In vivo study of apical cleaning

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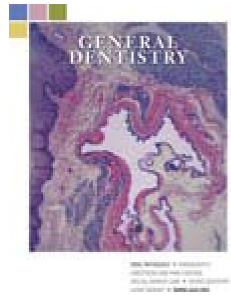

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This study sought to evaluate the efficiency with which debris is removed in the clinical environment by evaluating 53 teeth that had undergone *in vivo* root canal therapy and were extracted for various reasons, including fractures, pain, caries, and financial considerations. The teeth were cross-sectioned 1.0 mm from the apical constriction and 120 canals were evaluated for residual debris based on photographs taken at a magnification of 50x. Of the canals evaluated, 82% had residual debris. Canals treated with the crown down (with apical gauging) technique and/or the step-back technique were free of debris 1.0 mm from the apical constriction only 18% of the time. These techniques prematurely gauged the correct apical canal size because the gauging file bound either in the tangent of the curves or in the narrower dimension of the typical oval canal. All of the canals instrumented to a round shape were free of debris 1.0 mm from the apical constriction. Of the canals treated with tapered instruments, 48% were transported. Of the canals cleaned with the LightSpeed technique (that is, engaging the canal), 100% were free of debris 1.0 mm from the apical constriction.

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Root canal therapy is designed to clean the canal of bacteria and debris before sealing it to avoid percolation of potential residual toxins into the periradicular tissues. Unfortunately, canals have a very complex shape. According to Harty and Pitt Ford, “All root canal systems are curved in one or more planes…”[1] More than 80% of canals are oval in shape; in addition, many have fins, grooves, anastomoses, and deltas.[1-5] Of the oval shapes, 20–40% are extra wide, with a ratio of more than 2:1.[4,6] Spangberg noted in 2001 that “the most important part of the preparation is the very apical part of the root canal.”[7] Shuping et al reported that bacteria hide in the debris; as a result, the debris must be removed to remove the bacteria.[8] Even with the newer resin sealers, leakage studies typically evaluate the effectiveness of obturation in terms of how many canals leak, how long it takes them to leak, or how much leakage occurs.[9] Leakage happens. Research is being performed for the purpose of decreasing leakage and increasing the effectiveness of sealers. Leakage should not be a major issue if all of the debris and bacteria are removed.

The canal system terminates in an apical constriction that is similar to an hourglass (Fig. 1). Back in 1955, Kuttler reported the average foramen was 0.60 mm and the average apical constriction was 0.30 mm.[9] Behind the constriction, the actual canal sizes averaged 0.35–1.00 mm.[3-5,10-14]

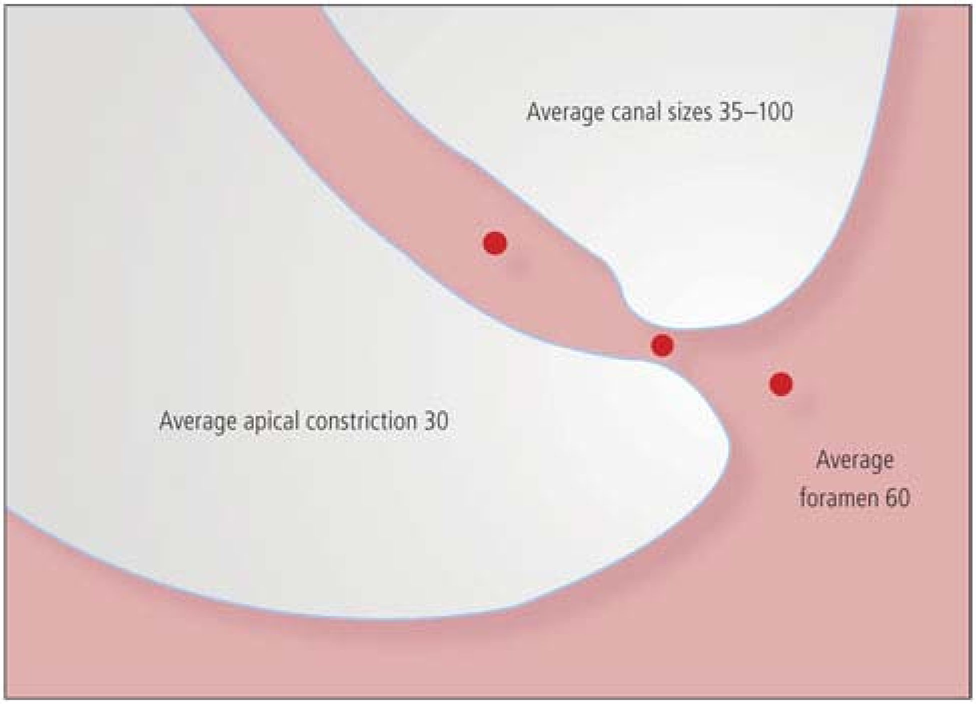

Fig. 1. The terminus of the canal has a large canal, a small apical constriction, and a large foramen.

How do we determine when the canal is clean? The step-back technique determines the proper size to which the canal should be cleaned by introducing a file sequentially into the canal until it is bound at working length. After working the next two to three larger files to working length, the last file used is the final apical size. Cleaning is completed by increasing file size sequentially and cleaning sequentially 1.0 mm back (a procedure known as the step-back technique) until the file no longer engages the walls.

The advent of nickel titanium (NiTi) instruments made it possible to reverse and speed up the step-back process by using tapered rotary instruments in a crown down technique. The canal is cleaned to working length using hand files up to approximately size 15 (establishing a guide plane) and tapered instruments are introduced sequentially until one goes to working length. Cleaning size is determined with apical gauging. Techniques vary slightly by manufacturer; for example, when a ProSystem GT (Dentsply Tulsa, Tulsa, OK; 800.662.1202) is used, the size 20 tip series of tapered instruments are cycled until the 20/.06 file reaches working length. At that point, a size 20 hand file is taken to working length.15 If the file binds at working length, apical gauging has determined the canal to have an apical size of 20. If the hand file is loose or goes beyond working length, it is necessary to repeat the crown down technique and apical gauging with larger tip sizes (that is, a ProSystem tip size 30 or 40) until an appropriate gauging file binds at working length. The apical size is gauged by the apical gauging file that binds at working length.

Another NiTi cleaning system is LightSpeedLSX (Discus Dental, Culver City, CA; 800.422.9448), which uses an active engaging technique with nontapered end cutting instruments, allowing dentists to determine when a canal is cleaned.16 LSX engages the canal until it is round and clean. The dentist establishes a glide path to size 15 with tapered rotary instruments, as described. The dentist then advances each LSX instrument sequentially to working length and keeps track of how far from working length the instrument starts to engage the canal (that is, when it meets resistance). When an instrument meets resistance continuously more than 4.0 mm from working length and is advanced to working length with steady pressure, the size of the last instrument used becomes the working width.16

This study was designed to evaluate how successfully debris is re-moved in the clinical environment.

Materials and methods

This study evaluated 53 teeth that had undergone root canal therapy and eventually were extracted for multiple reasons, including fractures, pain, caries, and financial considerations. Using a high-speed bur, the resulting 120 canals were ground back through the foramen to the apical constriction. The root was measured 1.0 mm back from this landmark and ground back just short of it with a high-speed bur. A scalpel blade was used to take the root to the final 1.0 mm measurement. A digital photograph was taken of the canal with ProScope using a 50x lens (Bodeline Technologies, Lake Oswego, OR; 800.441.6877). The picture was enhanced with iPhoto (Apple Inc., Cupertino, CA; 800.692.7753), enlarged on a computer screen, and evaluated for the presence of residual debris.

Results

The 53 teeth provided 120 canals for evaluation. The distribution of teeth is listed in the table. The patient's decision to extract a tooth usually was multifactorial. The most common primary symptom was a fractured tooth (27 of the 53 cases); other factors, such as pain, recurrent caries, periodontal status, need for crown and/or crown lengthening, retreatment, and cost were cited as reasons for extraction. The second primary symptom was failing root canal therapy (17 of the 53 cases), with similar multifactorial reasons for extraction. Of the 120 canals, 13 were not instrumented to within 1.0 mm of the apical constriction and were removed from the study, leaving a total of 107 canals to evaluate for debris removal. Eighty-eight of the 107 canals (82%) had residual debris 1.0 mm from the apical constriction (Fig. 2–4). Only 19 of the canals (18%) treated in a clinical environment were free of debris 1.0 mm from the apical constriction (Fig. 5).

Table. Types of teeth utilized in the present study.

	Central incisor	Lateral incisor	Canine	Premolar	Molar	Total
Maxilla	1	1	2	8	16	28
Mandible	–	–	–	7	18	25

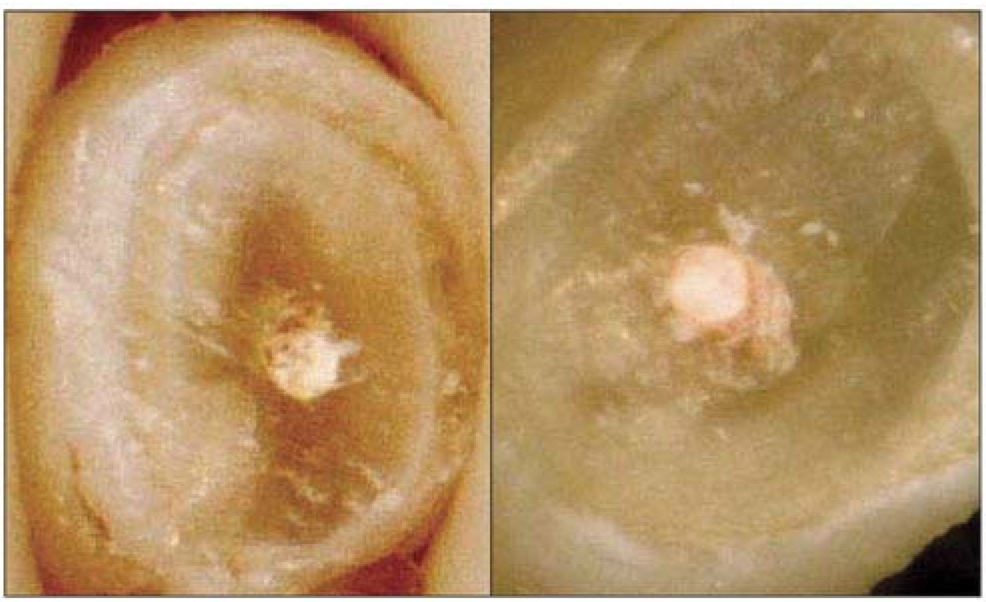

Fig. 2. Two of the canals treated with tapered instruments that had residual debris 1.0 mm from the apical constriction.

Fig. 3. An example of a grossly underprepared canal with residual debris all around the gutta-percha.

Fig. 4. An inadequately cleaned canal with residual debris all around the more centered gutta-percha. It probably was prematurely apically gauged on the tangent of the canal's curves.

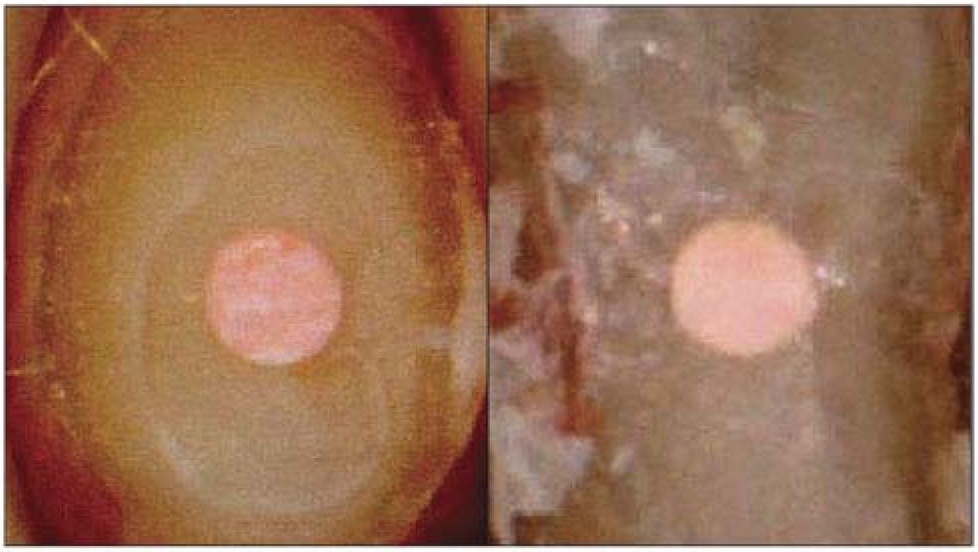

Fig. 5. *Left:* An example of a canal that was properly instrumented, irrigated, and obturated; all of the debris was removed 1.0 mm from the apical constriction. *Right:* A canal with a narrow root and plenty of supporting dentin around the gutta-percha. A second canal above the gutta-percha was not cleaned or obturated.

All 16 canals (100%) that were instrumented to a round shape, to the larger diameter of their oval, had no residual debris (Fig. 5). Of the 91 canals that were not instrumented to a round shape, only three were without debris (Fig. 6). Of the 88 canals with residual debris, 42 (48%) were transported (Fig. 7). The teeth in Figures 7–10 probably would have been cleaned adequately if the stiffer instruments had not transported out of the canal.

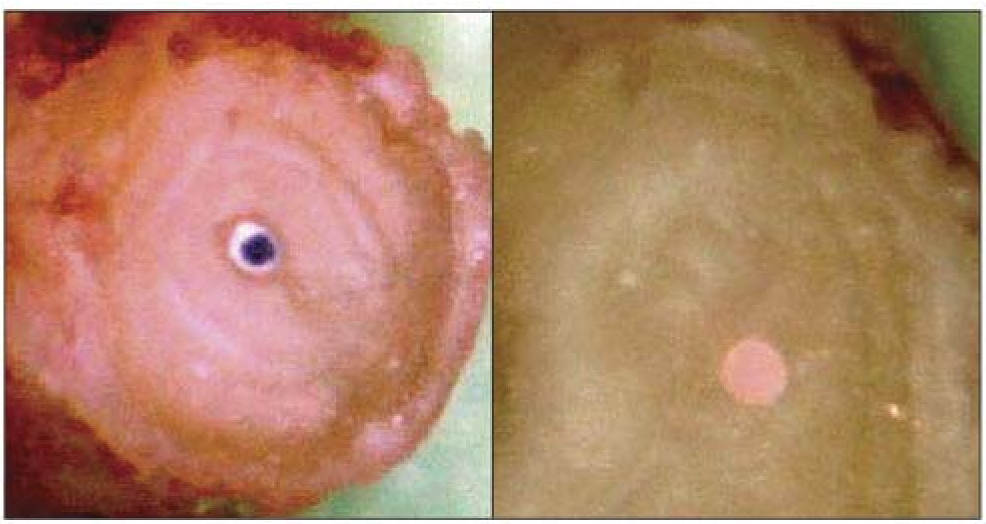

Fig. 6. *Left:* Instrumentation has a slight transportation or slight residual bump from the oval shape. It appears that the gutta-percha has been wiped off the carrier and the sealer has filled the canal. *Right:* A canal that is slightly oval with the round gutta-percha filling most of the canal and sealer filling the remaining area.

Fig. 7 and 8. A canal transported out one end of its oval, leaving residual debris in the center of the canal; the debris was not removed with irrigation or entombed with obturation.

Fig. 9. Debris is transported so far out of the canal with a stiff tapered instrument that there is almost a perforation out the side of the tooth. Sealer filled in the outer part of the transportation, with gutta-percha filling the middle of the "new" canal while leaving debris in the original canal.

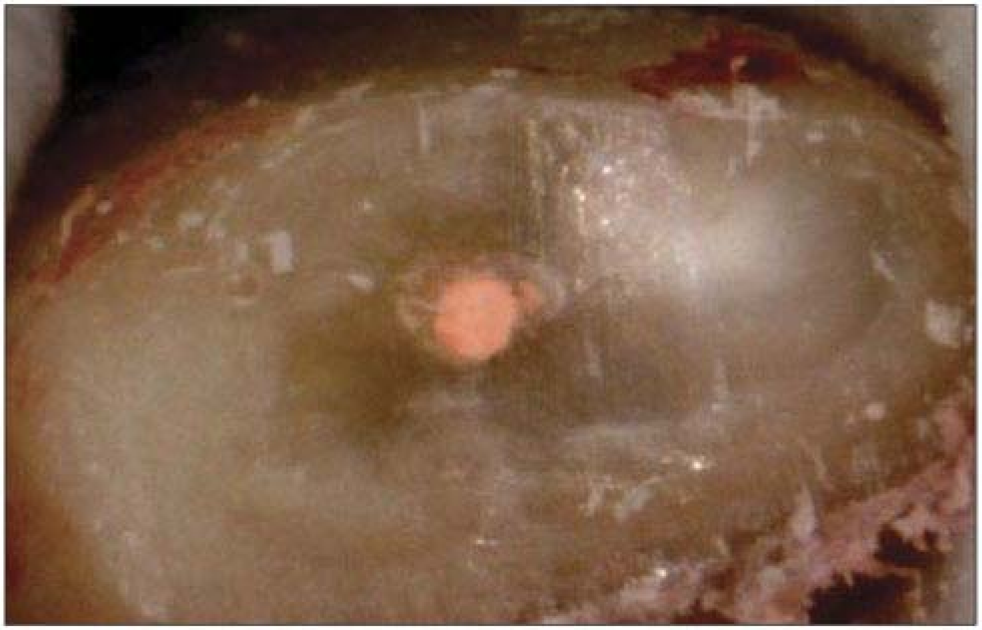

Fig. 10. The canal is underprepared and transported out the side and not the end of the oval. It probably was prematurely apically gauged in the curves and not in the oval of the canal. Irrigation did not remove the residual debris and the thermoplastic obturation technique did not entomb the residual debris 1.0 mm from the apical constriction.

The author was able to determine that endodontists treated 58 of the canals, while general dentists treated 13 canals. Endodontists were able to completely remove debris 1.0 mm from the apical constriction in 14% of the canals they treated, while general dentists were able to remove debris completely from 54% of the canals they treated. Sixty-eight of the 71 canals were cleaned using the apical gauging or step-back technique, with a debris removal rate of 18% (12 of 68). Three of the canals were cleaned with the LightSpeed technique; they demonstrated a 100% debris removal rate.

While performing root canal therapy, the identified dentists used NaOCl and other irrigation medications. In the present study, the irrigants could not dissolve or remove debris 1.0 mm from the apical constriction that was missed as a result of inadequate canal preparation. When dentists used thermaplastic gutta-percha techniques with sealer, the material followed the path of the instrumentation and did not surround or entomb residual debris that was packed up against the canal wall 1.0 mm from the apical constriction.

Discussion

These findings are consistent with Haga's 1968 study of 161 *in vitro* treated canals.17 **When evaulating teeth similar to those evaluated in the present study, Haga reported that approximately 20% of canals were cleaned adequately using the step-back technique:**

"Clinically, all the preparations 'felt' like they were adequate and thoroughly debrided because the files were cutting 5 to 6 mm from the apex and bringing up 'white dentin' chips."17

The crown down technique basic-ally reverses the step-back technique and uses apical gauging to determine when canals are cleaned to the appropriate size. The complete debris removal rate of 18% in this study indicates that apical gauging did not clean the canal at 1.0 mm from the apical constriction any more successfully than the step-back technique of 1968.

In theory, apical gauging should work except for two canal features: curves and ellipses. Approximately 74% of canals end short of the apex and exit out the side of the root in a curve.10 Canals can have multiple curves. The goal of apical gauging is to determine canal size in the critical apical third of the canal and remove as much debris and bacteria as safely possible. In theory, the apical gauging file should bind and get stuck between two opposing walls of the canal at working length. In reality, the gauging file does not bind at working length but in the tangent of the curve. In the curved area, the gauging file binds between the inner wall and the outer wall of the canal (Fig. 11). When curves are aggressively removed and shaped straight to the working length, the apical gauging file will bind in the curve of canal while exiting short of the apex (Fig. 10). Both canals in Figure 6 would measure as size 30 with the "blue" apical gauging file, although in these examples, both canals obviously are much larger than size 30.3-5,10-14

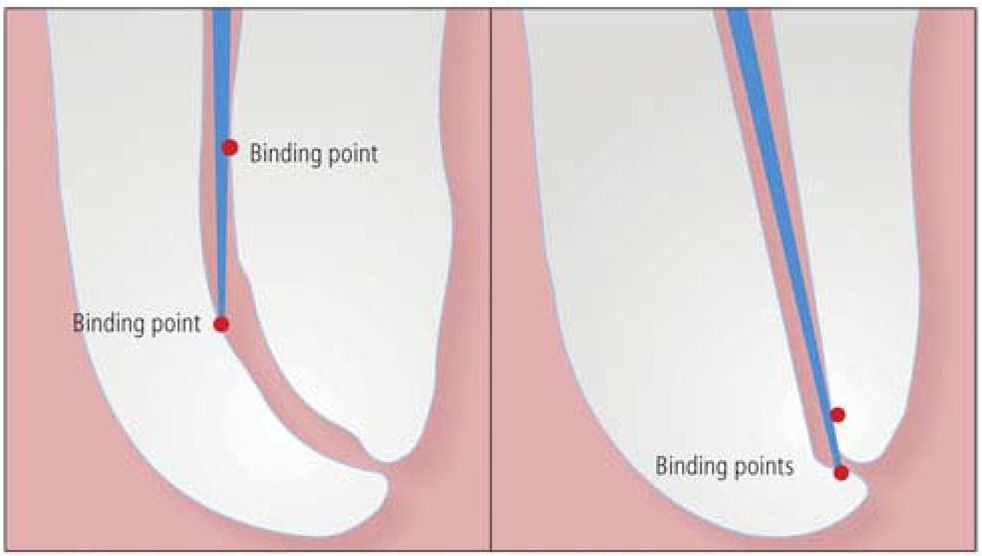

Fig. 11. *Left:* In the curved canal, the apical gauging file binds prematurely between the inner wall and the outer wall of the canal. *Right:* The apical gauging file binds between the inner wall and outer wall of the curve in the straight canal. Apical gauging/binding is not accomplished in the critical working length area.

Fig. 12. Apical gauging of the mesiobuccal canal resulted in a canal without residual debris. Apical gauging of the mesiolingual canal bound in the narrower diameter of the oval canal and resulted in debris on both sides of the gutta-percha. Irrigants did not remove the debris 1.0 mm from the apical constriction, nor did the gutta-percha or sealer entomb the residual debris to prevent leakage.

The oval shape of the canal is the second obstruction to effective apical gauging.4,6 If the apical gauging hand file and step-back file make it to working length without binding in a curve, the file binds in the narrower dimension of the oval canal (Fig. 12).

For 82% of the evaluated canals, apical gauging resulted in inadequate enlargement and debris removal at 1.0 mm from the apical constriction. Tapered instruments also caused a 48% transportation rate 1.0 mm from the apical constriction (Fig. 7).

When root canal therapy was performed in a clinical environment, irrigants were unable to remove the remaining debris of the underprepared canals. Canals that were not shaped round to the larger dimension of the oval demonstrated a cleaning rate of only 3%. This is consistent with the study by Usman et al, which reported that debris removal depended more on the type of instrument and working length of the root canal than on the amount or depth of irrigant used.18

Of the known providers who used thermoplastic obturation, the gutta-percha and sealer followed the path of instrumentation at 1.0 mm from the apical constriction and did not spread around or entomb the debris packed against the walls.

Tan and Masser reported that LightSpeed was able to instrument the canal to a round shape in the critical apical third of the canal 80% of the time.19 In this study, the LightSpeed technique created a round shape and removed all debris 1.0 mm from the apical constriction 100% of the time.

Conclusion

The crown down technique with apical gauging and the step-back technique were able to remove all debris 1.0 mm from the apical constriction only 18% of the time. All of the canals that were cleaned to a round shape were free of debris. Of the canals that were treated with tapered instruments and had residual debris, 48% were transported at 1.0 mm from the apical constriction. All of the canals treated with the LightSpeed system were free of debris 1.0 mm from the apical constriction.

Disclaimer
The author gives lectures on both Tulsa and LightSpeed Root Canal Therapy techniques. He is not an employee of either company. No company mentioned in this article has contributed to the research and writing of this article. The thoughts, views, and opinions expressed in this article are those of the author alone and not the opinion of Permanente Dental Associates or Kaiser Permanente Health Plan.

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