Scanning Electron Microscopic Analysis of the Integrity of the Root-end Surface after Root-end Management Using a Piezoelectric Device: A Cadaveric Study

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Abstract

Introduction: The introduction of piezoelectric instruments in endodontic surgery allowed clinicians to manage the bone tissue with precision reducing the risk of damaging soft tissues. Although such instruments can also be used to prepare root-end cavity, few information is available on the effect of piezosurgery on dentine. This cadaveric study investigated the integrity of root apices after root-end cavity preparation by piezoelectric instruments at different device settings. **Methods:** Fifty maxillary anterior teeth underwent endodontic treatment and apical resection *in situ*. Ten teeth were used as control. Retrograde cavities were prepared in 40 teeth (10 per group). In three groups, the piezoelectric device was set at constant vibration mode (CV), and three power levels were used. In another experimental group (n = 10), vibration + pulsation mode (VP) was selected, and low power was used. Each root was duplicated and analyzed by scanning electron microscopy for the presence of cracks and marginal chipping. **Results:** The number of cracks was significantly higher in the VP group, whereas no significant difference was found among CV groups. No difference between groups was found for crack type. The VP group showed a significantly poorer quality of cavity margin respect to the CV groups. **Conclusion:** Constant vibration mode is recommended for retrograde preparation with piezosurgery. *(J Endod 2010;36:1693–1697)*

Key Words

Apical surgery, piezosurgery, quality of cavity margin, root-end fracture, root-end surface, scanning electron microscopic analysis

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The outcome of endodontic surgery for the treatment of periapical lesions depends on a myriad of factors. The introduction of ultrasonic retrotips in endodontic surgery carried many advantages over the traditional hand pieces. The tooth long axis can be followed preserving the canal morphology (1); apical cavities may be shaped easily, safely, and with greater precision respect to those obtained using conventional hand pieces (2–3). The cutting bevel on the resected root end can be perpendicular to the canal long axis. This decreases the number of exposed dentinal tubules at the resected root surface, minimizing apical leakage (4). A better-shaped root-end cavity, more central and smaller than that produced by micro–hand pieces and burs, may reduce the risk of root perforation in deeply fluted roots (5). Despite the excellent results obtained with ultrasonic tips, some drawbacks have been associated with this technique (6). Dentinal cracks on the resected root end were shown after retrograde preparation with ultrasonic tips (1, 7–22). All these studies showed limitations because the transfer of results obtained with extracted teeth to the clinical practice is difficult. Some cadaveric studies (3, 23–25) were performed in order to overcome such a problem. The recent introduction of piezoelectric instruments vibrating in the ultrasonic frequency range represents an important issue in oral surgery (26, 27). Bone-tissue management and root-end cavity preparation can be performed with piezosurgery reducing the risk of damage to soft tissues. This study investigated root-end morphology after retrograde cavity preparation performed with a piezoelectric device at different power settings and working modes.

Material and Methods

Sixty monoradicular teeth deriving from 20 fresh human cadavers were eligible. The subjects had donated their body for research purpose. The age range was 47 to 87 (mean, 56) years with equal sex distribution. The study obtained ethical approval from the Department of Anatomy, Faculty of Medicine René Descartes, University of Paris 5, Paris, France.

Teeth were excluded in the presence of restoration, root filling, tooth cracking, or root fracture assessed by transillumination and radiographs. According to these criteria, 52 teeth (incisors and canines from 15 maxillae) were selected. All procedures were performed with teeth *in situ*. The pulp chamber was accessed. Proximal radiographs were taken with the endodontic file *in situ* to assess canal straightness and the working length and to exclude canals with unusual anatomy and immature apex. Two teeth were excluded because of their unusual anatomy. Fifty root canals were cleaned and shaped using a crown-down technique. The prepared working width was #25 for each canal. Canals were filled by vertical compaction of gutta-percha points.

Operative Procedure

After flap elevation, access to the root apex was made through the cortical bone using a round bur. Roots were apically resected orthogonally to their longitudinal axis, 3 mm from the apex, using a tungsten-carbide straight fissure bur (Maillefer Zerkya; Dentsply-Maillefer Instruments, Ballaigues, Switzerland) under constant water irrigation. The presence of cracks was assessed under stereomicroscope at 25× to 30× magnification using methylene blue dye as a marker. The 50 teeth were randomly

TABLE 1. Results of the Scanning Electron Microscopic Evaluation

Group	Control	CV–8 W	CV–4 W	CV–2 W	VP–8 W	Total
N° cracks per sample						
A: 0	10	4	7	6	3	30
B: 1-3	0	6	3	4	4	17
C: 4-6	0	0	0	0	2	2
D: ≥7	0	0	0	0	1	1
Cracks type						
Intradentinal	0	5	3	3	4	15
Incomplete	0	1	0	1	2	4
Complete	0	0	0	0	1	1
Quality of cavity						
Score 0	0	5	6	8	2	21
Score 1	0	4	3	1	5	13
Score 2	0	1	0	1	2	4
Score 3	0	0	1	0	1	2

CV, constant vibration; W, watts.

assigned to five groups (10 teeth/group): one control group (CG) and four treatment groups.

For three groups, the piezoelectric device (Piezon Master Surgery; EMS, Nyon, Switzerland) was set at the "standard" working mode (power range 2-8 W, constant vibration [CV], and 36-μm tip oscillation amplitude). Each group used a different power level (2 W, 4 W, and 8 W). In the fourth group, the "surgery" mode was used (power range 8-20 W, vibration + pulsation [VP], and 36/72-μm tip oscillation amplitude), setting the lowest power value. The frequency range was 25 to 32 kHz in all groups.

In the experimental groups, a 3 mm-deep root-end preparation was made using water irrigation to avoid overheating. The time required to prepare the root-end cavities was recorded. Brand new tips were used each time. A single operator (ST), with over 10 years of experience in endodontic surgery, performed all operations. Root ends were washed three times for 10 seconds with 17% EDTA solution buffered at a pH of 7.5 (Ogna, Milan, Italy) to remove the smear layer.

Parameter Evaluation

Impression of the resected root surface was obtained with polyvinylsiloxane (Exaflex; GC Corporation, Tokio, Japan) and mounted on an individual stub. The scanning electron microscopic evaluation was performed with a Zeiss Evo 50-EP (Carl-Zeiss, Oberkochen, Germany). For minimizing artifacts, sputtering was avoided. Specimens were coded for blind evaluation, photographed at 25× to 35×, and independently scored by two examiners. Any disagreement was resolved jointly by re-evaluating the sample under higher magnification (70-500×) until a consensus was reached.

The number of cracks per tooth was scored as follows: (1) no visible cracks, (2) one to three cracks, (3) four to six cracks, and (4) greater than or equal to seven cracks. The crack type was classified as complete, incomplete, or intradentinal (11). The quality of the root-end cavity margin was scored according to the degree of defects (25) as follows: (0) ideal preparation: no detectable defects; (1) imprint: a single visible defect, likely produced by the contact between the angulated portion of the tip and the cavity margin; (2) microchipped, ragged margin; and (3) chipped, ragged margin plus defects likely caused by the tips bouncing off the root face.

Statistical Analysis

A Fisher exact test and Pearson chi-square were used to compare the effects of treatment between groups. Analysis of variance and an unpaired Student t test were used to compare preparation times; p = 0.05 was considered as the significance level.

Results

Table 1 summarizes the results of the scanning electron microscopic evaluation.

Root Face Cracks Number

No crack was observed in the control group. Samples with greater than or equal to four cracks were observed only in the VP group. No significant difference could be found among the CV groups regarding the cracks incidence, whereas it was significantly higher in the VP group respect to other groups (Table 2).

Cracks Type

Figure 1*A* shows an incomplete dentinal crack. Only one specimen showed a complete canal crack (Fig. 1*B*). Incomplete and intradentinal cracks were detected in all groups (Fig. 1*C*). No significant difference between groups was outlined for crack type (Table 2).

Marginal Quality of Retrograde Cavity

A preparation without marginal defects is shown in Figure 1*E*. Figure 1*F* shows a single defect (score 1). In the VP group, two samples scored 2 and another one (Fig. 1*A*) scored 3. The samples of the VP group showed a significantly poorer quality of cavity margin with respect to those of the CV groups (Table 2). Few cases required a high magnification for making a decision on scoring (Fig. 1*D*, *G*, and *H*).

TABLE 2. Results of the Comparisons between Groups (p Values)

Comparisons	N° cracks	Crack type	Quality of cavity
CV–8 W vs CV–4 W	0.15	0.53	0.09
CV–8 W vs CV–2 W	0.24	0.53	0.07
CV–4 W vs CV–2 W	0.32	1	0.07
CV–8 W vs VP–8 W	0.04*	0.22	0.04*
CV–4 W vs VP–8 W	0.02*	0.32	0.02*
CV–2 W vs VP–8 W	0.03*	0.32	0.004*

CV, constant vibration; W, watts.

*Significant difference (Fisher test).

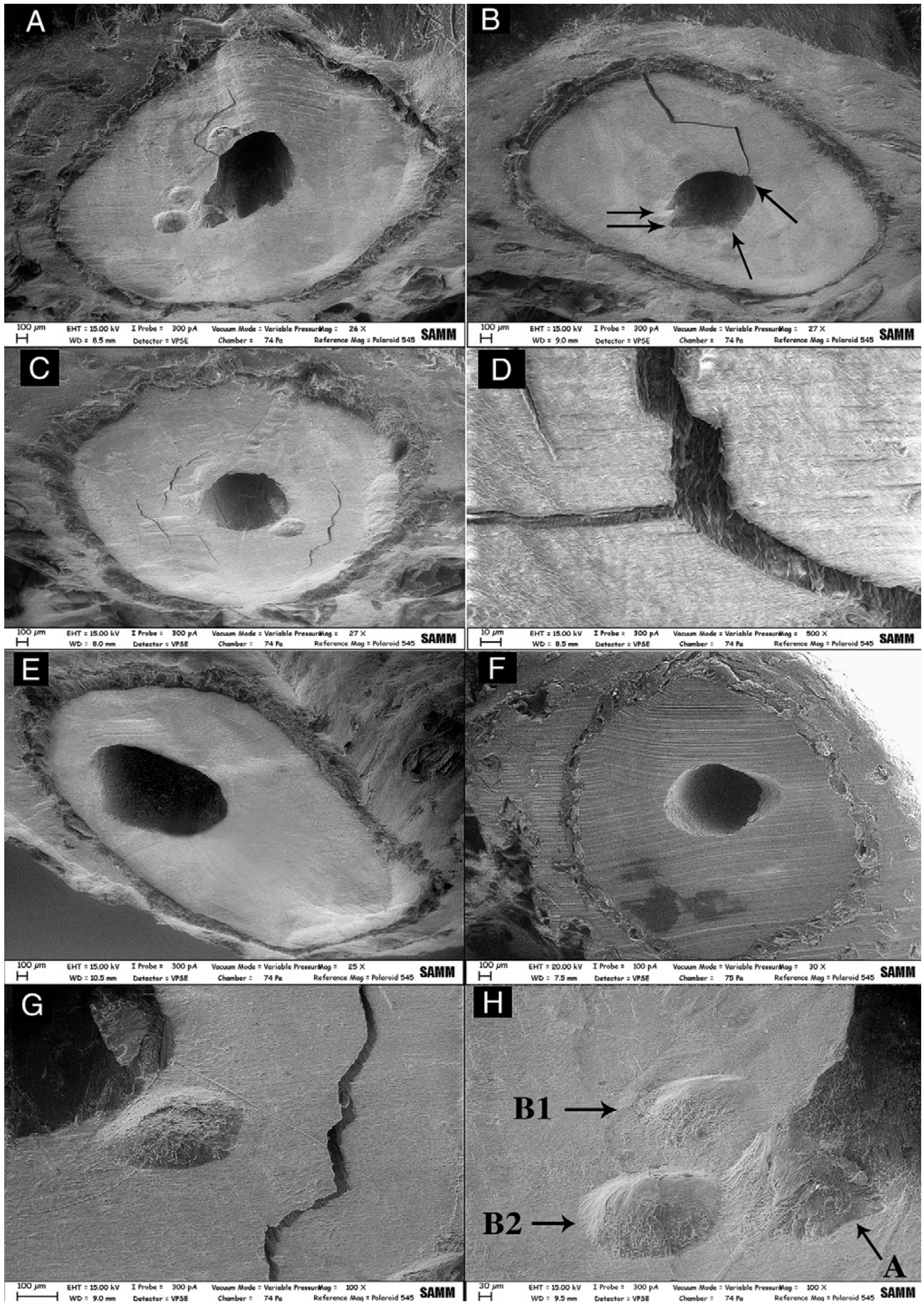

Figure 1. (*A*) An example of a root end with an incomplete canal crack and with chipping score 3. The sample belonged to the VP group. (*B*) An example of a root end with a complete canal crack and with a chipping score of 2 (pointed out with arrows). The sample belonged to the VP group. (*C*) An example of a root end with multiple intradentinal cracks belonging to the VP group. A chipping was also visible. (*D*) Magnification at 500× that emphasized the presence of dentinal cracks. (*E*) An example of a root end showing a chipping score of 0. (*F*) An example of a root end showing a chipping score of 1 (imprint); a single marginal defect is visible, likely produced by the contact between the angulated portion of the tip and the cavity margin. (*G*) Magnification at 100× of Figure 1*c* that showed the presence of a dentinal cracks and identified the presence of a defect because of the tips bouncing off the root face near the marginal cavity that could be confounded with an imprint defect. The picture showed the integrity of the marginal quality, and the shape of the defect was a round one, which was different than the oblong one that characterized the imprint defect. (*H*) Magnification at 100× of the specimen shown in Figure 1*a* showing an (*A*) imprint plus (*B1* and *B2*) some defects.

Time Required to Prepare Root-end Cavity

The mean time required for retrograde cavity preparation was not different among groups (overall range, 1.6-3.1 minutes; mean, 2.1 minutes). No correlation with time was found for any parameter evaluated. The group CV-2 W displayed a slower (but not significantly slower) preparation (2.6 min) than the other groups. In the samples with chipped and ragged margins, the preparation time was about 30 seconds higher than the average. However, because of the small number of cases, no correlation was attempted with preparation time.

Discussion

Endodontic surgery outcomes improved in the recent years because of the adoption of microsurgical instruments, which permit a better management of the root end (28, 29). It is unknown if root-end alterations induced by retro tips affect the clinical outcome, yet, any approach for minimizing adverse effects like cracks should be considered. The introduction of piezoelectric devices using various tip vibration patterns prompted the present investigation.

Number of Root Face Cracks

Some features of the studies based on extracted teeth such as the stress exerted during extraction, the risk of inappropriate teeth storage, or handling may predispose to dentine alterations (30). In the present study, teeth were not extracted, overcoming the previously described problems (25). The preservation of the periodontal ligament, a dampening and shock-absorbing structure that may limit cracks propagation during instrumentation, is another advantageous feature of the present study. Cracks in extracted teeth may occur also because of dehydration (5). The latter may alter the mechanical properties of the dentine, making it more prone to developing cracks respect to hydrated dentine (31). Progressive dehydration may also occur post mortem, possibly increasing the risk of crack propagation (32, 33). In the present study, only fresh cadavers were used, minimizing such risk. Furthermore, as previously advocated (1, 23–25) replicas of the root-end for scanning electron microscopic analysis were used to prevent drying artifacts caused by the gold sputtering procedure. Finally, dentine cracks were never detected in the control group, suggesting that the main cause for cracks was the retrograde preparation. The incidence of cracks in the CV groups was independent of the power level. Few studies have investigated the effect of changing the power level on root-end alterations using ultrasonic retrotips, reporting controversial results (1, 10, 12, 24).

Types of Cracks

Few studies examined the different types of cracks produced after root-end preparation with ultrasonic retrotips. Rainwater et al (15) compared a stainless steel and a diamond retrotip setting the ultrasonic device at low power and found no significant difference for both the number and type of cracks (15). Beling et al, using a stainless-steel retro-tip and setting the ultrasonic device at low power, found intradentinal and incomplete but not complete cracks after root-end preparation (11). In the present study, the absence of difference between groups regarding crack type could be caused by the few cracks observed.

Marginal Quality of the Retrograde Cavity

The power setting of the piezoelectric device did not affect the cavity margin quality, which was similar to other studies (1, 9–10, 25). The poorer quality observed in the VP group can be ascribed to the vibration modality to which pulsation is added.

Preparation Time

A correlation between the cracks incidence and the time for root-end preparation was previously reported (16). Conversely, in the present study, no such correlation was observed. Possibly the longer the preparation time the higher the chance of producing cracks and chipped margins as previously suggested (34). However, the literature evidence about this subject is scarce.

Differences between ultrasonic devices, retro-tips, and experimental design could prevent an accurate comparison of different studies (35). Further studies are needed to clarify the cause and the consequence of the different type of fractures, especially considering that the complete fracture is a pathway between the root canal system and the periodontal environment.

The present study showed that when the piezoelectric tip oscillates with constant vibration the power level does not affect the incidence or type of dentine cracks and the margin quality is fairly regular. Conversely, a significantly greater alteration of root end and a qualitatively worse cavity margin were observed when pulsation is added. The latter working mode is more aggressive and is suitable for cutting bone tissue. Yet, based on the present findings, its use is discouraged for retrograde cavity preparation because it increases the risk of dentine alteration.

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