Efficacy of 3 Different Irrigation Systems on Removal of Calcium Hydroxide from the Root Canal: A Scanning Electron Microscopic Study

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Abstract

Introduction: The purpose of this study was to evaluate the effectiveness of different irrigation systems on removing calcium hydroxide ($\text{Ca(OH)}_2$) from the root canal by using a scanning electron microscope. Methods: Forty extracted single-rooted teeth were divided randomly into 4 groups. Canal instrumentation was done, and the teeth were filled with Ca(OH)$_2$ paste. One week later, 4 techniques were used for Ca(OH)$_2$ removal. The first group, the canals were cleaned with a master apical file. The second, third, and fourth groups were irrigated using the EndoVac (Discus Dental, Culver City, CA), EndoActivator (Dentsply Tulsa Dental Specialties, Tulsa, OK), and ProUltra (Dentsply Tulsa, Tulsa, OK) systems, respectively. All the groups were irrigated with 3 mL (18%) EDTA and 3 mL (1%) NaOCl for 1 minute. The canal walls were viewed, and the remaining amount of Ca(OH)$_2$ was evaluated using a scanning electron microscope. A scoring system was used to assess the amount of residue Ca(OH)$_2$ on each third of the canal. The obtained data for comparisons between the conventional irrigation needle and each device were statistically analyzed using the Mann-Whitney $U$ test. Results: To compare the 4 devices, the results were statistically analyzed using the analysis of variance test. Conclusions: None of the investigated techniques removed the Ca(OH)$_2$ dressing completely. However, the EndoActivator System showed better results in removing Ca(OH)$_2$ in each third of the root canals in comparison with the other techniques. (J Endod 2015;41:97–101)

Key Words
Calcium hydroxide, EndoActivator System, EndoVac, irrigation, ProUltra

The reduction or elimination of microorganisms is considered 1 of the main goals of endodontic therapy (1). However, among the available instrumentation techniques, none achieve a completely cleaned root canal system (2).

Therefore, the use of intracanal medicaments has been advocated in order to enhance the disinfection process (3–5). The most commonly used intracanal medicament is calcium hydroxide ($\text{Ca(OH)}_2$) because of its antibacterial efficacy against the majority of endodontic pathogens (6) and its biocompatibility (7).

However, the Ca(OH)$_2$ medicament has to be removed before the root filling (8). It has been reported that residual Ca(OH)$_2$ on the root canal walls may increase apical leakage of gutta-percha root fillings when a zinc oxide–eugenol sealer is used (9). In addition, such a remnant changes the physical properties of some sealers, reducing the flow and setting time (10) and preventing the penetration of sealers into dentinal tubules (11). Therefore, complete removal of the intracanal dressing before root filling is important to avoid a negative influence between the root filling materials and remnants of the Ca(OH)$_2$ dressing (8).

Mechanical instrumentation with a master apical file (MAF) and copious irrigation with sodium hypochlorite (NaOCl) and EDTA is the most frequently described method for the removal of Ca(OH)$_2$ from the root canal (12, 13). However, several methods have been proposed over the years (eg, using rotary nickel-titanium instruments [14], using a patency file [15], and using different devices for the activation of an intracanal solution to improve the mechanical flushing action of the irrigant [16]). It has been reported that NaOCl solely and in combination with EDTA effectively removed all or most of Ca(OH)$_2$ (15, 17). The mechanical agitation provided by ultrasonic/sonic instrumentation or a rotary file together with irrigation might also enhance the removal of Ca(OH)$_2$. However, there is no general consensus regarding which is the best method for the removal of Ca(OH)$_2$.

The EndoActivator System (Dentsply Tulsa Dental Specialties, Tulsa, OK) was introduced as a new modality to improve the irrigation procedure. It is a sonic device that comprises a portable handpiece and 3 types of disposable flexible polymer tips of different sizes that do not cut root dentin. The design of the EndoActivator System allows activation of various intracanal agents and could produce vigorous intracanal fluid agitation (18). The EndoActivator System in conjunction with demineralizing agents like EDTA was reported to remove the smear layer and dislodged lumps of simulated biofilm within curved canals of molar teeth (19).

The ProUltra PiezoFlow ultrasonic irrigation needle (Dentsply Tulsa, Tulsa, OK) has been shown to be an effective tool for improved root canal irrigation (20). An ultrasonic unit is used in conjunction with these needles to provide the energy for tip oscillation. In contrast to other ultrasonic irrigation systems, the PiezoFlow irrigation needle is connected to an irrigation syringe to provide constant fresh irrigant into the canal system. According to the manufacturer, it was reported that continuous ultrasonic irrigation facilitates the introduction of irrigants into the root canal system, removes debris from isthmuses, provides better debridement of the root canal, and promotes the disruption of biofilms.

The EndoVac system (Discus Dental, Culver City, CA) uses a suction needle placed at the working length (WL). With negative pressure, the irrigant flows down from the pulp chamber into the canal to the apical areas (21). A study showed that EndoVac
irrigation resulted in significantly less debris at 1 mm from the WL (22, 23). This system has the advantage of less frequency of extrusion of irrigants compared with needle irrigation and superior results in removing the smear layer when compared with passive irrigation and passive ultrasonic irrigation (24, 25).

The aim of this scanning electron microscopic study was to evaluate the effectiveness of the different irrigation systems (EndoActivator, ProUltra PiezoFlow, and EndoVac) in removing Ca(OH)₂ from the root canal in combination with EDTA. The null hypothesis was that there is no difference in Ca(OH)₂ removal between different irrigation systems and a standard instrumentation technique.

Materials and Methods

Preparation of Specimens

Seventy single-canal human teeth extracted for periodontal reasons were used. Teeth were immersed for 48 hours in 3.0 % NaOCl to remove organic debris. Subsequently, the external root surfaces were scaled with ultrasonic instruments, washed with distilled water for the removal of any calculus or soft tissue from the root surface (14), and stored in 0.5 % chlorhexidine (Fresenius Kabi, Uppsala, Sweden).

Criteria for tooth selection included 1 single root canal; no visible root caries, fractures, or cracks; and a completely formed apex on visual examination. Moreover, the only included canals were the ones that had the first file size #K-20 (Dentsply Maillefer, Ballaigues, Switzerland) to bind to its apex. Both mesiodistal and buccolingual preoperative radiographs were obtained for each root to confirm the canal anatomy.

The specimens were decoronated to obtain a standardized root length of 15 mm by using a diamond disk. The teeth were randomly coded and blindly allocated into 4 experimental groups (A–D) (n = 5) positive controls received intracanal dressing but without subse-

Root Canal Instrumentation

The patency of the canals was verified by passing a file size #K-15 (Dentsply Maillefer) through the apical foramina. The WL was deter-
ned 1 mm short of the length where the file extruded the apical fo-
ramen. The root canals were prepared with the ProFile System (Dentsply Maillefer) in a crown-down sequence to MAF size 45/04.

The rotary files were used in a slow-speed, high-torque motor, with a continuous speed of 250 rpm (27). Between each rotary file, ca-
nals were conventionally irrigated with 1 mL 0.5 % NaOCl (Apoteksbolaget, Uppsala, Sweden) and rinsed with 1 mL 0.5 % NaOCl (Apoteksbolaget) followed by cleaning with the MAF (ProFile 45/04) to the WL. The canals were irrigated again with 1 mL 0.5 % NaOCl. After that, 3 mL 18 % EDTA (Ultradent Products) was introduced into the canals and agitated sonically with the EndoActivator device. Sequentially, the canals were first irrigated with 1 mL 0.5 % NaOCl (Apoteksbolaget) followed by cleaning with the MAF (ProFile 45/04) to the WL. The canals were irrigated again with 1 mL 0.5 % NaOCl and 3 mL 18 % EDTA for 60 seconds. A final rinse with 3 mL 0.5 % NaOCl ended the irrigation protocol.

Generally, when using conventional irrigation, the needle depth was standardized for each canal by placing the rubber stopper 1–2 mm short of the WL.

Group A: Conventional Irrigation (n = 15). The removal of Ca(OH)₂ was performed with conventional irrigation using a plastic syringe with a 30-G needle (Monoject endodontic needle). Sequentially, the canals were first irrigated with 1 mL 0.5 % NaOCl (Apoteksbolaget) followed by cleaning with the last file used in the instrumentation procedure (MAF = ProFile 45/04) to the WL. The canals were irrigated again with 1 mL 0.5 % NaOCl and 3 mL 18 % EDTA for 60 seconds. A final rinse with 3 mL 0.5 % NaOCl ended the irrigation protocol.

Group B: Sonic Irrigation (n = 15). The removal of Ca(OH)₂ was performed with sonic irrigation using the EndoActivator device. Sequentially, the canals were first irrigated with 1 mL 0.5 % NaOCl (Apoteksbolaget) followed by cleaning with the MAF (ProFile 45/04) to the WL. The canals were irrigated again with 1 mL 0.5 % NaOCl. After that, 3 mL 18 % EDTA (Ultradent Products) was introduced into the canals and agitated sonically with the EndoActivator device. Sequentially, a polymer tip #30/02 was used with a pumping motion for 60 seconds at 10,000 cycles per minute. A final rinse with 3 mL 0.5 % NaOCl ended the irrigation protocol.

Group C: Ultrasonic Continuous Irrigation (n = 15). The removal of Ca(OH)₂ was performed with the ultrasonic continuous irrigation using the ProUltra PiezoFlow ultrasonic irrigation needle. The needle was used in conjunction with a piezo-electric ultrasonic energy-generating unit (Satelec, P5 Newton; Acteon, Mergier Cedex, France) to provide the energy for tip oscillation. A syringe or other irrigation source was attached to the Luer lock connection on the ultrasonic needle. The removal of irrigant was performed through an operatory vacuum source. Sequentially, the canals were first irrigated with 1 mL 0.5 % NaOCl (Apoteksbolaget) followed by cleaning with the MAF (ProFile 45/04) to the WL. The canals were irrigated again with 1 mL 0.5 % NaOCl followed by a continuous irrigation flow with 3 mL 18 % EDTA that was maintained and agitated for 60 seconds using the ProUltra Piezo Flow device, whereas the high-volume suction was placed at the access opening to recover used irrigant. The ProUltra needle was inserted into the canals greater than 75 % of the WL as recommended by the manufacturer. The inactive needle was inserted into the canal to the premeasured depth, and the irrigation flow was started before activation of the suction mode. During activation, the needle was passively moved in an up-and-down motion to ensure it did not bind to the root canal wall. A final rinse with 3 mL 0.5 % NaOCl ended the irrigation protocol.

Group D: Negative Pressure Irrigation (n = 15). The removal of Ca(OH)₂ was performed under negative pressure irrigation using the EndoVac system. Sequentially, the canals were first irrigated with 1 mL 0.5 % NaOCl (Apoteksbolaget) using the macrocannula for 30 seconds. The macrocannula was positioned to the WL, and the canals were irrigated again with 1 mL 0.5 % NaOCl followed by 3 mL 18 % EDTA for 1 minute with the needle moving up and down. Finally, irrigation with 3 mL 0.5 % NaOCl using the microcannula for 1 minute was performed.

Scanning Electron Microscopic Evaluation

Grooves were first made along the buccal and lingual surfaces using a diamond disc (DT-126, PHP; Dentatus, Hagersten, Sweden). The teeth were split along their long axis in a buccolingual direction into 2
halves, and the separation was completed using a plastic instrument to prevent canal contamination. Apical, middle, and coronal thirds were established by marking the roots into 3 levels at 4, 8, and 12 mm from the root apex, respectively.

For scanning electron microscopic analysis, tooth halves were individually dehydrated, fixed on aluminum stubs (Silverpaint; Agar Scientific Ltd, Stansted, Essex, UK), sputter coated with a 20-nm platinum (Polaron Instruments Ltd, Hatfield, UK), and viewed with a scanning electron microscope (ULTRA 55; Carl Zeiss NTS GmbH, Oberkochen, Germany). To standardize the area examined for each sample (28), the central beam of the scanning electron microscope was directed to the center of each third of the root canal by the scanning electron microscope operator under 10× magnification; after which, the magnification was increased to 1000×, and the area of the canal wall captured on the screen of the scanning electron microscope was used for evaluating the remained amount of Ca(OH)2 on the canal wall.

Outcome: Evaluation of Cleanliness

The scoring procedure was performed by 2 calibrated and blinded evaluators who were trained in the evaluation procedure using the following 5-grade scale (18):

Score 1: 80%–100% removal of Ca(OH)2 (total cleanliness)
Score 2: 60%–80% removal of Ca(OH)2 (great cleanliness)
Score 3: 40%–60% removal of Ca(OH)2 (partial cleanliness)
Score 4: 20%–40% removal of Ca(OH)2 (light cleanliness)
Score 5: 0%–20% removal of Ca(OH)2 (no cleanliness)

Figure 1 shows representative scanning electron microscopic micrographs of evaluated scores from 1–5. In cases in which the scores of the 2 evaluators differed, scores from a third evaluator were used. The blinded code was subsequently broken, and each sample was assigned to its experimental group.

Statistical Methods

For comparisons between the conventional irrigation needle and each application device, the results were statistically analyzed using the Mann-Whitney U test at a significance level of P < .05. Comparing the 4 application devices with each other, the results were statistically analyzed using the analysis of variance test at a significance level of P < .001. The 4 groups had P values adjusted according to the Bonferroni procedure because of multiple testing. The original P values are multiplied by the number of comparisons (in this case 6).

Results

The result for trained evaluators showed a sufficient interobserver reproducibility. None of the groups showed complete removal of Ca(OH)2 dressing. The positive control teeth showed complete coverage of their canal walls with Ca(OH)2 as opposed to negative controls with total cleanliness. However, a statistically significant difference between the groups can be shown (P < .001) using the analysis of variance test.

Each device was compared with the conventional irrigation needle group. The EndoActivator group was significantly cleaner from Ca(OH)2 than the canals treated with only conventional irrigation in the coronal, middle, and apical parts (P < .001, P = .002, and P = .005), respectively. The EndoVac group was significantly cleaner from Ca(OH)2 than the canals in the conventional irrigation group when comparing the apical parts only (P = .017). The middle and coronal parts did not show any significant difference from the conventional irrigation needle group. No statistically significant difference can be seen between the conventional irrigation needle and the ProUltra Piezo Flow ultrasonic irrigation needle regarding the apical, middle, and coronal parts. Nonetheless, for the middle and coronal parts, there is an indicative difference (P = .053 and P = .065, respectively).

Taking each third individually, in the coronal third, the EndoActivator was significantly better in removing Ca(OH)2 than the EndoVac (P = .048). However, there is no significant difference in removing Ca(OH)2 between the EndoActivator and the ProUltra PiezoFlow ultrasonic irrigation needle. Although the EndoActivator did not show any significant difference from the conventional irrigation needle group in the coronal third, there is an indicative difference. Figure 2 shows the distribution of scores for all the devices in the coronal, middle, and apical thirds.

Moreover, the EndoActivator was significantly better in removing Ca(OH)2 in the middle third than the conventional irrigation needle.
(P = .02) and the EndoVac (P = .011). However, there is no significant difference in comparison with the ProUltra PiezoFlow ultrasonic irrigation needle.

In the apical third, the EndoActivator was significantly better in removing Ca(OH)\textsubscript{2} in comparison with all of the other devices (conventional irrigation needle, P < .001; ProUltra, P = .005; and EndoVac, P = .033).

**Discussion**

In the present scanning electron microscopic study, the main goal was to evaluate the effectiveness of conventional needle irrigation in comparison with the EndoVac, EndoActivator, and ProUltra PiezoFlow systems in combination with 0.5% NaOCl and 18% EDTA in removing Ca(OH)\textsubscript{2}.

The results of this study showed that none of the techniques removed Ca(OH)\textsubscript{2} dressing completely from the root canal surfaces. However, the EndoActivator System was more effective than the other techniques. Therefore, the null hypothesis that there is no difference in Ca(OH)\textsubscript{2} removal between the 3 devices and the standard irrigation technique can be rejected.

The use of the scanning electron microscope in evaluating the cleanliness of root canal walls surfaces has been described previously (13, 29, 31). These investigators showed that the use of the scanning electron microscope is a reliable method in examining and evaluating the removal of Ca(OH)\textsubscript{2} from the root canal walls when using different instrumentation and irrigation systems.

Sonics and ultrasonic irrigation were reported to improve removal of the smear layer in the apical third of curved root canals compared with conventional irrigation (31). Moreover, EDTA has been considered more effective than NaOCl in the removal of inorganic substances such as the smear layer and Ca(OH)\textsubscript{2} (13).

The efficiency in eliminating Ca(OH)\textsubscript{2} from root canals by the EndoActivator in combination with irrigation may be caused by its primary function, which has been reported to produce vigorous intracanal fluid agitation through acoustic streaming and cavitations (32, 33). This sonic system has been reported to improve the penetration, circulation, and flow of irrigant into the more inaccessible sites of the root canal system (31).

The EndoVac has been found to be used safely to the WL without extrusion of irrigating solution beyond the apical constriction of the canal (34). It uses a combination of a macro- or microcannula attached to the suction device. The cannula, which is connected to a high-speed suction, creates a negative pressure that pulls the irrigant to the tip of the cannula and evacuates the irrigation solution and debris through small holes (35). In addition, it has been found to leave significantly less debris 1 mm from the WL compared with traditional needle irrigation, but at 3 mm from the WL, there was no significant difference (22).

In this study, the EndoVac showed better results in the apical part of the canals than conventional irrigation with a needle; however, in the middle and the coronal parts, no differences could be observed. This is in agreement with other studies, which showed that the EndoVac is better than conventional irrigation (36, 37). One of the shortcomings of the EndoVac system in not completely removing Ca(OH)\textsubscript{2} could be related to the 12 filtration holes in the microcannula, which may have been clogged by large particles of the Ca(OH)\textsubscript{2}. However, during this study, the manufacturer’s protocol for the EndoVac was strictly followed. Moreover, it is believed that because the evacuation system continued working effectively by moving the fluid through the suction tubes, clogging may not have been an issue in the removal of Ca(OH)\textsubscript{2}.

The use of passive ultrasonic irrigation is based on the transmission of energy from an ultrasonically oscillating instrument to the irrigant in the root canal (4). The efficiency of passive ultrasonic irrigation not only depends on the duration of activation but is also enhanced with the replacement of fresh irrigant (27).

In this experiment, the use of PiezoFlow created relatively cleaner root canal walls in the coronal and middle thirds than in the apical one compared with conventional needle irrigation. However, the difference is only of an indicative significance and could be caused by the small sample size used. Moreover, the manufacturer’s recommendation for the use of PiezoFlow is to maintain a continuous irrigation flow of 15 mL/min for a total of 1 minute. However, to standardize the irrigation protocol in this study, a total of 3 mL EDTA irrigant was administered in 1 minute. Therefore, the increase in the volume of the irrigation would have probably contributed to a better removal of Ca(OH)\textsubscript{2} from root canal walls when using ultrasonic irrigation.

Another consideration associated with the result of this study might be related to the decoronation procedure of the specimens. The teeth used were all decoronated, which eliminates any coronal reservoir for the irrigation solution.
The results of this study showed that the use of the MAF in combination with the other irrigation systems may result in better removal of Ca(OH)$_2$. However, complete removal of Ca(OH)$_2$ from the root canal walls could not be achieved regardless of the removal technique; further studies should be undertaken with other techniques of root canal irrigation to evaluate the complete removal of intracanal dressing from the root canal walls.

In conclusion, it seems that the investigated techniques did not remove Ca(OH)$_2$ dressing completely. However, the EndoActivator System showed better results in removing Ca(OH)$_2$ in the coronal, middle, and apical parts of the root canals than the other techniques.

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The authors deny any conflicts of interest related to this study.

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