Efficacy of Sonic and Ultrasonic Activation for Removal of Calcium Hydroxide from Mesial Canals of Mandibular Molars: A Microtomographic Study

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Abstract

Background: The purpose of this study was to use micro–computed tomography (micro-CT) scanning to evaluate the efficacy of sonic and passive ultrasonic irrigation (PUI) on calcium hydroxide ($Ca[OH]_2$) removal and to measure the volume and percentage of $Ca(OH)_2$ remaining in the root canal system. **Methodology:** The root canals of 46 extracted human mandibular molar teeth were prepared with rotary instruments and randomly assigned to two experimental groups (n = 40) as well as positive and negative controls (n = 6). In each experimental group, 20 teeth were assigned to each irrigation protocol, sonic or passive ultrasonic irrigation. All experimental teeth and the positive controls were filled with $Ca(OH)_2$, whereas the negative control teeth did not receive $Ca(OH)_2$. All teeth were scanned using micro-CT scanning to determine the dressing volume. After 7 days, the $Ca(OH)_2$ was removed in the experimental groups using rotary instrumentation only, and the teeth were again scanned using micro-CT scanning to calculate volume and percentage of $Ca(OH)_2$ removed. Positive control teeth were not subjected to rotary instrumentation. Experimental samples were then irrigated using either sonic or passive ultrasonic and the volume of remaining $Ca(OH)_2$ was calculated using micro-CT. **Results:** Remnants of $Ca(OH)_2$ were found in all experimental groups. No $Ca(OH)_2$ was found in the negative controls, whereas a mean of 8.7 mm^3 of $Ca(OH)_2$ was recorded in the positive controls. Rotary plus passive ultrasonic irrigation removed significantly more $Ca(OH)_2$ (85.7%) than rotary plus sonic irrigation (71.5%) ($p < 0.001$). **Conclusions:** The combination of rotary instrumentation and passive ultrasonic activation for 3 periods of 20 seconds results in significantly lower amounts of $Ca(OH)_2$ remnants in the canal compared with sonic irrigation. *(J Endod 2011;37:235–238)*

Key Words

Calcium hydroxide, endo-activator, passive ultrasonic irrigation, removal, sonic irrigation

Chemomechanical debridement and root canal disinfection remains the most critical factor related to the outcome of endodontic therapy. Although mechanical instrumentation procedures have improved considerably over the years, none of the existing techniques can completely disinfect the root canal system (1, 2). Thus, chemical disinfection with sodium hypochlorite is still required because of its antimicrobial spectrum as well as its unique capacity to dissolve necrotic tissue remnants (3–5). In addition, the use of calcium hydroxide ($Ca[OH]_2$) as an intracanal medication has also been recommended, particularly for teeth with apical periodontitis (6). The combination of its antimicrobial potential (7), tissue dissolution (8), and degradation of lipopolysaccharide (9) have all made it the intracanal medication of choice.

Some concerns have been raised related to the use of $Ca(OH)_2$ as an intracanal medicament. In 1999, Waltimo et al (10) were the first to report microbial resistance to calcium hydroxide. One year later, Dahlen et al (11) identified enterococcal species in 29 endodontic infections undergoing treatment with $Ca(OH)_2$ dressings. In addition to this microbiological limitation, the effect of residual calcium hydroxide in the canal system influences dentine bond strength (12) as well as penetration of sealers into dentinal tubules (13). Kim and Kim (14) also found that residual $Ca(OH)_2$ may increase apical leakage after obturation when zinc oxide–eugenol sealer is used. The remnants could also react chemically with the sealer and affect the hermetic seal of the permanent root canal filling (15). Therefore, the complete and predictable removal of $Ca(OH)_2$ dressing before the root canal filling is critical and could be directly related to the outcome of treatment (16).

The removal of $Ca(OH)_2$ has been investigated using a range of products and techniques (16–20). The most frequently described method is instrumentation of the root canal using a master apical file and copious irrigation (17). Nevertheless, canal irregularities may be inaccessible for conventional irrigation procedures, and $Ca(OH)_2$ may remain in these extensions (19). Sonic-activated devices such as the EndoActivator (Dentsply Tulsa Dental, Tulsa, OK) were recently introduced to improve the irrigation phase. Its design allows for the safe activation of intracanal solutions and could produce vigorous intracanal fluid agitation (21). The EndoActivator system has been shown to better irrigate simulated lateral canals at 4.5 and 2 mm from the working length (WL) as compared with traditional needle irrigation alone (22). Passive ultrasonic irrigation (PUI) was first described by Weller et al (23). During PUI, a small file is placed at

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the center of a previously shaped root canal and activated to produce acoustic streaming (24). This streaming creates small, intense, circular fluid movement around the instrument. The eddying occurs closer to the tip than in the coronal end of the file, with an apically directed flow at the tip (25). Because the root canal is already enlarged, the file can vibrate freely in a way to enable acoustic streaming, transferring its energy to the irrigant inside the canal.

Overall, passive ultrasonic irrigation was shown to be more effective in dentine debris removal from the root canal walls than delivery of the irrigant by positive pressure (26, 27). These results were in agreement with the results reported by Kenee et al (18) and van der Sluis et al (19) in which passive ultrasonic irrigation was more effective in removing $Ca(OH)_2$ paste than syringe delivery. To date, no study has measured the volume and percentage of $Ca(OH)_2$ remaining in the canal system when comparing passive ultrasonic and sonic irrigation. Hence, the purpose of this study was to use micro–computed tomography scanning to compare the efficacy of sonic versus passive ultrasonic irrigation on $Ca(OH)_2$ removal and to measure the volume and percentage of $Ca(OH)_2$ remaining in the root canal system.

Material and Methods

Forty-six extracted human mandibular molars with mature apices and a curvature between 20° and 30° were used in this study. After extraction, the teeth were stored in 6% sodium hypochlorite (NaOCl) at room temperature. Forty specimens were randomly assigned to 2 experimental groups according to the $Ca(OH)_2$ removal technique: sonic (n = 20) and PUI (n = 20). The remaining 6 teeth served as negative (n = 3) and positive controls (n = 3).

Specimen Preparation

Each sample had a root canal curvature between 20° and 30° as determined using a modified Schneider technique (28). Each sample was decoronated at the cementoenamel junction, and the distal canal was amputated and sealed. Radiographic images from the buccal and proximal aspects of each sample were exposed and used to confirm the root canal morphology (type II or III). Root canal morphology was equally distributed among experimental groups, with type II morphology being more prominent in both groups. Standard access preparation was accomplished using high-speed carbide burs with water spray. A size 10 Flex-O file (Maillefer, Ballaigues, Switzerland) was placed into the canal until it was visible at the apical foramen. The WL was established 1 mm short of this length. In order to resemble the clinical situation, a closed system was then created by sealing the apical foramen with soft modeling wax. Samples were then mounted on a tabletop vice grip device.

Root Canal Preparation

The canal space was shaped with nickel-titanium rotary instruments (GT Series X; Tulsa Dental Products, Tulsa, OK) to a size/taper 40/.04 at WL. Between the instruments, each canal was irrigated with 5 mL 6% NaOCl and 5 mL 14% EDTA using a 30-G side-vented needle (ProRinse, Dentsply Tulsa) positioned 2 mm short of the WL. Apical patency was confirmed with a size 10 K-file between each instrument.

Both mesial buccal and mesial lingual canals were dried with paper points (Hygienic; Coltene-Whaledent Inc, Cuyahoga Falls, OH). UltraCal XS (Optident Ltd, International Develop Centre, West Yorkshire, UK) $Ca(OH)_2$ was placed into mesial buccal and mesial lingual canals 2 mm short of the WL (29, 30). The access cavities were temporarily sealed with a cotton pellet and a 3-mm depth Cavit restoration (3M ESPE, St Paul, MN). The roots were then placed in a sponge saturated with natural water and incubated in 100% relative humidity at 37°C for 7 days.

Micro-computed Tomography Imaging

Teeth were placed in a styrofoam holder loaded with a silicone-based impression material (Aquasil Ultra; Dentsply International, New York, NY) that allowed precise placement in the scanning unit without interfering with the scanning process. The scanning procedure was completed using 100 kV (10 W, 100 μA), a 1-mm-thick aluminum filter, a 320-millisecond exposure time and 0.50° rotation step, and an isotropic voxel size of 35 μm. A total of 126 scans were performed (40 preliminary scans, 40 post-rotary scans, 40 post-irrigation scans, and 6 control scans). The acquired raw scan data were then reconstructed into a three-dimensional dataset using NRecon software (V1.6.1.0; SkyScan, Brussels, Belgium).

Instrumentation with Rotary Alone

After the initial scan was completed, all specimens were accessed and instrumented with a 40/.04 GT Series X file (Tulsa Dental Products, Tulsa, OK), and the specimens again subjected to micro–computed tomography scanning.

Irrigation Protocol

All canals were irrigated following a standardized protocol that included three irrigants: 17 mL 6% NaOCl, 3 mL 14% EDTA and 3 mL 6% NaOCl, each using a 30-G endodontic needle at 2 mm from the WL. The volume and time were standardized for both experimental groups. Irrigation was delivered at a flow rate of 3 mL/min, and that ratio was carefully monitored and recorded in each sample.

For the sonic group 1 (group 1, n = 20), sonic activation was delivered for 20 seconds between each irrigant using the EndoActivator (Advanced Endodontics, Santa Barbara, CA) set at 10,000 cycles per minute and a 15/.02 tip. The total activation time was 60 seconds.

For the passive ultrasonic group (group 2, n = 20), ultrasonic activation was delivered for 20 seconds between each irrigant using a stainless steel ultrasonic file 15/.02 (Irri-Safe Satelec; Acteon Group, Merignac, France) mounted on a Suprasson P5 Booster ultrasonic unit (Satelec, Acteon Group) with the power setting at 10. The total activation time was 60 seconds.

For both groups, the respective device was inserted and activated at 2 mm from the WL. The specimens were then scanned again using micro–computed tomography scanning CT as previously described.

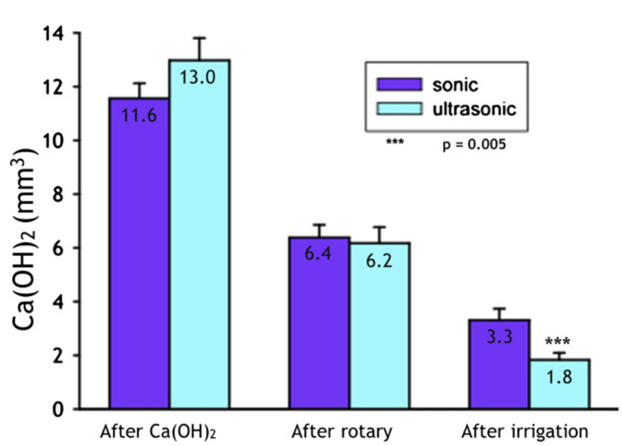

Figure 1. The volume of the $Ca(OH)_2$ dressing (mm^3) after placement and remaining after the rotary and irrigation protocols.

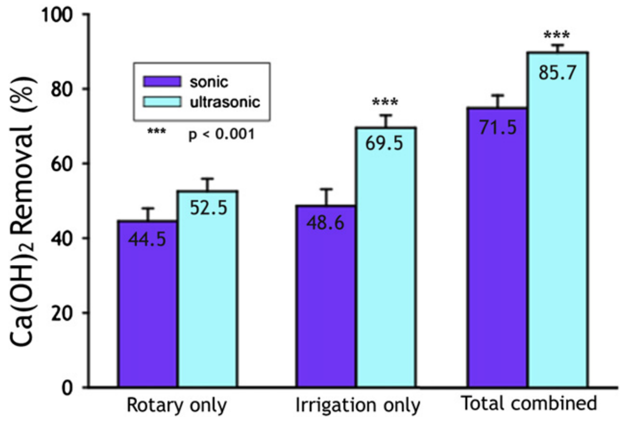

Figure 2. The percentage of $Ca(OH)_2$ removed after rotary only, activation only, and both combined.

Negative controls included three teeth in which no $Ca(OH)_2$ was placed to ensure that analysis of clean canals did not yield false-positives of remaining debris. Positive controls included three teeth that received $Ca(OH)_2$ without subsequent removal to ensure that $Ca(OH)_2$ was uniformly present throughout the length of the canals and that the amount initially placed was significantly different from any amounts remaining after removal attempts (18).

Outcome Assessment

The calculation of $Ca(OH)_2$ volume in each specimen was performed using CTan software (SkyScan). Each dataset was also segmented using a uniform grayscale threshold (CTan software) to visualize and quantify the volume of residual $Ca(OH)_2$ material. Volumes of $Ca(OH)_2$ were expressed as mm^3. The volume of $Ca(OH)_2$-coated surface for each canal, rotary step (enlargement to size 40/.04), and irrigation step (sonic or ultrasonic) was also determined. The remaining $Ca(OH)_2$ was also visualized using volume exploration software (Drishti V2; Australian National University, Canberra, Australia).

Analysis

A *t* test was used to compare the sonic versus ultrasonic groups using SigmaStat 3.5 software (SigmaStat, Berkeley, CA). Differences in volume after instrumentation and after irrigation were calculated as a total volume and a percent of the preinstrumentation total $Ca(OH)_2$ volume.

Results

A mean of 8.7 mm^3 of $Ca(OH)_2$ was recorded in the positive control samples, whereas no $Ca(OH)_2$ was found in the negative controls. Complete removal of $Ca(OH)_2$ from the canal walls of experimental groups was not obtained under the conditions tested, leaving a mean of 3.3 mm^3 of $Ca(OH)_2$ in the sonic group and 1.8 mm^3 in the ultrasonic group (Fig. 1). There was no significant difference in the percentage $Ca(OH)_2$ removed using rotary alone for either group. Statistically significant differences were found among the experimental groups in relation to $Ca(OH)_2$ removal.

Ultrasonic activation removed significantly more $Ca(OH)_2$ (69.5%) than sonic activation (48.6%). Ultrasonic activation combined with rotary instrumentation removed significantly more $Ca(OH)_2$ (85.7%) than sonic combined with rotary instrumentation (71.5%) ($p < 0.001$) (Fig. 2). The percent removed by irrigation alone was the amount of $Ca(OH)_2$ remaining after rotary; hence, the percentages removed by rotary and irrigation do not add up to the total percent removed. The segmented datasets used for subsequent visualization using the volume exploration software Drishti V2 shows a typical example of the remaining $Ca(OH)_2$ in each experimental group (Fig. 3).

Discussion

The effect of ultrasonic agitation of the irrigants has been evaluated with contradictory results (19). PUI is based on the transmission of

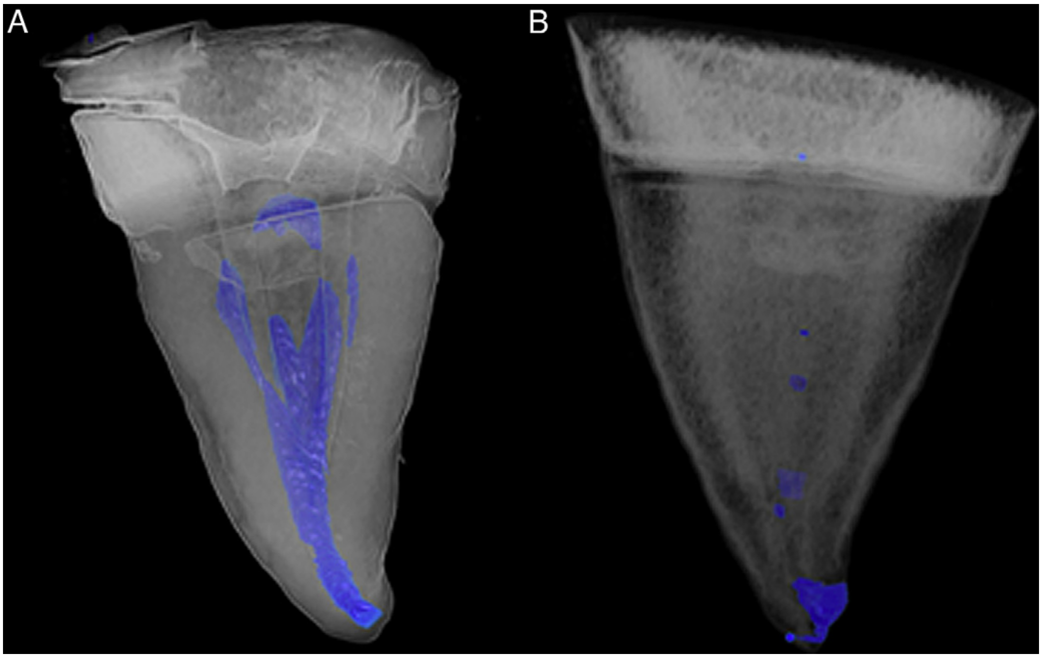

Figure 3. Rendered images showing $Ca(OH)_2$ remaining after rotary plus either (*A*) sonic or (*B*) ultrasonic activation. The blue color represents $Ca(OH)_2$ material. Segmented datasets were rendered using the Drishti volume exploration software.

energy from an ultrasonically oscillating instrument to the irrigant inside the root canal (19). It has been shown that an irrigant solution in conjunction with ultrasonic vibration was directly associated with the removal of organic and inorganic debris from the root canal walls (18, 19). Thus, considering that the effectiveness of irrigation could depend on both the mechanical flushing action and the chemical ability to dissolve tissue (8, 24), in the present study an attempt was made to ensure a similar amount of the irrigant solution during sonic and ultrasonic irrigation techniques.

In this study, the complete removal of $Ca(OH)_2$ from the canal walls was not obtained under the conditions tested, and remnants of $Ca(OH)_2$ were found in all experimental groups regardless of the removal technique (Fig. 3). This result is similar to the findings of previous studies, which showed considerable amounts of $Ca(OH)_2$ lingering on the canal walls, notwithstanding the removal technique used (16–19, 31). Rotary plus passive ultrasonic irrigation removed significantly more $Ca(OH)_2$ (85.7%) than rotary plus sonic irrigation (71.5%) ($p < 0.001$) (Fig. 2). The higher velocity and volume of irrigant flow created by passive ultrasonic irrigation (32) may explain its efficiency in flushing out loose $Ca(OH)_2$ from root canals (19). However, some consideration must be made for the fact that the teeth used in this study were decoronated, which may eliminate any coronal reservoir for the irrigation solution. When activating the intracanal solution using ultrasonic irrigation, a considerable amount of solution may be lost coronally, decreasing the hydrostatic pressure toward the apex.

Conclusion

Within the limitations of this study, neither sonic nor ultrasonic were able to completely remove calcium hydroxide from the root canal system of mesial roots of mandibular molars. The combination of rotary instrumentation and passive ultrasonic activation for 3 periods of 20 seconds each results in significantly lower amounts of $Ca(OH)_2$ remnants in the canal compared with sonic irrigation.

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