SEM evaluation of sonic and ultrasonic devices for root canal preparation


Introduction

An important phase of root canal treatment is root canal preparation, in which the canal walls are cleaned of pulpal tissue and infected debris. Studies investigating the ability of different methods of preparing the root canal by hand indicate that pulpal remnants and uninstrumented areas are often found. Of the different methods, the step-back enlargement technique is often found to be superior, but at best only 85% of the canal walls are effectively debrided. Hence, there is need for a more efficient root canal preparation technique.

Martin reintroduced the concept of using ultrasound for root canal preparation first proposed by Richman in 1957. In initial studies, a laminated transducer-type ultrasonic source produced cleaner canals than did hand preparation, even in isthmus areas which were inaccessible to instrumentation. Since these encouraging reports, a range of sonic and ultrasonic devices for root preparation have become available.

Other studies in which modified ultrasonic scaling units were used to energize the files for root canal preparation found no significant differences in the ability of ultrasonic and hand instrumentation to clean the canals, although the ultrasonic technique seemed to produce cleaner canals.

Evaluations of commercial products are divided as to whether hand or ultrasonic methods of canal preparation are superior. Capurro and Mosca found the ultrasonic system superior to hand preparation, but Langeland et al. found no significant differences between the two. Langeland et al. also evaluated a sonic device and found no significant differences between that device, hand preparation, and the ultrasonic system; however, their findings could be explained by the different files and irrigants used with the different systems.

The purpose of this study was to evaluate the ability of hand, sonic, and ultrasonic methods of root canal preparation to clean moderately curved root canals when a common irrigant and standardized files are used.

Method and materials

Root canal preparation was performed on extracted human maxillary molars stored in 10% formalin. Teeth were radiographically examined and those with canals which permitted no larger than a No. 15 file to penetrate the foramen and had moderately curved canals (10° to 20°) were selected using a modification of Schneider’s technique. The curvature was measured as the angle formed by one line drawn through the long axis of the root canal and another line which extended from a point 1 mm coronal to the apical foramen to the point where the first line leaves the long axis the tooth (Fig. 1). The teeth were divided into three groups of ten and were prepared, using a step-back enlargement technique, by hand, sonically (Micro Mega Endo Sonic Air 3000), or ultrasonically (ENAC OE-2), with similar K-type files.

An apical stop was created with a No. 30 file, then stepped back three sizes larger, with water used for irrigation. The sonic and ultrasonic devices allowed for continuous irrigation, and the flow rate was measured to be approximately 15 ml/min. For hand instrumentation, approximately 2 ml of water was used to irrigate the canal between each instrument change, and 5 ml was used for a final flush. Step-back enlargement for the sonic and ultrasonic technique was per-

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formed by hand; the respective devices were only used to energize a No. 30 file for 15 seconds to recapitulate. The ENAC unit was used at maximum power setting of 3, as recommended by the manufacturer. Paper points were used for drying the prepared root canals, which were then split with wire cutters along a line made with a diamond disk on both sides of the root along the plane of canal curvature. In four teeth the roots split incorrectly, and additional teeth had to be prepared to maintain the sample sizes. The roots were dehydrated and then sputter-coated for SEM evaluation. Photomicrographs at both low and high power of the apical and middle thirds of each root canal were made and printed at ×2 enlargement for evaluation. They were coded and then graded independently by three persons, who compared them against a standard set of photomicrographs\(^5\) which represented varying amounts of debris and smear layer on a scale of 0 (no debris/smear layer) to 3 (most debris/smear layer).

The data were analyzed using the Friedman test, a nonparametric two-way analysis of variance, and the differences between groups were analyzed using the Wilcoxin rank sum test.

**Results**

The cumulative scores for the three observers for the three different techniques of root canal preparation are shown in Table 1.

The Friedman test indicated a statistically significant difference between debris ($P < .05$) and smear layer ($P < .05$) scores of the three groups. The Wilcoxin rank sum test (Table 2) indicated that the statistically significant differences existed between hand and sonic techniques for debris ($P \leq .001$) and smear layer ($P < .05$). There were no statistically significant differences between the scores for middle and apical thirds of the prepared canals.

None of the three techniques produced an absolutely clean canal: each often left areas or fins which were not instrumented. In the sonically and ultrasonically prepared canal groups, one tooth in each group had a shallow saucer-shaped area in the middle third of the canal which could not have been directly instrumented. However, these saucer-shaped areas were relatively free of debris or smear layer, while the surrounding areas were obviously instrumented and covered with a smear layer (Figs. 2 and 3). The ultrasonically prepared canals usually left a thick smear layer, though in regions the underlying dentinal tubules were just visible (Fig. 4). The sonically prepared canals usually left behind a thin smear layer which was perforated by the patent apertures of the underlying dentinal tubules (Fig. 5). The hand-prepared canals usually had a thick smear layer which obliterated any evidence of the underlying dentinal tubules, although sometimes a few underlying dentinal tubules were visible (Fig. 6).

There was complete interexaminer agreement of 61.7% and 63.3% for debris and smear layer evaluation, respectively, while at least two of the three examiners agreed in the other instances.

**Discussion**

Initial reports using a laminated transducer-type ultrasonic generator indicated that root canal preparations in which ultrasonically energized files are used in conjunction with sodium hypochlorite are superior to hand instrumentation in areas which are obviously inaccessible to instrumentation\(^7\) but can still be cleaned. This study, however, found no significant dif-
### Table 1  Cumulative debris and smear layer scores*

<table>
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<tr>
<th>Preparation method</th>
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<td>B</td>
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<td>Total</td>
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* Total scores for ten teeth per group as scored by three observers (A, B, and C). Minimum total score = 0, maximum total score = 90.

$^{1} \chi^2 = 9.650; \text{d.f.} = 2; P = .008$

$^{2} \chi^2 = 7.350; \text{d.f.} = 2; P = .023$

### Table 2  Wilcoxin ranked sum test

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**Fig. 2**  Middle third of a canal prepared using ultrasonics. The portion of the saucer-shaped area (right) is relatively clean with little debris and smear layer, while the other areas have a smear layer obliterating the underlying dentinal tubules (original magnification $3 \times 10^9$).

**Fig. 3**  Middle third of a canal sonically prepared, showing the junction between the saucer-shaped area (top) which is clean and devoid of any smear layer, while the surrounding area is covered with a smear layer (original magnification $3 \times 10^9$).
Fig. 4 Apical third of an ultrasonically prepared canal showing little debris and a thin smear layer remaining, with the apertures of the dentinal tubules just visible (original magnification 2 × 10⁹).

Fig. 5 Apical third of a sonically prepared canal showing little debris and the apertures of the underlying dentinal tubules just visible (original magnification 2 × 10⁹).

Fig. 6 Apical third of a hand-prepared canal showing debris and smear layer. Some patent dentinal tubules can be seen, although usually none were visible (original magnification 2 × 10⁹).

Differences between hand and ultrasonic preparation techniques in which water is used for irrigation, although we observed a tendency for ultrasonics to produce marginally lower debris and smear layer scores. The difference between our results and those of previous studies⁷,⁸ may be due to both the method of generating the ultrasonic vibration and the type of irrigant used. Transducer-type ultrasonic generating units heat the irrigant as it emerges at the file tip. This does not occur to the same extent with the Enac OE-2, which is a piezo electric unit. Cunningham and Balekjian have shown that the tissue solvent action of 2.6% sodium hypochlorite when warmed to 37°C is as effective as 5.2% sodium hypochlorite used at room temperature⁷; hence, the vastly superior ability of ultrasonics could probably be attributed to both the superior tissue solvent action of heated hypochlorite solution and ultrasonic vibration.

Cunningham et al. found that ultrasonic root canal preparation produces minimal smearing, with patent dentinal tubules exposed, compared to the heavy smear layer produced by hand instrumentation.⁸ In this study, although ultrasonic root canal preparation produced marginally less smear layer, the difference was not significant. The differences observed in the two studies may be explained by the fact that Cunningham et al. used ultrasonics exclusively, whereas in this study, the step-back phase was performed using hand instrumentation, with ultrasonics used for recapitulation only, as recommended by the manufacturer. Hand instrumentation probably created a thick smear layer, and no significant amounts of it were removed during recapitulation with the ultrasonically energized file. If the final recapitulation was subject to a longer duration of ultrasonic vibration, a greater portion of the smear layer would probably have been removed.¹⁸ The removal of the smear layer could be desirable because it has been shown to reduce the leakage of gutta percha fillings used in conjunction with a sealer by allowing better adaptation to the cleaner walls and improved mechanical interlocking of the sealer into patent dentinal tubules.¹⁹,²⁰

The sonic technique was superior to both hand and ultrasonic techniques of root canal preparation. The reason for its superiority to the ultrasonic technique is not entirely clear. The Micro Mega Sonic 3000 has an oscillation frequency of 30 Hz while the ENAC oscillates at 30 KHz; perhaps the lower frequency
range is more effective for removing debris and smear layer or the amplitude of vibration is more important than its frequency. Subjective evaluation of the sonically energized file indicated that it appeared to remove more dentin than the ultrasonically energized file when placed in contact with the external cervical area of the tooth. The instruction manual for the ENAC ultrasonic unit recommends that, for endodontics, the unit should not be used on a higher setting than 3 to prevent file breakage. Perhaps this recommendation is too conservative, and the unit may be more effective at a higher power setting.

Both the sonically and ultrasonically energized files demonstrated that some areas which were inaccessible to direct instrumentation could be cleaned (Figs. 2 and 3), although other canals showed gross remnants of pulpal tissue, particularly those which were ultrasonically prepared. This indicates that the use of sonic or ultrasonic vibration per se does not necessarily guarantee a cleaner canal will result. An advantage of ultrasonic vibration, however, is its ability to lyse bacteria by disrupting the bacterial cell wall, which reduces the bacterial population in the root canal more effectively and efficiently compared to hand preparation. Further, the antimicrobial efficiency of ultrasonics is enhanced if a bactericidal irrigant like sodium hypochlorite is also used. Therefore, sonic and ultrasonic devices can be a useful adjunct for root canal preparation. Dentists who find it difficult to manipulate endodontic hand instruments while wearing gloves will appreciate these sonic and ultrasonic systems, although changing files with the ENAC unit was particularly inconvenient.

Conclusions

The sonic technique of root canal preparation was superior to hand and ultrasonic techniques in removing debris and smear layer. There were no significant differences between the hand-instrumented and the ultrasonically instrumented canals. There were no significant differences between the debris and smear layer scores at the apical and middle thirds of all instrumented canals. None of the three techniques produced an absolutely clean canal.

References