CLINICAL ARTICLES

Comparison of Ultrasonic and High-Speed-Bur Root-End Preparations Using Bilaterally Matched Teeth

David S. Mehlhaff, DMD, J. Gordon Marshall, DMD, and J. Craig Baumgartner, DDS, PhD

The purpose of this study was to compare ultrasonic and high-speed-bur root-end preparations. Seventy-six roots from 29 bilaterally matched pairs of human teeth in cadavers were used in this study. In group 1 ultrasonic preparations were made in 38 roots and filled with amalgam. In group 2 highspeed bur preparations were made in 38 roots and filled with amalgam. The size of the bony crypt was measured and the teeth were extracted and radiographed mesial-distally and buccal-lingually. None of the root-end preparations resulted in root perforation. The mean mesial-distal minimum depth of ultrasonic and high-speed bur preparations were 2.11 mm and 1.39 mm, respectively. The mean buccal-lingual minimum depth of preparation was 2.51 mm for the ultrasonic and 2.05 mm for the highspeed bur preparations. The depth of the ultrasonic preparations was significantly greater for both measurements. A significantly greater bevel angle was associated with the bur preparations. 35.1° versus 16.0° for the ultrasonic preparations. The incidence of ultrasonic root-end preparations deviating from the uninstrumented canal spaces was found to be 2.6%. All bur root-end preparations were at an acute angle to the long axis of the root. The bony crypt size for bur preparations was significantly greater than that for ultrasonic preparations.

Although orthograde endodontic therapy achieves a high success rate, surgical endodontic therapy may be required when an orthograde approach is not feasible or has failed (1, 2).

Rud and Andreasen (3) reported that the most common cause of orthograde root canal therapy failure was incomplete canal debridement. They also state that the main object of periapical surgery is to enable complete debridement and placement of a root-end filling (4). Lin et al. (5) concluded that root-end amalgam fillings should be placed in roots of almost all teeth which require periapical surgery. Harrison and Todd (6) showed that root resection with a high-speed handpiece did not disrupt the apical seal of a canal well obturated with gutta-percha and sealer. However, as Nicholls (7) stated, one cannot always see defects in root canal obturation. A radiographically well-condensed gutta-percha root canal may be misleading because voids buccally or palatally will be superimposed on the root filling and may not be visible. A root-end filling has been recommended if any doubt exists regarding the adequacy of obturation (5–7).

Tidmarsh and Arrowsmith (8) showed that there are approximately 13,000 dentinal tubules/mm² near the dentinocemental junction. Because these tubules are potential avenues for leakage, they recommend a minimal bevel and a root-end filling deeper than the level of the most coronal aspect of the bevel. Leakage studies performed by Vertucci and Beatty (9, 10) showed that significantly more leakage occurred in apical preparations filled with amalgam that did not extend to the coronal height of the beveled root-end resection. Gilheany et al. (11) studied the periapical leakage via patent dentinal tubules originating from the resected buccal root surface and extending to a point beyond the depth of the root-end filling. They reported that the optimum depths for root-end fillings are 1.0, 2.1, and 2.5 mm for 0-, 30-, and 45-degree angles of resection, respectively. The importance of the root-end filling depth to achieve an apical seal was demonstrated by Mattison et al. (12). They concluded that a 3-mm amalgam root-end filling significantly reduced apical leakage and that varnish applied to the cavity preparation further reduced leakage.

Carr (13) has stated that an ideal root-end preparation should be placed so that its outline form is parallel to and coincident with the anatomic configuration of the pulpal space. He lists the following requirements to accomplish these goals: the apical 3 mm of the root is cleaned and shaped, the preparation is parallel to the anatomic outline of the pulpal space, there is adequate retention form, all isthmus tissue is removed, and the remaining dentinal walls are not weakened.

Recently, several reports advocating ultrasonic root-end preparations have been published (14, 15). They claim that a deeper

Vol. 23, No. 7, July 1997

Class I preparation can be made and that ultrasonic tips follow the root canal space better than conventional techniques (13–15). It has been reported that ultrasonic tips require less bone removal and a flatter bevel angle to perform the root-end filling procedures (15). Pannkuk (16) has stated that it is desirable to have the smallest bevel angle necessary to achieve adequate access, thereby minimizing root-end filling surface area and maximizing the potential reattachment area. It has been suggested that the use of ultrasonic instruments may result in more thorough removal of debris from the canal space and be less likely to perforate the root (17).

The purpose of this study was to compare ultrasonic and highspeed bur root-end preparations. Matched pairs of teeth in human cadavers were used to compare the size of bony crypt, the minimum depth of root-end filling in a mesial-distal and buccal-lingual direction, the length of the root-end filling along the resected root surface, and the root-end resection bevel angle.

MATERIALS AND METHODS

Twenty-nine bilaterally matched pairs of teeth from three adult human cadavers were used in this study. Preoperative radiographs were used to confirm that the teeth had no previous root canal therapy, apical surgery, or post, which might compromise root-end preparation. Radiographs were taken at 70 kVp and 15 mA (S.S. White, model 90s) using Kodak E-speed film (Eastman Kodak, Rochester, NY). An XCP radiograph paralleling instrument (Rinn Corp., Elgin, IL) was positioned and stabilized by molding a vinyl polysiloxane putty (Express, 3M, Minneapolis, MN) over the teeth and around the XCP instrument. This molded positioning device allowed reproducible film placement in the cadaver heads.

To simulate in vivo conditions, all surgical procedures were performed with the teeth in the cadavers by one operator. A rectangular, full-thickness flap was reflected with a #9 periosteal elevator (Schein, Port Washington, NY). A Minnesota retractor (Schein, Port Washington, NY) was used to retract the flap during the root-end preparation. A Lindemann bone bur (Brassler, Savannah, GA) was used for removal of buccal cortical bone and the root-end resection. The size of the bony crypt and the root bevel angle was determined by the need for access and visualization to complete root-end preparation and filling. Approximately 2 to 3 mm of root was resected. Methylene blue dye 1% (Roth International, Chicago, IL) was applied with a cotton pellet and rinsed with water to determine root outline, canal space, and to identify any isthmuses (20).

Ultrasonic root-end preparations were performed with an EIE piezoelectric unit with ultrasonic tips (Excellence in Endodontics, San Diego, CA). The ultrasonic unit was used at the lowest power setting with constant water spray on the cutting tip and a feather-like back and forth motion (13). The CT-5 tip was used to start all preparations and outline any isthmuses. The CT-1 tip was then used to refine and increase the depth of the preparation. An attempt was made to create a root-end preparation to a depth of 3 mm. The preparation was then dried and a root-end amalgam filling (Valiant Ph.D., Caulk/Dentsply, Milford, DE) was placed with a Messing gun (Union Broach Corp., Emigsville, PA) and condensed using amalgam pluggers (EIE, San Diego, CA). Excess amalgam was removed from the root-end surface, and the restoration was then burnished with a 31L spoon excavator (Schein, Port Washington, NY).

High-speed root-end preparations were made with a size 1/2 surgical length round bur (Brassler, Savannah, GA) using a fiber-



Fig 1. Maxillary canine preparation done with ultrasonic tip. Mesialdistal radiographic view is pictured on the left and bucco-lingual view to right. Lengths A and B are the shallowest depth of root-end preparation. Length C is the length of the amalgam along the resected root surface.

optic high-speed handpiece (Midwest-Tradition, Sybron Corp., Des Plaines, IL). An attempt was made to produce a 3-mm deep preparation that followed the long axis of the root. However, due to lack of direct access to the resected root-end, preparations were made at an angle to the long-axis and confined to the resected root surface (18, 19). The preparation was extended slightly toward but never onto the buccal root surface. Isthmuses were included in the root-end preparations (20). After completion of root-end preparations, amalgam was placed as described for the ultrasonic preparations. To prevent operator fatigue, no more than five preparations were done at a single sitting.

Upon completion of root-end filling, the bony crypt size was measured to the nearest 0.1 mm with a digital micrometer (Mitutoya, Tokyo) by an independent investigator without knowledge of which technique was used. The bony crypt was measured both vertically and horizontally. Buccal cortical bone was then removed with the Lindemann bur to facilitate forcep extraction of the teeth. After extraction the teeth were radiographed (70 kVp, 15 mA, 0.5 sec) from both a buccal-lingual and a mesial-distal direction. In teeth with multiple roots the roots were separated with a 557 bur before being radiographed. Palatal roots of maxillary molars were not surgically treated in this study and were removed with a 557 bur.

Radiographs were projected at 10 power onto a solid white background. All measurements were performed on the enlarged image by a single independent investigator with the digital micrometer to the nearest 0.1 mm and divided by ten. The mesial-distal radiographic view was used to measure the length of the amalgam along the resected root surface (Fig. 1). Measurement of the

Journal of Endodontics



Fig 2. Maxillary canine preparation done with high speed bur. Mesial-distal radiographic view is pictured on the left and bucco-lingual view to right. Lengths A and B are the shallowest depth of root-end preparation. Length C is the length of the amalgam along the resected root surface.

minimum root-end preparation depth was recorded for both the mesial-distal and buccal-lingual radiographs. The minimum depth of the root-end preparation was defined as the shallowest depth from the resected root surface to the canal space (Figs. 1 and 2). A cephalometric protractor was placed over the radiographic projections, and the root resection bevel angle was measured to the nearest degree, relative to the root long-axis.

Roots were examined visually and radiographically for perforation, either mesial-distally or to the lingual. Ultrasonic preparations were also evaluated radiographically on their ability to follow the root long-axis. The preparation was considered to have deviated from the long-axis if the base of the preparation was outside the canal space.

Data were entered into a statistical software package (StatView 4.01, Abacus Concepts, Berkeley, CA) and descriptive statistics were calculated. Statistical analysis was performed using a paired t-test to determine significant differences between root-end preparation techniques and tooth location (anterior, premolar, molar). Statistical significance was set at p = 0.05.

RESULTS

None of the 76 root-end preparations resulted in root perforation. The incidence of ultrasonic root-end preparations deviating from the canal space and the long-axis of the root was 2.6% (1/38). The ultrasonic preparation, which was considered off-line toward the distal, was in the mesial-buccal root of a maxillary molar. All bur root-end preparations were at an acute angle to the long-axis of the root. Twenty-nine teeth with 38 roots (11 anterior, 13 premolar, 14 molar) received ultrasonic preparation, and the corresponding contralateral roots were prepared with a high-speed $\frac{1}{2}$ round bur.

Measurements from the radiographs are summarized in Table 1. The amalgam length along the resected root surface (Figs. 1 & 2) was statistically greater for bur preparations overall (p < 0.0001) and when evaluated by tooth location (p < 0.0001). The mean difference was 1.4 mm. The mean shallowest depth of preparation when measured from a mesial-distal view (Fig. 1) was significantly greater for the ultrasonic technique (2.11 mm) compared to the bur technique (1.39 mm) (p < 0.0001). A statistically significant difference was also found when the techniques were compared by location; anterior (p = 0.0001), premolar (p < 0.0001), and molar (p = 0.003). The shallowest depth of preparation when measured from a buccal-lingual direction, the view seen clinically, was found to be deeper for both techniques (mean ultrasonic = 2.51 mm, bur = 2.05 mm) than when viewed mesial-distally. Overall the buccal-lingual depth for the ultrasonic preparations was statistically greater than the bur preparations. The mean difference was 0.5 mm. A statistically significant difference was found when comparing the bur versus ultrasonic for anterior (p = 0.014) and premolar (p < 0.0001) preparations but not when the molar rootend preparations were compared (p = 0.437).

The root-end resection bevel angle measurements are shown in Table 2. The mean bevel angle overall for the bur preparations (35.1°) was more than double that for the ultrasonic preparations (16.0°) . The difference was statistically significant (p < 0.0001). The mean bevel angle remained similar when compared by location. When the maxillary and mandibular anterior root-end resection bevel angle measurements were examined separately, the mean ultrasonic bevel angle was 9.0° for the maxillary and 22.2° for the mandibular anterior teeth. The mean bur preparation bevel angle for the maxillary and mandibular teeth were 40.0° and 37.5° respectively.

Table 3 summarizes the size of the bony crypt for each technique. The size of the vertical bony crypt required to perform the ultrasonic preparations was smaller than for bur preparations both overall and when compared by tooth location. The overall mean difference was 1.1 mm (p < 0.0001). When measured horizontally, the bone crypt required for the ultrasonic preparations was statistically smaller overall as well. The overall horizontal mean difference was 0.4 mm (p = 0.019).

DISCUSSION

Wuchenich et al. (17) examined root-end preparations on anterior teeth using a scanning electron microscope (SEM) and found the ultrasonic preparations to be deeper (2.5 mm) than the bur preparations (1 mm). They also found that ultrasonic tips produced root-end preparations that followed the direction of the canal space better and had cleaner cavity surfaces than those produced by the bur preparations. Bur preparations were done using a microhead slow-speed contra-angle with a 33 $\frac{1}{3}$ inverted cone bur.

This study used matched teeth to provide a direct comparison of techniques in teeth with similar morphology. The mean root-end preparation depth as measured from a proximal view was 0.72 mm deeper in the ultrasonic group. The high-speed handpiece root-end cavity preparations were purposely extended toward the buccal root surface creating an oblique angle toward the canal space. This technique provides greater cavity preparation depth along the buccal axial wall. This is reflected in our average bur preparation depth

|--|

	Ultrasonic Preparations			Bur Preparations			Stat. Sig.
	Mean	Stand Dev	Range	Mean	Stand Dev	Range	p-value
ALRS-TOTAL	1.76	0.96	0.9-4.1	3.19	0.92	1.3-5.4	< 0.0001
Anterior	1.27	0.31	0.9-1.9	3.14	0.56	2.0-3.9	<0.0001
Premolar	1.34	0.64	0.9-3.3	3.01	1.17	1.3-5.4	0.0002
Molar	2.46	1.09	1.0-4.1	3.37	0.91	1.8-5.1	0.0011
Depth/MD-Total	2.11	0.45	1.0-3.1	1.39	0.38	0.6-2.2	< 0.0001
Anterior	2.22	0.44	1.5-2.9	1.56	0.36	1.1-2.1	0.0001
Premolar	2.36	0.32	1.83.1	1.42	0.43	0.6-2.2	<0.0001
Molar	1.81	0.41	1.0-2.4	1.23	0.31	0.8-1.7	0.0031
Depth/BL-Depth	2.51	0.35	1.43.4	2.05	0.53	1.1-3.4	<0.0001
Anterior	2.61	0.35	2.1-3.1	2.14	0.41	1.4-2.6	0.0136
Premolar	2.57	0.22	2.2-2.9	1.75	0.46	1.1-2.6	< 0.0001
Molar	2.39	0.43	1.4-3.4	2.25	0.58	1.4-3.4	0.4371

ALRS-Amalgam length along resected root surface (mesial-distal radiograph).

Depth/MD-Shallowest depth of preparation to canal space (mesial-distal radiograph).

Depth/BL-Shallowest depth of preparation to canal space (buccal-lingual Radiograph).

Bevel Angle		Ultrasonic Preparations			Bur Preparations			
	Mean	Stand Dev	Range	Mean	Stand Dev	Range	p-value	
Total	16	8.5	0.0-31.0	35.1	7.6	16.0-47.0	<0.0001	
Anterior	16.2	7.9	4.0-28.0	38.6	6.5	30.0-47.0	0.0001	
Premolar	14.5	7.6	4.0-26.0	33.9	6.7	20.0-41.0	<0.0001	
Molar	17.4	9.9	0.0–31.0	33.5	8.7	16.0-44.0	<0.0001	

TABLE 3. Bony Crypt Size (mm)

	Ultrasonic Preparations			Bur Preparations			Stat Sig
	Mean	Stand Dev	Range	Mean	Stand Dev	Range	p-value
Vertical-Total	5.19	0.88	3.6-7.4	6.34	0.99	4.8-9.0	< 0.0001
Anterior	4.46	0.82	3.6-6.1	6.02	0.99	4.8-7.3	0.0088
Premolar	5.24	0.57	4.0-6.2	6.52	1.22	5.0-9.0	0.0052
Molar	5.69	0.81	4.8-7.4	6.42	0.72	5.0-7.6	0.0192
Horizontal-Total	4.25	1.24	3.0-8.4	4.69	1.31	2.6-7.5	0.0433
Anterior	3.71	0.79	3.0-5.1	4.06	0.95	2.6-6.2	0.1913
Premolar	3.83	0.51	3.2-5.2	4.28	0.85	3.0-5.7	0.0648
Molar	5.11	1.56	3.3-8.4	5.61	1.43	3.7-7.5	0.3579

of 1.39 mm compared to the 1 mm depth measured by Wuchenich et al. (17). Ultrasonic tips are 3 mm in length and in all cases the deepest portion of the cavity preparation was approximately 3 mm. However, our measurements were designed to determine the shallowest depth of preparation from the resected root surface to the canal space. This clinically more relevant definition of the shallowest preparation depth to the canal space resulted in an average preparation depth of 2.11 mm. Gilheany et al. (11) evaluated the apical leakage associated with various depths of root-end fillings placed in root apices that had been resected at different bevel angles. They reported that the optimum depths for a root-end filling are 1.0, 2.1, and 2.5 mm for 0° , 30° , and 45° bevel angles, respectively. Applying their findings to the present study the ultrasonic preparations would have attained an adequate depth as the mean preparation depth was 2.11 mm and bevel angle was 16.0° However, the high-speed bur preparations may be susceptible to leakage via the buccal dentinal tubles, because their mean depth of preparation was 1.39 mm and bevel angle was 35.1°

Due to the difference in preparation design between the two techniques it is not surprising that the length of the amalgam root-end filling along the resected root surface for the high-speed bur preparations was found to be significantly longer. This may be important as an increased area of root-end filling material could decrease the potential for reattachment as stated by Pannkuk (16).

Some molar roots were treated through individual bony crypts. When the roots were in close proximity to each other or an extensive amount of buccal bone removal was required for root visualization, a single crypt was required to gain access to the roots. This accounts for the large variation in range values recorded for the molar roots.

The difficulty associated with bur access and subsequent rootend preparation is reflected in the decreasing mean depth of preparation measurements (mesial-distal); anterior (1.6 mm), premolar (1.4 mm), and molar (1.2 mm). The mean values for the ultrasonic preparations remained about 2 mm.

The buccal-lingual view used clinically to evaluate the quality

452 Mehlhaff et al.

of the root-end filling did not show a significant difference between the techniques for the molar teeth. This finding is related to the steeper bevel angle required for bur preparations. Therefore, the amalgam filling when viewed buccal-lingually with an increased bevel angle gives the illusion of a greater preparation depth.

In this study the root canal spaces were not instrumented and obturated before performing endodontic surgery. This is similar to surgery on roots with calcified or blocked canals. This experimental design was used to provide a worst case scenario for evaluation of root-end preparations. Despite the fact that there was no guttapercha to identify the canal space during ultrasonic root-end preparations, only one preparation was determined to deviate from the long-axis. None of the 38 ultrasonic preparations resulted in root perforation. The use of amalgam in this study as the root-end filling material enabled us to clearly see when amalgam was condensed into the unfilled canal space beyond the root-end preparation depth (Fig. 1). Measurements were made only to the depth of the preparations.

The results of this study indicate that the ultrasonic tip produces a deeper root-end preparation and that less bevel of the root-end is required to facilitate preparation and root-end filling placement. The ultrasonic preparation also followed the direction of the canal space better than bur preparations even when no previous canal instrumentation or obturation had been done. Under the conditions of this study it appears that ultrasonic root-end preparations are superior to highspeed bur root-end preparations.

Dr. Mehlhaff is a former postgraduate student in endodontics at Oregon Health Sciences University and currently in private practice in Vancouver, Washington. Dr. Marshall is associate professor of Endodontics, OHSU School of Dentistry. Dr. Baumgartner is professor and Chairman of the Department of Endodontics, OHSU School of Dentistry. Address requests for reprints to Dr. Baumgartner, Department of Endodontics, OHSU School of Dentistry, 611 SW Campus Dr., Portland, OR 97201.

Journal of Endodontics

References

1. Gutmann JL, Harrison JW. Surgical endodontics. Boston: Blackwell Scientific Publications, 1991:36.

2. Luebke RG, Glick DH, Ingle JI. Indications and contraindications for endodontic surgery. Oral Surg 1964;18:97–113.

3. Rud J, Andreasen JO. A study of failures after endodontic surgery by radiographic, histologic, and stereomicroscopic methods. Int J Oral Surg 1972;1:311–28.

4. Rud J, Andreasen JO. Operative procedures in periapical surgery with contemporaneous root filling. Int J Oral Surg 1972;1:297–310.

5. Lin L, Skribner J, Shorlin F, Langeland K. Periapical surgery of mandibular molar teeth: anatomical and surgical considerations. J Endodon 1983; 9:496–501.

 Harrison JW, Todd MJ. The effect of root resection on the sealing property of root canal obturations. Oral Surg 1980;50:264–72.

7. Nicholls F. Retrograde filling of the root canal. Oral Surg 1962;15:463-73.

 Tidmarsh BG, Arrowsmith MG. Dentinal tubules at the root ends of apicected teeth: A scanning electron microscopic study. Int Endod J 1989; 22:184–9.

9. Beatty R. The effect of reverse filling preparation design on apical leakage. J Dent Res 1986;65:259. Abstract 805.

10. Vertucci FJ, Beatty RG. Apical leakage associated with retrofilling techniques: a dye study. J Endodon 1986;12:331-6.

11. Gilheany PA, Figdor D, Tyas MJ. Apical dentin permeability and microleakage associated with root end resection and retrograde filling. J Endodon 1994;20:22–6.

12. Mattison GD, Von Fraunhofer JA, Delivanis PD, Anderson AN. Micoleakage of retrograde amalgams. J Endodon 1985;11:340-5.

13. Carr GB. Surgical Endodontics. In: Cohen S, Burns RC, eds. Pathways of the pulp. 6th ed. St. Louis: CV Mosby, 1994:544.

14. Carr GB. Microscopes in endodontics. Calif Dent Assoc J 1992;20: 55-61.

15. Carr GB. Advanced techniques and visual enhancement for endodontic surgery. Endo Report 1992;7:6-9.

16. Pannkuk TF. Endodontic surgery: the treatment phase and wound healing part 2. Endo Report 1992;7:14–9.

17. Wuchenich G, Meadows D, Torabinejad M. A comparison between two root end preparation techniques in human cadavers. J Endodon 1994; 20:279-82.

18. Gutmann JL, Harrison JW. Posterior endodontic surgery: anatomical considerations and clinical techniques. Int Endo J 1985;18:8–34.

19. Cambruzzi JV, Marshall FJ. Molar endodontic surgery. J Can Dent Assoc 1983;1:61-6.

20. Cambruzzi JV, Marshall FJ. Methylene blue dye: an aid to endodontic surgery. J Endodon 1985;11:311-4.

You Might Be Interested

Once something appears in print in the medical literature it becomes almost unexpungable. A truly bizarre example is the citation of a rare complication of a human eye disorder cited in a respected ophthalmology text. A curious resident tracing references found that the original, and only, reference was to an observation on a Paramecium (BMJ 312:292). You recall Paramecia . . . they are those little guys you observe in a drop of water with a microscope in Biology 101.

Well, maybe someone was afraid one might climb up the microscope into a viewer's eyeball.

Cosby Newell