Scanning Electron Microscopic Evaluation of Root-End Preparations

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The use of an ultrasonic apical preparation technique has been advocated recently. Root-end preparations in 30 extracted single-canaled human teeth were evaluated, comparing those prepared with ultrasonic instrumentation alone, or in combination with rotary bur preparation, to those prepared with rotary instrumentation alone. Specimens were evaluated for the presence of debris, smear layer, and the smoothness and uniformity of the preparations. The apical preparations were completed according to the varying techniques, examined, and photographed under scanning electron microscopy. Those cavities prepared with the ultrasonic, either alone or in combination with rotary instrumentation, showed the presence of significantly less smear layer compared with those made by burs alone. Cavities prepared with ultrasonic instrumentation in combination with rotary instrumentation contained significantly less debris than those prepared with rotary instrumentation alone. There were no significant differences between the techniques in the smoothness or uniformity of the preparations.

Ultrasonic instrumentation has been commercially available for orthograde endodontic therapy since the introduction of the Cavi-Endo system (Dentsply, York, PA). Although an ultrasonic instrument was designed by Richman (1) in 1956 for root resection and Bertrand (2) presented a modified Cavitron (Dentsply) for root-end preparation in 1976, commercially available ultrasonic instruments for surgical endodontics have only been recently introduced.

Specially designed tips for root-end preparation during periapical surgery have been produced for use with two preexisting ultrasonic devices: the Neosonic (Amadent, Cherry Hill, NJ) and the ENAC (Osada Electric Co., Los Angeles, CA).

The development of miniaturized ultrasonic tips to perform retropreparations has attracted much attention and seems to have addressed the major shortcomings of rotary-type bur preparations (3).

Ultrasonic Retrotips from EIE (Excellence in Endodontics, San Diego, CA) are designed to provide improved access to the root-end and to create more conservative root-end preparations while decreasing the amount of retained debris (3).

A review of the literature indicates that there is a need for scanning electron microscopic evaluation of the efficiency of ultrasonic instrumentation in the preparation of root ends in endodontic surgery.

Numerous investigations have been performed to evaluate the cleansing efficiency of ultrasonic intracanal instrumentation, with conflicting results. Mandel et al. (4) and Goldman (5) used scanning electron microscopy (SEM) to assess the cleansing efficiency of ultrasonic intracanal instrumentation. They reported difficulty in obtaining completely clean root canals, regardless of the technique used.

Baker et al. (6) used SEM to compare the debridement of root canal systems following ultrasonic and hand instrumentation. They found ultrasonic instruments were not superior to hand instruments in cleaning canals. There are other reports in the literature on the efficacy of the use of ultrasonic instrumentation and its lack of superiority over conventional root canal preparation (5, 7).

Many of these studies used irrigating solutions containing NaOCl and found that the role of irrigant seems to be important in increasing the effectiveness of the system (8, 9). The irrigant of choice is a 2% to 3% solution of NaOCl (7), which would not be appropriate in a surgical environment.

The purpose of this study was to use SEM to evaluate the topography of root-end cavities prepared with ultrasonic instrumentation, their smoothness and uniformity, and the presence of debris and the smear layer compared with conventional rotary bur root-end preparations.

MATERIALS AND METHODS

Thirty extracted human canine and incisor teeth with unknown clinical histories were used in this study. All teeth were autoclaved at 121°C at 15 lb pressure for 15 min, then stored in 2% glutaraldehyde before use. All teeth were radiographed to determine the existence of a single relatively straight canal. Root canal integrity was established by inserting a #10 file to length. All teeth were stored in normal saline solution throughout the experiment and were prepared by the principal investigator.

Standard endodontic access preparations were made in all crowns. Working lengths were established 1 mm short of the anatomical apex by visually identifying a #10 or #15 K-file at

the apical foramina and subtracting 1 mm. NaOCl (2.5%) irrigant was used in all cases.

Root canals were filed wet and flushed with irrigant after each file size. The canals were instrumented with standardized K- and Hedstrom files to a minimum master file size of 25, and serially flared to size 45. Gates Glidden burs (#2 to #4) were used to flare the orifice after the apex was prepared to a size 20 K-file. Following instrumentation, the canals were dried with sterile paper points, and obturated with laterally condensed gutta-percha (Mynol Block Drug Co., Jersey City, NJ) and Roth 801 sealer (Roth Intl., Chicago, IL).

The apices were resected with a surgical bur (Caulk super bur, Dentsply, Milford, DE) at high speed, with irrigation at a distance between 3 and 5 mm from the anatomical apex and beveled at a 45-degree angle to the facial surface. The teeth were randomly divided into three equal groups, and root-end preparations were made using three methods.

In group 1 (both conventional rotary and ultrasonic), the preparations were made using a combination of the straight handpiece and ultrasonic instrumentation (25 to 40 kHz), with the Amadent Neosonic Unit and tips designed specifically for root-end preparation. The straight handpiece was used first, followed by the ultrasonic instrument to refine the preparation and remove debris with irrigation. In group 2 (conventional rotary), the teeth were prepared with a #1 carbide bur in a straight handpiece. In group 3 (ultrasonic only), ultrasonic instrumentation was used only. Preparations were made to a minimum depth of 3 mm in the long axis of the root. The preparation was enlarged to a clinically acceptable dimension with proper retention form to accept the retrofilling material.

The root-end preparations were visually inspected without magnification for cleanliness and flushed with a saline rinse in an irrigating syringe with a 27-gauge needle and suctioned with a surgical suction tip at high volume. The crowns were removed at the cementoenamel junction. One specimen in group 2 fractured vertically and was discarded. The remaining roots were coded and stored in saline until all specimens were prepared.

The samples were air-dried, glued/mounted on stubs with Duco household cement, and gold-palladium (60/40 ratio) sputter coated 20 to 25 nm thick with a Hummer V Sputter coater.

Samples were then stored in a dessicating cabinet until evaluated under SEM to keep them dry. In the microscope, a JEOL model JSM840A, a minimum of three photomicrographs of each specimen were taken: one of the root-end face at ×20, and two of a representative area of the wall, at ×600 and ×2000.

Postoperative scanning electron photomicrographs were made of each specimen to compare the general topography of the surfaces, the presence of debris in the preparations, and the presence of the smear layer.

The photomicrographs of the internal walls of the preparations at ×600 were compared. This magnification was chosen because it showed the detail required while maintaining as large a field as possible (10).

The photomicrographs were evaluated by four independent observers, all experienced endodontists and diplomates of the American Board of Endodontics. Each evaluator was oriented by the principal investigator on the method to record the amount of smear layer and remaining debris.

To score the photomicrographs, the examiners viewed slides made from the negatives taken at ×600 magnification projected onto a screen. The slides were projected in a random order; the evaluators were not aware from which group any sample was taken. Two separate scores were recorded for each photomicrograph: one for the quantity of debris and one for the quantity of remaining smear layer.

The amount of pulpal debris was graded from 0 to 3 (0 = none, 1 = minimal debris, 2 = moderate, and 3 = heavy). The smear layer was also scored 0 to 3 (0 = no organic smear layer with all the tubules opened, 1 = little smear layer with >50% tubules open, 2 = moderate smear layer with <50% tubules open, and 3 = heavy smear layer with outlines of tubules indistinguishable. The scores were statistically evaluated using the Kolmogorov-Sirnov Two Sample Test.

RESULTS

The total number of evaluator responses for rating the smear layer and remaining debris are shown in Tables 1 and 2.

Those cavities prepared with the ultrasonic instrument in combination with rotary instrumentation showed significantly less debris than those prepared with rotary instrumentation alone ($p < 0.05$; see Fig. 1).

There was no significant difference between ultrasonic and rotary instruments used alone in debris removal, or between the combined use of ultrasonic and rotary instrumentation and ultrasonic instruments alone.

The combined use of ultrasonic and rotary instruments showed significantly less smear layer than those prepared with rotary instrumentation alone ($p < 0.01$; see Fig. 2). The use of ultrasonics alone showed significantly less smear layer than combined instrumentation or rotary instruments alone ($p < 0.01$; see Fig. 3).

Interjudge variability was evaluated for all sets of scores and was found to be nonsignificant. An interesting observation was noted with some ultrasonically treated specimens. The surface appears fractured or hatcheted (see Fig. 4). This

TABLE 1. Evaluation of remaining debris

	Rotary and Ultrasonic	Rotary Only	Ultrasonic Only
Heavy	9	8	9
Moderate	4	10	12
Minimal	13	17	8
None	14	1	11

$n = 116$. 0 = None, 1 = minimal, 2 = moderate, and 3 = heavy.

TABLE 2. Evaluation of smear layer

	Rotary and Ultrasonic	Rotary Only	Ultrasonic Only
Heavy	11	32	16
Moderate	25		2
Minimal	3	2	6
None	1	2	16

$n = 116$. 0 = No smear layer, all tubules open; 1 = little smear layer, >50% tubules open; 2 = moderate smear layer, <50% tubules open; and 3 = heavy smear layer, outlines of tubules indistinguishable.
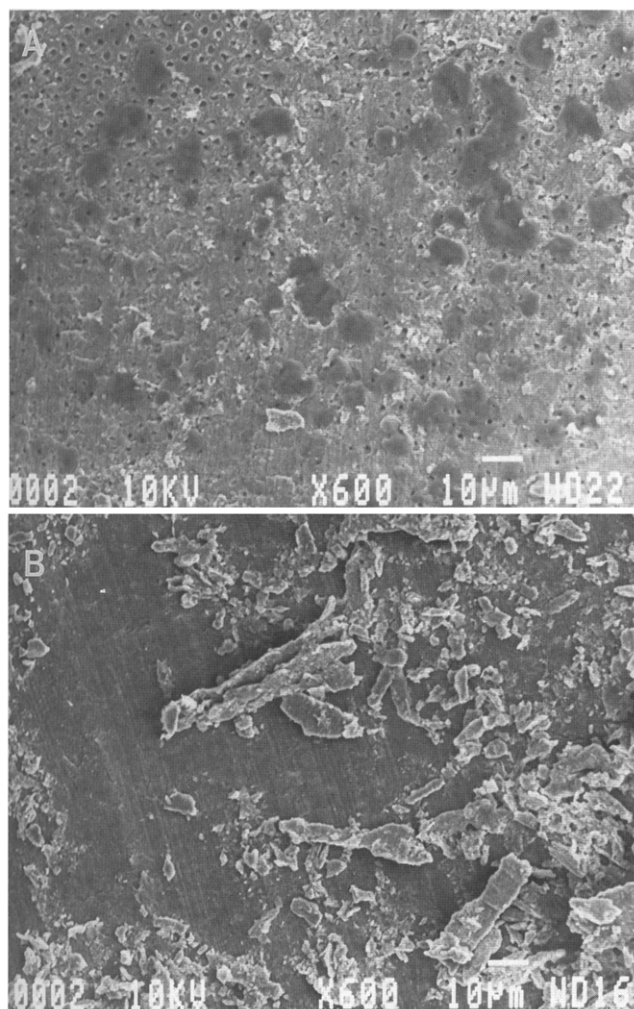
FIG 1. The internal walls of the apical preparation viewed under the scanning electron microscope. A, Specimen from group B: both rotary and ultrasonic instrumentation (original magnification ×600). B, Specimen from group C: conventional rotary instrument only (original magnification ×600).

FIG 2. A, Specimen from group B: both rotary and ultrasonic instrumentation showing patent tubules (original magnification ×2000). B, Specimen from group C: conventional rotary instrument only. Showing heavy smear layer with the outlines of the tubules indistinguishable (original magnification ×2000).

could be attributed to the cavitational energy of the ultrasonically energized tip producing microfractures (11–13).

Fractures were observed on the root face of many specimens (see Fig. 5). It is the opinion of the authors that these were artifact from the drying procedures preparing the specimens for SEM evaluation. There were no differences observed in the incidence of fractures between the techniques. Qualitative assessment of the smoothness of the preparations revealed no significant differences between the techniques.

DISCUSSION

It is assumed that cleanliness and the absence of debris are highly desirable in root-end preparations. The results from this study indicate that the ultrasonic instrument can produce very clean preparations, with a reduced smear layer and less surface debris.

The significantly cleaner preparations produced by using the ultrasonic instrument are attributed to the phenomena of cavitation (11, 12) and acoustic streaming (10). The rapid
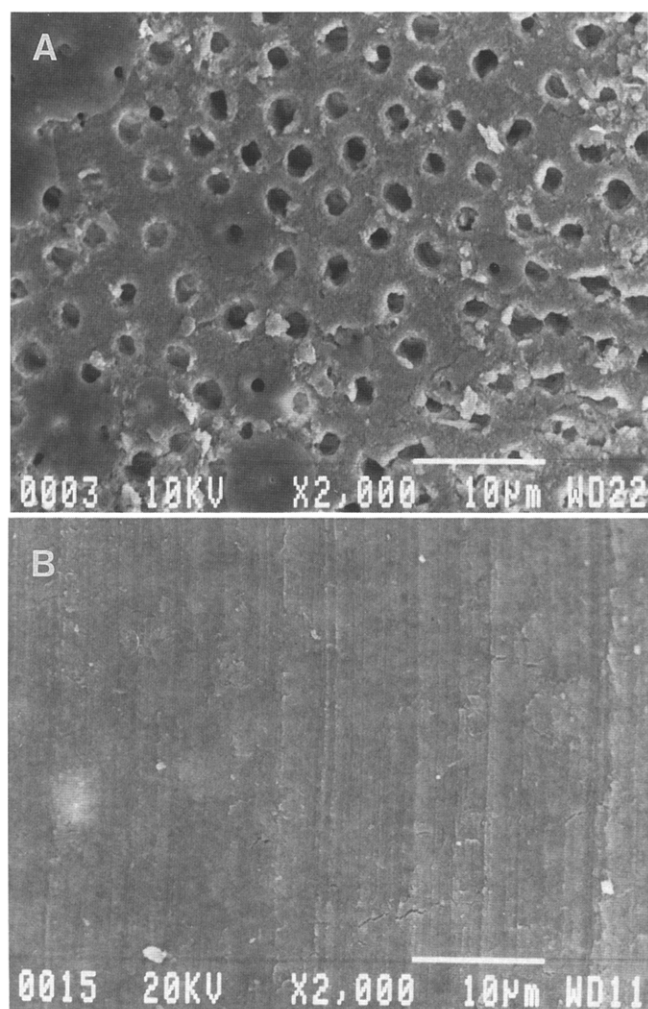
formation and collapse of the bubbles of irrigant in concert with the local circulation and vortex flow fields generated by the freely vibrating instrument tip produce hydrodynamic shear stresses large enough to remove debris and the smear layer from the walls of the root-end preparations.

According to Ahmad et al. (10) direct contact of the instrument tip with the canal wall results in restriction or damping of the transverse displacement amplitude of the file, substantially decreasing the acoustic streaming. As a result, the canal walls were less clean than those exposed to high levels of acoustic streaming. This could explain those areas in the ultrasonic preparations where debris and/or smear layer remained on the walls of the cavity preparations.

Further studies of amplitude setting versus time (how long the instrument should be used) need to be done to find the optimum cleaning ability of these devices. In this study, the instruments were used long enough to create a clinically acceptable apical preparation, between 1 and 3 min.

All techniques utilized in this study produced residual debris. Baker et al. (6) reported that the removal of debris and microorganisms from the root canal system seemed to be a
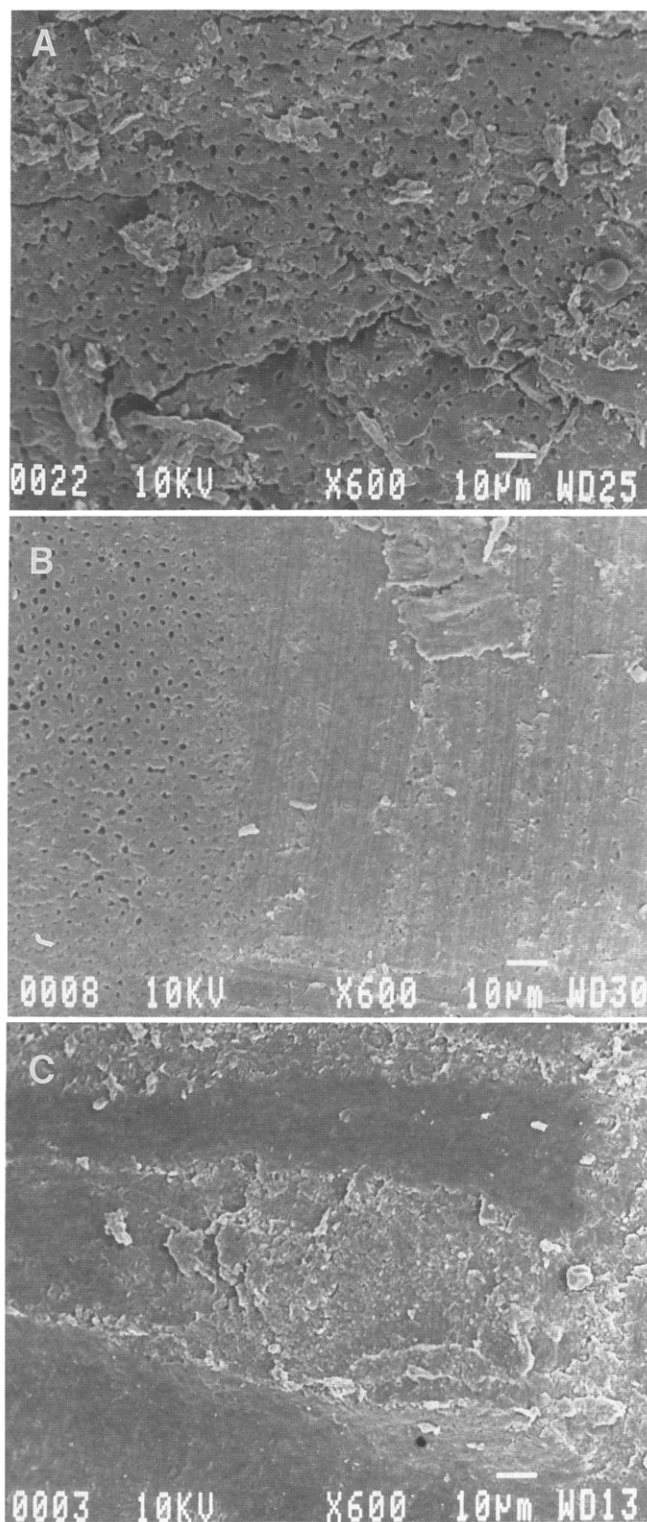
FIG 3. A, Specimen from group U: ultrasonic instrumentation only. Showing little smear layer with >50% of tubules open (original magnification ×600). B, Specimen from group B: both rotary and ultrasonic instrumentation (original magnification ×600). C, Specimen from group C: rotary instrument only. Heavy smear layer with tubules indistinguishable (original magnification ×600).
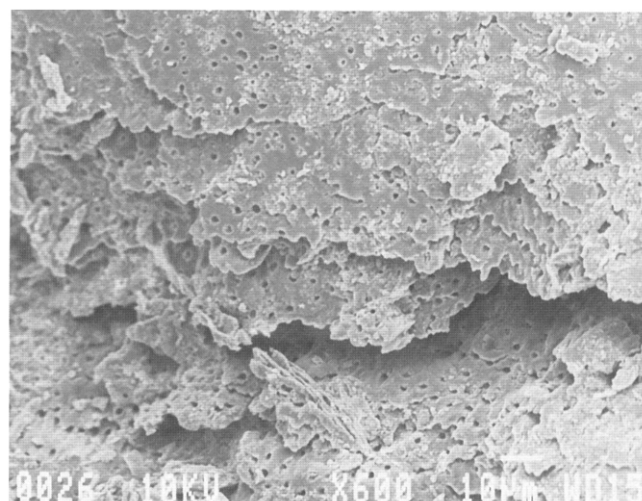

FIG 4. Specimen from group U: ultrasonic instrumentation only. Note the hatcheted surface relatively free of debris or smear layer (original magnification ×600).
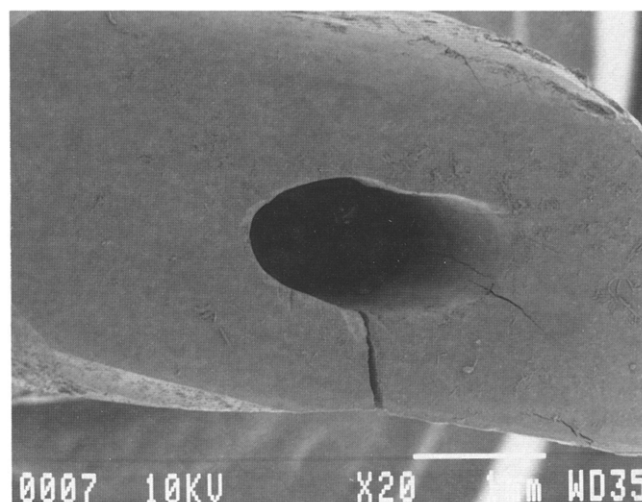

FIG 5. Specimen showing artifactual fractures common to all treatment groups (original magnification ×20).

function of the quantity of irrigating solution rather than the type of solution used. The flushing action of the solutions seemed to be the significant factor. Irrigants used in this study were saline via irrigating syringes and tap water via the water line connected to the ultrasonic unit. Allowing the ultrasonic instrument tip to vibrate freely in the completed preparation for a period of time may be helpful in flushing out retained debris. Ahmad et al. (10) have suggested a period of 5 min in their investigations of intracanal ultrasonic instrumentation.

Using the SEM, it is difficult to distinguish between hard and soft tissue debris (5). If the debris is indeed small chips of dentin removed during the cavitation process, then perhaps this is of small import. It is not known whether this debris can be harmful. There have been no publications to date that have attempted to assess this parameter (5).

If the debris contains soft tissue, then there is another aspect that must be considered. Soft tissue can become necrotic and can harbor microbes. The presence of microorga-

nisms is not desirable and despite one's best efforts may not be entirely removed.

Whether ultrasonic instrumentation creates a smear layer has not been reported in the literature. If it does not, it also would not create smear plugs, leaving the tubules patent.

Smear layers are created on hard tissues whenever they are cut with hand or rotary instruments (14). When smear layers are created, grinding debris is forced into each tubule to form a smear plug composed of microcrystalline cutting debris embedded with denatured collagen. Functionally, it occludes all of the tubules, making them only 22% as permeable as they would be if the smear layer was absent.

The role of the smear layer is still controversial (8). It may be beneficial in reducing dentin permeability and may slow external penetration of bacteria into the dentinal tubules (15). On the other hand, the smear layer may be detrimental, because it prevents irrigants and filling materials from penetrating the dentinal tubules (16).

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You Might Be Interested

The two basic conditions for the evolution of life from a primordial sea are self-replicating molecules and the formation of a means, a cell membrane, to isolate them from the surrounding ionic brew. Current theory is that cell membranes are basically double layers of phospholipid molecules and it has been shown that under the right conditions phospholipid molecules will indeed coalesce into membrane-like assemblies.

For structural reasons, however, such a membrane requires molecular mechanical reinforcement. In eukaryotes—the higher organisms—the membrane reinforcer is none other than—cholesterol.

That just shows that most everything is useful in the right place—in the case of cholesterol the right place is cell membranes not the intima of arteries.

William Cornelius