Ultrasonic root-end preparation Part 1. SEM analysis

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Summary

Preparations of apical cavities in resected root ends using rotary burs, with and without citric acid rinse, and ultrasonic tips were compared based on the presence or absence of superficial debris and smear layer. Three groups of 20 extracted teeth each were prepared as follows: I. a size 010 round bur was used to prepare an apical cavity 2-3 mm down the long axis of the root; II, treatment as per group I followed by a 60-s rinse with a solution of 10:3 (10% citric acid, 3% Fe₂Cl₃); and III, an ultrasonic retrotip was used to prepare a 2-3 mm deep apical cavity. Roots were grooved longitudinally, split and prepared for SEM analysis at $\times 100$ and $\times 780$ magnification. Examiners were calibrated to a standardized grading system. Extensive statistical analyses indicated statistically significant differences within and among the groups (P<0.05). Root-end preparation with a bur created a heavy smear layer at all levels of the preparation. This layer was partially removed during ultrasonic preparation in the apical two-thirds. A greater removal of the smear layer was achieved with the citric acid rinse (P<0.05). Coronally, root-end preparations were contaminated with moderate to heavy amounts of debris with all techniques.

Keywords: root end preparation, ultrasonics.

Introduction

Root-end preparation and filling are commonly employed procedures during periradicular surgery (Gutmann & Harrison 1991). Their specific goals are to create a mechanically designed cavity which can be filled, hence sealing the apical terminus of the root canal system. Multiple techniques and instruments have been advocated for root-end preparation (Gutmann &

Correspondence: Professor James L. Gutmann, D.D.S., Department of Restorative Dentistry, Baylor College of Dentistry, 3302 Gaston Avenue, Dallas, TX 75246 USA. Harrison 1991). As early as 1939 Tangerud (1939) developed a miniature handpiece to facilitate access to and preparation of the apical opening of the canal. This technique was the standard approach in clinical practice until the recent development of ultrasonic retrotips and ultrasonic preparation techniques (Excellence in Endodontics, San Diego, CA, USA) (Carr 1990, 1992, Pannkuk 1992). Advantages of this new approach have been cited as elimination of the need for bevelled root ends to gain access to the apical canal system, the ability to create a preparation in the long axis of the root, greater depth of preparation, and the ability to debride the root end effectively, especially of cements, pastes and foreign objects. An evaluation of this technique of rootend preparation by Wuchenich et al. (1993) showed that ultrasonically created cavities had more parallel walls, deeper depths for retention, preparations which followed the line of the root canal, and cleaner surfaces then those created with burs.

Concomitant with the creation of any cavity preparation is the development of a smear layer (Pashley 1984). It is tenacious, not easily removed by water, and generally requires acid etchants (citric acid) (Register & Burdick 1975) or chelating agents (ethylene diaminetetraacetic acid, EDTA) for removal (Ciucchi *et al.* 1989). Likewise, ultrasonic cleaning has been suggested as an adjunct for removal, especially in the root canal system (Cunningham & Martin 1982). The smear layer has been identified as containing fine inorganic particles of calcified tissue, tissue debris, blood cells, and, potentially, microorganisms (McComb & Smith 1975, Goldman *et al.* 1982) (Fig. 1). In the root-end preparation, root canal obturating materials such as guttapercha, sealers and pastes would be included.

The presence of the smear layer has been postulated as an avenue for leakage and source for bacterial growth and ingress (Pashley 1984), particularly following rootend preparation and filling (Pitt Ford & Roberts 1990). Likewise, it may serve to support growth of bacteria left in the dentinal tubules (Olgart *et al.* 1974, Brannstrom



Fig. 1. SEM appearance of a smear layer created in a root-end preparation. Dentinal chips are intermingled with organic debris which are both packed against the dentine wall and loosely arranged on the surface. Original magnification ×780.

1984). It would appear logical to attempt to remove the apical cavity smear layer, thereby enhancing root-end filling material adaptation and potentially minimizing or eliminating apical leakage.

The purpose of this study was to determine the degree of superficial debris and smear layer present on the dentinal walls of root-end cavity preparations, using three techniques: cavity preparation with a bur only, cavity preparation with a bur followed by a 10:3 citric acid: Fe_3Cl_3 rinse, and cavity preparation with an ultrasonic retrotip. Part 2 of this study further assesses the seal obtained over short and long term time periods, with each apical cavity preparation technique.

Materials and methods

Sixty single-rooted, recently extracted premolars and canines were endodontically accessed, and root canals were cleaned and shaped using a modified double-flare technique (Saunders & Saunders 1992). Subsequently, the canals were obturated with gutta-percha and Sealapex (Kerr Manufacturing Co., Romulus, MI, USA) using the hybrid technique according to Tagger (1984).

Root ends were resected at a 45° angle using a highspeed diamond bur with water spray. Twenty teeth per group had apical cavities prepared as follows.

Group I. A size 010 round bur in a slow-speed handpiece with water cooling was used to prepare a cavity 2-3 mm down the long axis of the canal. All visible guttapercha was removed from the cavity walls. Cavities were rinsed with water and dried with paper points. Group II. Following cavity preparation as in group I, a solution of 10% citric acid and 3% ferric chloride (10:3) (pH \approx 1.62) was used to lightly flush the apical cavity and resected root surface for 60 s. Subsequently, the cavity was rinsed with water and dried with paper points.

Group III. A 2-3 mm deep apical cavity preparation was cut using an ultrasonic retrotip on the ENAC ultrasonic system (Osada Electric Co., Los Angeles, CA, USA) at a power setting of 10 under water spray. All cutting occurred in a period of 3-5 min. Cavities were dried with paper points.

All roots were longitudinally grooved, buccallingually, with a small round bur without penetrating into the cavity preparation. The teeth were split with a chisel and the two halves were dried, mounted on a single stud, and sputter coated with gold (Denton DV-502 Sputter Coater. Denton Vacuum, Cherry Hills, NJ, USA) for SEM evaluation (JEOL JSM-35CF, JEOL, Peabody, MA. USA). Specimens were coded for blind evaluation.

Specimen viewing and evaluation were done by two calibrated examiners at magnifications of ×100 for assessment of the superficial debris layer, and ×780 for assessment of the remaining smear layer. These levels of viewing were chosen because they showed best the detail required to make an accurate evaluation, while still maintaining as large a field as possible. Criteria of evaluation were modified from Baumgartner et al. (1984) (Tables 1 and 2) after both examiners mutually reviewed, at random, 12 coded SEM photomicrographs at both levels of magnification. Prior to scoring the test specimens, the examiners reviewed samples to ensure calibration and to reach a mutual understanding as to what amounts of superficial debris, smear layer, and patent or blocked dentinal tubules constituted each ranking from 1 to 4. Four photomicrographs of the superficial debris (×100) and four of the smeared laver $(\times 780)$ were taken to represent the four gradations of

Table 1. Superficial debris

Score	Criteria					
1	Little or no superficial debris covering up to 25% of the specimen					
2	Little to moderate debris covering between 25 and 50% of the specimen					
3	Moderate to heavy debris covering between 50 and 75% of the specimen					
4	Heavy amounts of aggregated or scattered debris covering over 75% of the specimen					

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Table 2. Smear layer

Score	Criteria				
1	Little or no smear layer; covering less than 25% of the specimen; tubules visible and patent				
2	Little to moderate or patchy amounts of smear layer; covering between 25 and 50% of the specimen: many tubules visible and patent				
3	Moderate amounts of scattered or aggregated smear layer; covering between 50 and 75% of the specimen; minimal to no tubule visibility or patency				
4	Heavy smear layering covering over 75% of the specimen; no tubule orifices visible or patent				

the scoring system (Figs 2 and 3). These photomicrographs served as visual reference standards for the examiners during the scoring of the test specimens. Both halves of each root were independently evaluated at each magnification within each group. In the apical, middle, and coronal portions of the preparation. As the specimens were scanned, the examiners independently scored each area. Statistical analyses were carried out on the qualitative scores among the levels within the groups (Friedman two-way test/Wilcoxon signed ranks test), and between the groups (Kruskal–Wallis test/ Mann–Whitney U test) to determine whether there were any significant differences in the degree of superficial debris or smear layer with each technique at different cavity levels.

Results

Superficial debris ($\times 100$)

A Friedman two-way test within the groups showed that statistically significant differences (SSD) existed in the degree of superficial debris (P<0.05). Application of the Wilcoxon signed ranks test showed there were



Fig. 2. Standardized gradations of superficial debris used for specimen evaluation (×100)(see Table 1 for descriptions). (a) = Score 1; (b) = score 2; (c) = score 3; and (d) = score 4.



Fig. 3. Standardized gradations of smear layer used for specimen evaluation (\times 780)(see Table 2 for descriptions). (a) = Score 1; (b) = Score 2; (c) = Score 3; and (d) = Score 4.

SSD among all levels in group II (cavity preparation rinsed with citric acid), with the apical level the cleanest (Table 3). Within group I (cavity preparation only) there were SSD between the apical one-third and the middle one-third, and apical one-third and coronal one-third of the preparation, but not between the middle and coronal one-thirds. There were no SSD among all three levels with the ultrasonic preparation, each demonstrating the same amounts of superficial debris. The least amount of superficial debris was present in the apical one-third of the cavity preparations rinsed with citric acid.

Among the groups, a Kruskal–Wallis test showed SSD (P<0.05). Further assessment with the Mann–Whitney U test showed that differences occurred between groups I and III, and groups II and III. In other words, greater amounts of superficial debris were present with both bur preparation techniques compared with ultrasonic preparation. However, there were no differences between groups I and II (Table 4).

Smear layer (×780)

Here also, application of the Friedman two-way test indicated there were SSD among the levels evaluated. The Wilcoxon signed rank test showed the differences to be among all levels in group II. with the apical level being the most devoid of smear layer (Table 3). Most specimens demonstrated a clean dentinal surface with patent tubules. Group I had no SSD among its levels, with all levels demonstrating a heavy smear layer covering over 75% (by definition in Table 2) of the specimen with no tubule orffices visible (Fig. 4).

Group III also showed no SSD among all three levels, with moderate amounts of scattered or aggregrate smear layer covering up to 50% (by definition in Table 2)

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Group		Apical 1/3	(SD)	Middle 1/3	(SD)	Coronal 1/3	(SD)	Р
1	Debris (×100)	1.900	(0.82)	2.475a	(0.99)	2.625a	(1.09)	0.0210*
	Smear (×780)	3.950b	(0.15)	3.975b	(0.11)	4.000b	(0.00)	0.8936
II	Debris (×100)	1.350	(0.46)	2.125	(0.60)	3.000	(0.86)	< 0.0001*
	Smear (×780)	1.225	(0.44)	2.375	(1.05)	3.200	(0.98)	< 0.0001*
ш	Debris (×100)	1.700c	(0.85)	1.700c	(0.82)	1.700c	(0.68)	0.9162
	Smear (×780)	2.625d	(0.43)	2.725d	(0.60)	2.875d	(0.67)	0.1304

Table 3. Within-group analyses (mean values)

* Indicates significance at α level = 0.05

Values followed by the same letter show no significant differences.

(SD) = standard deviation

Table 4. Between-groups analyses (mean values)

Magnification	I	(SD)	п	(SD)	ш	(SD)	Р
×100	2.33a	(0.85)a	2.16	(0.51)	1.70	(0.70)	0.0095*
×780	3.98	(0.08)	2.27	(0.71)	2.74	(0.52)	< 0.0001*

* Indicates significance at α level = 0.05

Values followed by the same letter show no significant differences

(SD) = standard deviation

of the tubules. Also evidenced was the cutting or gouging of the root canal walls with the ultrasonic tip, which created an irregular, layered effect (Fig. 5).

Analyses among the groups using the Kruskal–Wallis test showed there were SSD (P<0.05). The Mann–Whitney U test showed the differences to be among all three groups, with group II showing the least amount of smear layer and the greatest amount of clean dentine and patent tubules (Table 4).

Discussion

The presence of debris in the apical cavities, both superficial and smear, is consistent with findings in restorative dentistry (Pashley 1984); likewise is the removal of this debris with cavity cleansers and acid etchants (Register & Burdick 1975, Baumgartner *et al.* 1984, Ciucchi *et al.* 1989). While the removal of this debris subsequent to coronal cavity preparation and



Fig. 4. Cross section of dentinal wall from root-end preparation with a bur. Note heavy smear layer covering entire dentin surface. Smear layer is forced into the tubules as plugs. Original magnification ×2400.



Fig. 5. Ultrasonic root-end preparation with irregular surface texture and variable amounts of smear layer. Original magnification $\times 780$.

restoration has been advocated in some clinical situations (Brannstrom 1984), the removal of this debris from apical cavity preparations has not been clinically addressed. However, because these layers of debris can serve as either an avenue for leakage or impediment to seal, or as a bacterial substrate (Pitt Ford & Roberts 1990), the removal of this debris prior to apical filling may be clinically appropriate. This is especially applicable if root-end filling materials which can bond to dentine are advocated, i.e. glass ionomer cements, or if penetration of the filling material into the dentinal tubules is considered as ideal.

All three techniques resulted in a significant accumulation of dentine debris and root canal filling materials in the base (coronal one-third) of the apical cavity. This deeply placed debris could serve as a reservoir of future contamination in the presence of either apical or coronal leakage. While the ultrasonic preparation was more effective in removing the superficial debris in this portion of the preparation, neither the ultrasonic nor the acid rinse was effective in removing of the smear layer.

While the use of ultrasonics would tend to favour the removal of cavity debris, in this study ultrasonic retrotips provided little more removal than that noted in the cleaning of root canal systems (Cunningham & Martin 1982, Goldman *et al.* 1982). Apparently, for any current ultrasonic system to be effective in debris removal, specific irrigants, acids or chelates must be used in conjunction with the vibratory action.

Standard cavity preparation with a bur followed by an acid rinse provided a cleaner cavity preparation in the coronal two-thirds than the use of ultrasonic preparation only. In this respect the use of the 10% citric acid: 3% ferric chloride (10:3) cavity cleaning solution might not only provide a cleaner apical cavity, but it also may enhance cemental deposition on the resected root end (Gutmann & Pitt Ford 1993). First, the use of citric acid alone has been shown to be highly effective in the removal of the smear layer from the root canal system (Baumgartner et al. 1984). Second, the use of the citric acid:ferric chloride combination (10:3) as a surface cleanser has been shown: (1) to enhance the adherence of restorative materials which bond to both the organic and inorganic phases of dentin; (2) to provide a clean dentinal surface, free of smear layer and debris; (3) to stabilize the dentine collagen during the demineralization process (Wang & Nakabayashi 1991). In additionally, applications of higher concentrations of citric acid alone for longer periods have been shown to denature the collagen (Wang & Nakabayashi 1991), which may affect the quality of the collagen available for splicing with newly formed collagen fibrils during precemental formation. This may be critical to the quality of the initial healing on the resected root end.

The cutting of the root-end preparations with the ultrasonic retrotips required a greater amount of time than did preparation with a bur. Also, the gutta-percha filling material was difficult to remove without spending additional time with the retrotip or the adjunctive use of hand instruments. This may have been a function of the ultrasonic unit, retrotip, power setting or operator skill. The power setting of 10 on the ENAC ultrasonic unit was chosen based on a pilot study which determined the most efficacious technique for cavity preparation. Because this was the same setting commonly used for removal of cemented or foreign objects in the root canal, it is possible that the level of vibration may have had a deleterious effect on the thin unsupported, resected root ends. Although no visible cracks or craze lines were present prior to dehydration and preparation for SEM analysis, a further assessment of this possibility is warranted (see Part 2 of this study).

Statistical analyses of the qualitative data have shown that SSD exist in the amount of remaining debris with the different root-end cavity preparation techniques. While the use of an ordinal scale to rank observable. qualitative phenomena is acceptable, this approach to analyses may not have revealed all pertinent differences that were present. However, it was obvious that none of the techniques was capable of eliminating the superficial debris or smear layers which occurred as a result of cavity preparation. The role and significance of this remaining debris in the root-end preparation has not been addressed with regard to clinical success or failure. with a plethora of studies indicating leakage of all rootend filling materials to some degree (Gutmann & Harrison 1991). Yet there are many studies which have addressed the effective removal of all tissue debris. superficial debris and smear layer in the root canal during non-surgical root canal treatment, using a multitude of irrigating agents coupled with ultrasonic devices. These studies have been based on the premise that thorough debridement before sealing the root canal system is the key to long-term successful endodontic treatment. It would seem reasonable then, that techniques of root-end preparation should receive the same emphasis on thorough cleaning prior to filling and their success would be based on the same premise.

Conclusions

1. There were significant differences (P<0.05) in the

amount of superficial debris remaining in root-end preparations in both the bur-prepared cavities and the bur-prepared cavities rinsed with a solution of 10% citric acid and 3% ferric chloride.

- There were no significant differences at all levels in the amount of smear layer produced with the bur preparation only. All levels showed a thick layering of adherent debris.
- 3. There were significant differences (P<0.05) at all levels in the amount of smear layer with the bur preparations which were rinsed with the solution of 10% citric acid and 3% ferric chloride. The apical one-third demonstrated the least amount of smear layer of all techniques and areas evaluated.</p>
- There were no significant differences at all levels of root-end preparations made with the ultrasonic retrotip for either superficial debris or smear layer.
- 5. There were significant differences (P<0.05) between the three methods of cavity preparation with regard to both superficial debris and smear layer. The least amount of superficial debris was observed in the ultrasonic group; the least amount of smear layer was observed in the bur preparation rinsed with a solution of 10% citric acid and 3% ferric chloride.
- 6. No technique effectively removed the smear layer in the coronal one-third of the preparation.

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