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Cleaning of Oval Canals Using Ultrasonic or Sonic Instrumentation

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This study investigated the effect of direction of file oscillation on the amount of debris and smear remaining within oval canals. Sixty-five lower premolars were allocated to six experimental groups (*n* = 10) and one control group (*n* = 5). Canals were prepared using Gates Glidden burs and hand instruments. Preparations were completed using either an ultrasonic size 15 K file or a sonic size 15 shaper file. Three preparation techniques were used: (a) file oscillation toward oval recesses within the canal, (b) file oscillation at right angles to the recesses, and (c) rotational movement of handpiece. Canals were examined under the scanning electron microscope and blindly scored for debris and smear layer. Log linear analysis revealed no significant difference ($p > 0.05$) between sonic or ultrasonic instrumentation as to debris or smear layer remaining. File oscillation directed toward oval recesses left the least amount of debris ($p < 0.05$). Smear layer remained unaffected by all techniques.

Energized vibratory handpieces have become an established part of root canal therapy technique (1–3). Such systems consist of an oscillating file operated at either ultrasonic (20 to 40 kHz) or sonic (1.5 to 3 kHz) frequencies. The ultrasonically activated file oscillates in a transverse manner with a series of nodes and antinodes running along its length with the largest antinode occurring at the unconstrained tip (4). In contrast the sonically powered file has one node nearest to the driver and one large antinode at the tip (5).

During file oscillation, various irrigants pass over the oscillating file (6–9). The efficacy of the system may be attributed to acoustic microstreaming within the irrigant (9). This is a property of an ultrasound field in which complex, steady-state, streaming fields are generated within a liquid medium. Characteristically such fields produce large hydrodynamic shear stresses close to the oscillating body (i.e. endosonic file). These stresses are capable of disaggregating clumps of bacteria (10) or disrupting cells (11). In the ultrasonic and sonic systems, acoustic microstreaming occurs along the length of the file. The greatest streaming and therefore the greatest shear stresses occur around points of maximum displacement such as the tip of the file and other antinodes along its length (12).

These streaming fields have been shown to be effective in cleaning the root canal (9) as they serve to forcibly move the irrigant around for maximum debridement. The amount and force of streaming, however, is dependent upon two factors: (a) amount and freedom of file movement and (b) the length of time the file is used in the canal (13). Therefore, the shape and curvature of the canal is critical; narrow and/or curved canals would constrain and limit the action of the vibratory instrument.

Most investigators have only portrayed the two-dimensional effect of the streaming phenomenon (9), although when placing an activated file within water a three-dimensional effect clearly is present. Therefore, there are probable variations in streaming patterns associated with different instruments considering the reported differences in file action (4, 5).

This three-dimensional streaming around both ultrasonically and sonically activated files has been demonstrated in vitro using a model system of slow setting plaster (14). For ultrasonic files, streaming occurred mainly in front of and behind the file parallel to the handpiece in contrast to the sonic file with which the plaster was disturbed evenly around it. With both types, most activity occurred around the file tip, and it became less toward the driver. Streaming patterns associated with the ultrasonic device were found to be dependent on both the power setting of the instrument and whether the file was in contact with a solid surface. The sonic device produced a large disturbance around the freely oscillating tip; however, when constrained, this streaming occurred along the whole length of the file. These in vitro investigations (14) showed that streaming does occur with the current instruments available, although it is dependent upon their operating conditions (i.e. power setting and constraint).

Canals vary in their cross-section and many have an oval shape. A file oscillating toward a recess would have most of its streaming directed into it. Conversely, much of the beneficial effect of streaming could be lost with a file oscillating at right angles to the recess as maximum streaming forces would not be directed to this part of the canal. A compromise may be to rotate the handpiece, and therefore direction of file oscillation, in order to try to direct the streaming forces against all walls evenly.

The aim of this study was to investigate whether this three-dimensional streaming characteristic was of assistance in the reduction of remaining debris or smear layer in oval canals.

Both ultrasonic and sonic instrumentation systems were used and compared with three different preparation approaches (Fig. 1): (a) file oscillting toward the oval recess, (b) file oscillating at right angles to the recess, and (c) rotational technique where the driver was rotated, thereby allowing the file to oscillate toward all areas of the canal.

MATERIALS AND METHODS

A randomized sample of 65 freshly extracted mandibular premolars of length between 20 and 22 mm was stored in 1% Thymol which acted as a preserver and antibacterial agent. Teeth were radiographed from the mesiodistal aspect to confirm the presence of one oval-shaped canal. Canal integrity was established by inserting a #15 file to the apical foramen.

Canal Preparation

Each tooth was accessed and instrumented in a step-down manner, first using Gates Glidden drills #4 to 6 mm, then #3 to 8 mm, and then #2 to 10 mm. The remainder of the preparation was with K-Flex files (Kerr, Romulus, MI) in series used in a circumferential manner sizes 15 through 30. The last file used at the apical stop was #30. Irrigation between each instrument was 1 ml of sterile water through a 27-gauge needle. All 65 canals were prepared in this manner and were then divided into experimental and control groups. The controls were five canals instrumented only with hand files and Gates Glidden drills as described. These were randomly picked from the sample and examined for the presence of debris and smear layer. These controls with hand and Gates Glidden instrumentation alone were compared with the three different preparation techniques using sonic or ultrasonic preparation.

The remaining 60 teeth were randomly distributed into six experimental groups consisting of 10 teeth in order to determine the effect of using sonic preparation (Micromega 1500 sonic air; Prodonta, Geneva, Switzerland), tuned to a file displacement amplitude of 0.5 mm, or ultrasonic (Cavi-Endo; Dentsply Ltd., Long Island, New York) preparation, at three-quarters power setting, with one of the three techniques. Specifically 10 canals were prepared with the #15 Endosonic Cavi-Endo file oscillating toward the recess (that is with the handpiece parallel), 10 with the file oscillating at right angles to the recess (handpiece at right angles) and 10 in a rotational manner. This rotation was achieved by moving the instrument handle through a 90-degree arc. Three similar groups of 10 teeth were instrumented in each of the three ways using the Micromega 1500 and #15 shaper file tuned to a file displacement amplitude of 0.5 mm. In both the ultrasonic and sonic groups canal instrumentation was conducted for 2 min each with water irrigation at a rate of 20 ml/min. Files in all groups were constantly moved circumferentially with an up and down movement of 2 mm. The canals were finally irrigated with 1 ml of sterile water using a 27-gauge needle.

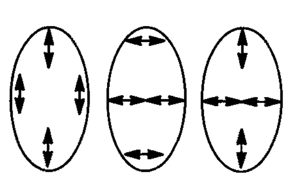
a b c

FIG 1. Diagram showing three different preparation techniques. *a*, toward recess; *b*, across recess; and *c*, rotational movement.

Specimen Preparation for Scanning Electron Microscopy

After canal enlargement a paper point was placed into the canal orifice to block debris during sectioning. The long axis of the root was grooved on the mesial and distal surfaces with a 700L bur and the root was split lengthwise with rongeurs. Experimental and control roots were coded for blind scanning electron microscopic evaluation. Canal surfaces were sputter coated with gold. Photomicrographs of the canal surfaces were made for every specimen at 2 mm (apical), 6 mm (middle), and 10 mm (coronal) from the apical foramen. Photomicrographs were at ×350 to show the detail required with a large field width.

Evaluation

The specimen photomicrographs were coded and randomized before examination. The amount of debris and smear layer present was determined by two experienced endodontic clinicians. To score the photomicrographs examiners had two sets of three comparison photomicrographs. One set showed canal areas at ×350 representing increasing gradations of debris accumulation (Fig. 2). The second set represented increasing gradations of smear layer (Fig. 3). Evaluators scored each specimen photomicrograph in one of four categories with scores of 1 (less debris than Fig. 2*a*), 2 (debris between Fig. 2*a* and *b*), 3 (debris between Fig. 2*b* and *c*), and 4 (debris greater than Fig. 2*c*). Each specimen photomicrograph was also scored for smear (Fig. 3) using patency of dentin tubules as a guide. Therefore, two separate scores were recorded for each photomicrograph for quantity of either debris or smear layer. After scoring the code was broken and each group identified. In order to determine differences between the amount of debris and between the amount of smear layer remaining among the six groups (ultrasonic or sonic with three different preparation techniques, respectively, in three different areas of the canal), the individual scores were statistically evaluated using a log linear computer analysis (15).

RESULTS

Controls

The control teeth prepared only by hand instruments and Gates Gliddens with water irrigation confirmed the oval shape of the canals and showed heavy deposits of debris and smear layer with scores of 3 or 4 in all canals. This confirmed the presence of debris and smear layer after hand instrumentation

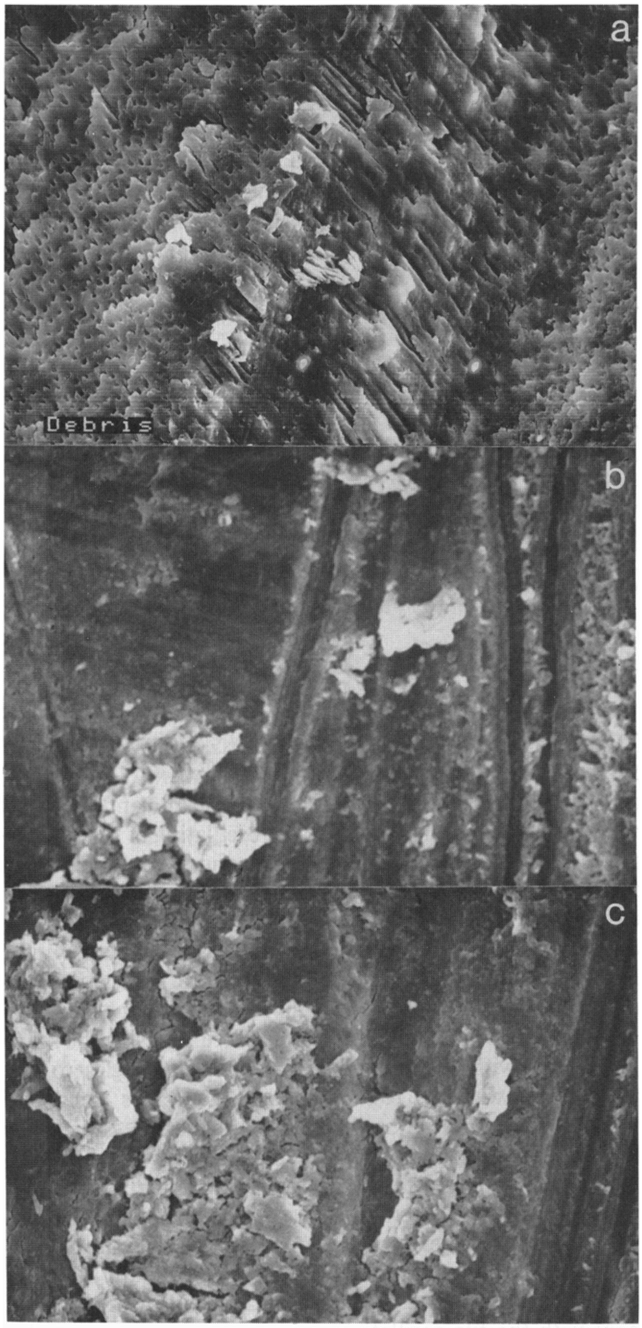

FIG 2. The three photomicrographs used to represent the gradation of debris accumulation (*a*, little debris; *b*, moderate debris; *c*, high debris). The examiners were asked to place photomicrographs between these gradations, giving sliding scale of 1 to 4 (1 clean to 4 greatest debris) (original magnification ×350; field width = 300 μm).

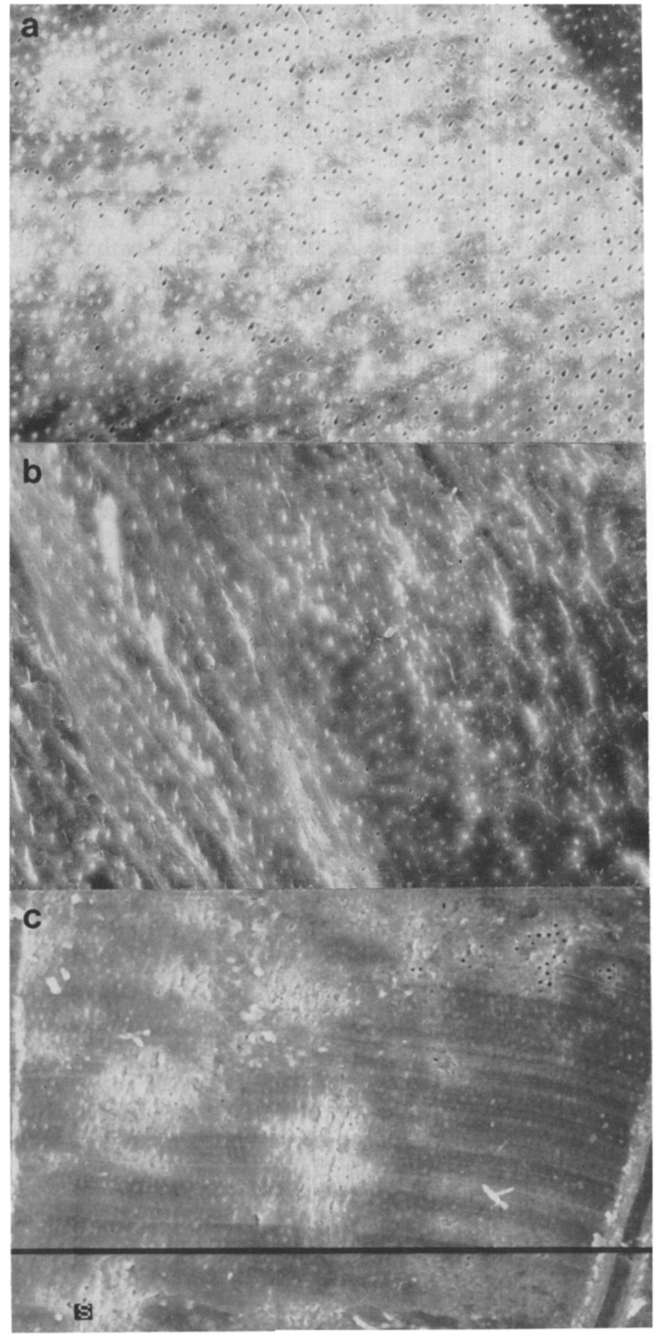

FIG 3. The three photomicrographs used to represent the graduation of smear accumulation (*a*, little smear; *b*, moderate smear; *c*, high smear). The examiners were asked to place photomicrographs between these gradations, giving sliding scale of 1 to 4 (1 clean to 4 greatest smear) (original magnification ×350; field width = 300 μm).

with water but before either sonic or ultrasonic instrumentation.

Experimental

A contingency table was drawn up using the following five variables. Debris score (SCO), observer (OBS), handpiece, ultrasonic or sonic (HAN), technique (TEC), and canal position apical, middle, coronal (ARE).

A logit log linear analysis was undertaken with debris score (SCO) as the response variable. The independence model was not a good fit to the data (χ^2_L = 180.34, df = 105, $p < 0.37$). A model with the first order interactions SCO BY OBS, SCO BY TEC, and SCO BY ARE did provide a good fit (χ^2_L = 90.11, df = 79, p = 0.19); adding the interaction SCO BY HAND to this model provided a better fit (χ^2_L = 83.60, df = 76, p = 0.26), but not significantly so (for the difference: χ^2_L

= 6.52, df = 3, $p > 0.05$). Hence, the former model was accepted as the most parsimonious model of adequate fit. It is to be noted that this model did not include the variable HAN, nor any second order interactions. There was no significant difference ($p > 0.05$) among the coronal, middle, and apical parts of the canals.

For the interaction SCO BY TEC, all parameters were significant ($p < 0.05$), positive for scores 1, 2, and 3 with the file oscillating toward the recess, for score 4 with the file oscillating at right angles to the recess, and for score 4 with the rotational technique. If the difference between score 3 and score 4 can be regarded as the critical threshold of efficient debris removal, then these results suggest that the technique with the file oscillating toward the recess is most efficient. The relevant contingency table is shown in Table 1.

In none of the models does the variable HAN (ultrasonic/sonic) appear, i.e. the scoring was not affected by sonic or ultrasonic instrumentation and no difference between them was therefore noticed. There was also no significant difference ($p > 0.05$) between the coronal, middle, or apical region of the canals. However, Table 1 shows an increased number of score 1's for sonic compared with ultrasonic instrumentation with the file oscillating at right angles to the recess and with the rotational technique. This difference however was not significant. This difference was not apparent when the file oscillated toward the recess; on the contrary the ultrasonic showed an increased number of scores compared with the sonic.

TABLE 1. Contingency table showing comparison of debris score for different groups

Score	Technique					
	Toward Recess		Across Recess		Rotation	
	Sonic	Ultrasonic	Sonic	Ultrasonic	Sonic	Ultrasonic
1	19	25	19	5	10	2
2	28	28	25	27	29	32
3	13	7	12	21	15	23
4			4	7	6	3

TABLE 2. Contingency table showing comparison of smear scores for different groups

Score	Technique					
	Toward Recess		Across Recess		Rotation	
	Sonic	Ultrasonic	Sonic	Ultrasonic	Sonic	Ultrasonic
1		1	1	1	2	1
2	9	6	6	8	17	7
3	24	30	23	29	26	30
4	27	23	30	21	15	22

Smear Layer

The independence model provided a good fit to the data ($\chi^2_L = 109.07$, df = 105, $p = 0.37$). Thus, the smear score was not significantly affected by differences between observers, between handpieces, among techniques or among areas, i.e. in terms of the smear scores given by the two observers. No one area (coronal versus middle versus apical) was significantly better or worse than any other. Neither handpiece nor any of the three techniques produced different results than any other. The relevant contingency table is shown in Table 2.

DISCUSSION

Acoustic Microstreaming has been shown to be a relevant factor in the debridement of root canals (9) and an in vitro model system (14) has demonstrated the three-dimensional effect of streaming. Streaming is most effective in the direction of oscillation of an ultrasonic file, i.e. in front and behind parallel to the handpiece (14). It would appear to be least effective at right angles to an ultrasonically oscillating file; however, it is more uniform around a sonic instrument (14). This study was designed to relate this variation in streaming to the clinical situation. The oval root canals were cleaned with the direction of file oscillation directed either at right angles or toward the oval recesses. A third movement attempted to combine the other two by rotating the handle of the instrument during instrumentation in a 90-degree arc of movement. The amount of debris and smear layer remaining were used as indicators of canal cleanliness. The debris was significantly reduced between the score 3 and score 4 levels when the file oscillation was directed at the oval recesses ($p < 0.05$) compared with the other two procedures. Apparently the file used in the rotational technique was not oscillating toward the recess for a sufficient period of time and therefore resulted in a similar result to the file oscillating at right angles to the recess. This would appear to confirm the hypothesis that knowledge of the three-dimensional effect of streaming should be related to an understanding of canal morphology with respect to the incidence of oval-shaped canals during debridement. Interestingly, no significant difference was observed between ultrasonic and sonic instruments in this study. However, there was a trend for more score 1's using the sonic instrument with the file oscillating at right angles to the recesses and with the rotational technique. This trend was reversed when the file oscillated toward the recess with the ultrasonic recording more score 1's. This may be explained by the fact that the ultrasonic and sonic instruments have differing patterns of oscillation (4, 5). The eliptical oscillation of the sonic instrument produces more even streaming around the file and this could explain the reduced amount of debris left within the recesses compared with the ultrasonic instrument with the file oscillating across the recess and with the rotational technique. Conversely, the trend toward reduced debris being left after use of the ultrasonic instrument with the file oscillating toward the recess could be explained by the fact that the ultrasonic file has a more transverse action and streaming forces are more concentrated toward the recess, resulting in less debris being left. These factors may help explain the reported superiority of a sonic instrument (16).

Another factor which could have affected the results is that unrestricted movement of the file was assumed. There could be an increased likelihood of constraint when the file oscillates at right angles to the recess which may contribute to the differences found between the three preparation techniques in this study.

The amount of smear layer remaining was unaffected by any variable. This may reflect the choice of water as irrigant (9). Further research utilizing sodium hypochlorite (6) or EDTA (7, 8) is required to assess whether there is an interaction between the technique and irrigant used. Another variable may be file size, as only size 15 files were chosen for this study. Further research into the interaction of file size and cleaning is also indicated.

This study suggests that when using vibratory instrumentation the clinical technique should be modified with respect to matching root canal anatomy and direction of file oscillation wherever possible. In other words, with large oval-shaped canals file oscillation should be directed toward the recesses to maximize the potential debridement effect of streaming.

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References

1. Martin H, Cunningham WT. Endosonics—the ultrasonic synergistic system of endodontics. Endod Dent Traumatol 1985;1:201-6.

2. Nehammer CF, Stock CJR. Preparation and filling of the root canal. Br Dent J 1985;158:285-91.

3. Lumley PJ, Walmsley AD, Laird WRE. Ultrasonic instruments in dentistry 2. Endosonics. Dent Update 1988;15:362-9.

4. Walmsley AD, Williams AR. The effect of constraint on the oscillatory pattern of endosonic files. J Endodon 1989;15:189-94.

5. Walmsley AD, Lumley PJ, Laird WRE. The oscillatory pattern of sonic files. Int Endod J 1989;22:125-32.

6. Griffiths BM, Stock CJR. The efficiency of irrigants in removing root canal debris when used with an ultrasonic preparation technique. Int Endod J 1986;19:277-84.

7. Cameron JA. The use of ultrasound and an EDTA-urea peroxide compound in the cleansing of root canals. An SEM study. Aust Dent J 1986;29:80-5.

8. Tronstad L, Barnett F, Schwartzben L, Frasca P. Effectiveness and safety of a sonic vibratory endodontic instrument. Endod Dent Traumatol 1985;1:69-76.

9. Ahmad M, Pitt Ford TR, Crum LA, Walton AJ. Ultrasonic debridement of root canals: acoustic streaming and its possible role. J Endodon 1987;13:490-9.

10. Williams AR, Slade JS. Ultrasonic dispersal of aggregates of Sarcina lutea. Ultrasonics 1971;9:85-7.

11. Williams AR, Chater BV. Mammalian platelet damage *in vitro* by an ultrasonic therapeutic device. Arch Oral Biol 1980;25:175-9.

12. Walmsley AD. Ultrasound and root canal treatment: the need for scientific evaluation. Int Endod J 1987;20:105-11.

13. Krell KV, Johnson R, Madison S. Irrigation patterns during ultrasonic canal instrumentation. Part I. K-type files. J Endodon 1988;14:5-8.

14. Lumley PJ, Walmsley AD, Laird WRE. Streaming patterns around endosonic files. Int Endod J 1992;24:290-7.

15. Everitt BS. The analysis of contingency tables. London: Chapman and Hall, 1977.

16. Barnett F, Trope M, Khoja M, Tronstad L. Bacterialogical states of the root canal after sonic, ultrasonic and hand instrumentation. Endod Dent Tramatol 1985;1:228-31.