatment but fail to address the fundamental challenges of root canal morphology. Morphologic studies reveal the complexity of the root canal system, particularly in the apical portion. Most studies show that canals are not circular but oval in shape. In evaluating current techniques, the authors discovered that much of the canals are left untouched both in instrumentation and obturation.

There can be a number of reasons for overlooking the buccolingual extension of root canals. One reason could be the fact that root canal treatment is usually judged by radiographic esthetics. The current instrumentation and obturation techniques work effectively in the mesiodistal direction; therefore, finished root canal treatments appear esthetically pleasing on a radiograph. However, radiographs are 2-dimensional renditions that fail to accurately reflect the buccolingual appearance of root canal treatments.

The solution to preventing the development or persistence of apical periodontitis is to first recognize the forgotten buccolingual dimension of oval canals by enlarging the apical preparations. Such enlargements can be achieved without presenting any additional risk of root fracture. Also, adequate debridement may be enhanced by the addition of ultrasonics into routine root canal treatment. These are only preliminary recommendations; further investigation is needed for treating oval canals.

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