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# Efficacy of self-adjusting file and passive ultrasonic irrigation on removing calcium hydroxide from root canals

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The aim of this study was to evaluate the efficiencies of the self-adjusting file (SAF) system, passive ultrasonic irrigation (PUI), and conventional irrigation (CI) in removing calcium hydroxide (CH) from root canals. Fifty-one mandibular premolars were used. After root canals were instrumented and filled with a CH paste, 45 teeth were randomly assigned to three experimental groups according to CH removal technique: SAF system, PUI, or CI. The remaining 6 teeth served as positive and negative controls. All samples were evaluated by scanning electron microscopy (SEM) and scored. None of the techniques removed CH completely. However, results at coronal, middle and apical thirds showed that PUI technique was significantly more effective than SAF and CI in removing CH dressing residues from root canal walls.

*Keywords*: Calcium hydroxide removal, Self-adjusting file, Passive ultrasonic agitation, Root canal

## INTRODUCTION

A primary goal of root canal treatments is to reduce or eliminate bacteria and their by-products from infected root canal systems[1]. This is accomplished through a combination of mechanical instrumentation, irrigation solutions, and antibacterial dressings placed into the canal. For many years, calcium hydroxide (CH) is the most widely used intracanal dressing in root canal theraphy because of these attractive benefits: favorable biological properties, antimicrobial activity, and capacity to inactivate the toxic effects of bacterial endotoxin[2,3].

CH placed inside a root canal must be completely removed before the latter can be filled with a permanent filling material. This is because CH residues on root canal walls reduce dentinal bond strength and compromise endodontic sealing by interfering with the penetration and adhesion of root canal sealers into dentinal tubules[4-6].

Several studies[7-11] have examined CH removal methods, and the most frequently described method is root canal instrumentation using a master apical file in combination with copious irrigation[7]. Other methods include mechanical instrumentation with rotary nickel-titanium (NiTi) files[8] and patency file[7], or laser irradiation[10] and passive ultrasonic irrigation (PUI)[9]. To date, there is no consensus on which method is the best for CH removal.

A newly developed instrumentation and irrigation device, the self-adjusting file (SAF) system, was introduced by ReDent-Nova (Ra'anana, Israel). It uses a hollow reciprocating instrument that allows for simultaneous irrigation throughout the mechanical preparation process[12]. When inserted into a root canal, the SAF adapts itself to the canal's shape longitudinally and in cross-section[12]. It operates in a transline (in-and-out) vibrating motion, and coupled with the abrasive surface of the lattice threads, promotes a uniform removal of dentin[12]. Peters and Paque[13] also showed that the SAF system is capable of touching all the canal walls. However, to date, no studies have evaluated the CH removal ability of the SAF system and compared the results with other removal methods.

The aim of this study was to evaluate the efficacy of the SAF system, PUI, and conventional irrigation (CI) techniques in the removal of CH from root canals. The null hypothesis to be tested was that there would be no significant differences in CH removal efficiency among these three techniques.

## MATERIAL AND METHODS

*Root canal preparation*

A total of 51 freshly extracted, human mandibular premolars with a straight root and a single canal were used in this study. Teeth with caries, internal or external resorption, cracks, and immature apices were excluded. Periapical radiographs were taken in both buccolingual and mesiodistal directions to confirm root canal anatomy.

After removing the tooth crowns, the roots were adjusted to a standardized root length of 14 mm. A size 10 K-file (Mani, Tochigi, Japan) was placed into the canal until the tip of the file became visible at the the apical foramen. Working length (WL) was determined by subtracting 1 mm from this measurement for positioning the file. All canals were instrumented with Revo-S rotary files (Migro-Mega, Besançon, France) up to 40/.06 as the master apical file according to the manufacturer's instructions. At every instrument change, root canals were irrigated with 2 mL of 3% sodium hypochlorite (NaOCl) using a plastic syringe and a 30-gage closed-end needle (Irrigation Probe, KerrHawe, Bioggio, Switzerland). Final irrigation was

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completed using 5 mL of 3% NaOCl and 5 mL 17% EDTA.

After drying with sterile paper points, a premixed CH paste (MM-Paste; Migro-Mega) was injected into each canal using the manufacturer-supplied dispenser and packed to the WL using a lentulo spiral. Radiographs of all teeth were taken to confirm that all canals were completed filled with CH paste. Access cavities were temporarily sealed with a cotton pellet and a glass ionomer cement (Ionofil U, Voco, Cuxhaven, Germany). The roots were stored at 37°C in 100% relative humidity for 1 week.

*Experimental groups according to CH removal technique*

Forty-five teeth were randomly assigned to three experimental groups ($n$=15 per group) according to CH removal technique: SAF system, PUI, or CI. Remaining 6 teeth served as positive ($n$=3) and negative ($n$=3) controls.

1. Group 1: CH removal by SAF

In Group 1(SAF), CH residues on root canal walls were cleaned using the SAF system. The SAF file was operated using a dental handpiece which provided a vertical (in-and-out) vibrating motion[12]. The vibrating movement, combined with intimate contact along the entire circumference and length of the canal, removed CH with a grinding motion. A special irrigation device (VATEA, ReDent-Nova) was connected to the irrigation hub on the file, and the hollow design allowed for continuous flow of irrigant throughout the procedure. The file was operated in two cycles of 2 min each for a total of 4 min per canal. After each cycle, the file was removed for inspection.

For irrigation, 3% NaOCl was used as the irrigant during the first minute of each cycle and 17% EDTA during the second minute. Flow rate of the irrigants was set at 5 mL/min, resulting in a total volume of 10 mL of each irrigant per canal. After completing two cycles, a final short flush was performed using 5 mL of 3% NaOCl with the vibrational mechanism turned off to remove the remaining EDTA.

2. Group 2: CH removal by PUI

In Group 2 (PUI), CH residues were removed by ultrasonic irrigation using a piezoelectric unit (miniMaster, EMS, Nyon, Switzerland). A non-cutting ultrasonic tip (EMS) was placed at 1 mm from the WL. Oscillation of ultrasonic tip and irrigation began almost at the same time, with oscillation directed towards the apical foramen and intensity set on endomode. According to the manufacturer, the frequency employed under these conditions was approximately 30 kHz.

Root canals were ultrasonically irrigated for 2 min using a continuous flow of 3% NaOCl and 17% EDTA. Ultrasonic irrigation was operated in two cycles of 1 min each for a total of 2 min per cycle. During the first cycle, 10 mL 3% NaOCl was used as the irrigant; during second cycle, it was 10 mL of 17% EDTA. After completing two cycles, a final short flush using 5 mL of 3% NaOCl was performed using a closed-end needle that was inserted to the deepest apical point possible without binding to remove the remaining EDTA.

3. Group 3: CH removal by CI

In Group 3 (CI), root canals were irrigated with 10 mL of 3% NaOCl and 10 mL of %17 EDTA using a plastic syringe and a 30-gage closed-end needle. Final irrigation was completed using 5 mL of 3% NaOCl. Each irrigant was delivered at a flow rate of 5 mL/min. During irrigation, the needle was constantly moved up and down within the apical third.

*Negative and positive control groups*

In the Negative Control Group, root canals were not filled with CH. In the Positive Control Group, root canals were filled with CH but no removal procedure was applied.

*Scanning electron microscopy evaluation*

Grooves were prepared on the buccal and lingual surfaces with a diamond bur used with a high-speed water-cooled handpiece, thus preserving the innermost surface of dentin surrounding each canal. Teeth were split along their long axis in a buccolingual direction using a hammer and chisel. The roots were left to dry at room temperature for 24 h and then coated with 20-nm gold-palladium particles for scanning electron microscopy (SEM) examination (LEO Evo 40 XVP, Carl Zeiss AG, Oberkochen, Germany).

At ×1,000 magnification, digital images were taken at the centre of coronal (9 mm from apex), middle (6 mm from apex), and apical (3 mm from apex) thirds of each canal in both root segments to evaluate the persence of CH residues. To standardize the SEM examination area, the method described by Paque *et al.*[14] was used. The central beam of the SEM was directed to the center of each root canal third by the SEM operator under ×10 magnification. Magnification was gradually increased to ×1,000, and then the canal wall region appearing on the screen was photographed and scored.

The following scoring system[8] was used to evaluate the presence of CH residues on root canal walls, where score 0: absence of any residue; score 1: small amount of residues (up to 20% of the surface covered); score 2: moderate amount of residues (20–60% of the surface covered); and score 3: large amount of residues (more than 60% of the surface covered) (Fig. 1). Evaluation was performed by two calibrated examiners independently and in a blind manner. Scores were compared, and where a difference was found, the sample in question would be re-examined. If the examiners could not reach an agreement, a third examiner would assist in the scoring of the sample.

*Statistical analysis*

Differences in CH residue score among the three experimental groups were analyzed using the Kruskal-Wallis and Mann-Whitney $U$ tests. Level of statistical

significance was set at 95% confidence ($p<0.05$). All statistical analyses were performed using SPSS 16.0 software (SPSS Inc., Chicago, IL, USA).

## RESULTS

Table 1 shows the distributions of the scores and the percentage values of residual CH at coronal, middle, and apical thirds of root canals. In addition, Table 2 shows the median and minimum-maximum values of each root section for each experimental group.

None of the groups showed complete removal of CH from the canal walls. Kruskal-Wallis test revealed that there were statistically significant differences in CH removal results among the experimental groups ($p<0.05$). At all root canal sections, Group 2 was statistically superior to Group 1 ($p<0.05$). Between the Group 2 and 3, there were no statistically significant differences in coronal-third values ($p>0.05$). Between Groups 1 and 3, there were no statistically significant differences in middle- and apical-third values ($p>0.05$).

Within Groups 1 and 2, intra-group differences among all the root canal sections were not statistically different ($p>0.05$). Within Group 3, coronal-third values were statistically different from middle- and apical-third values.

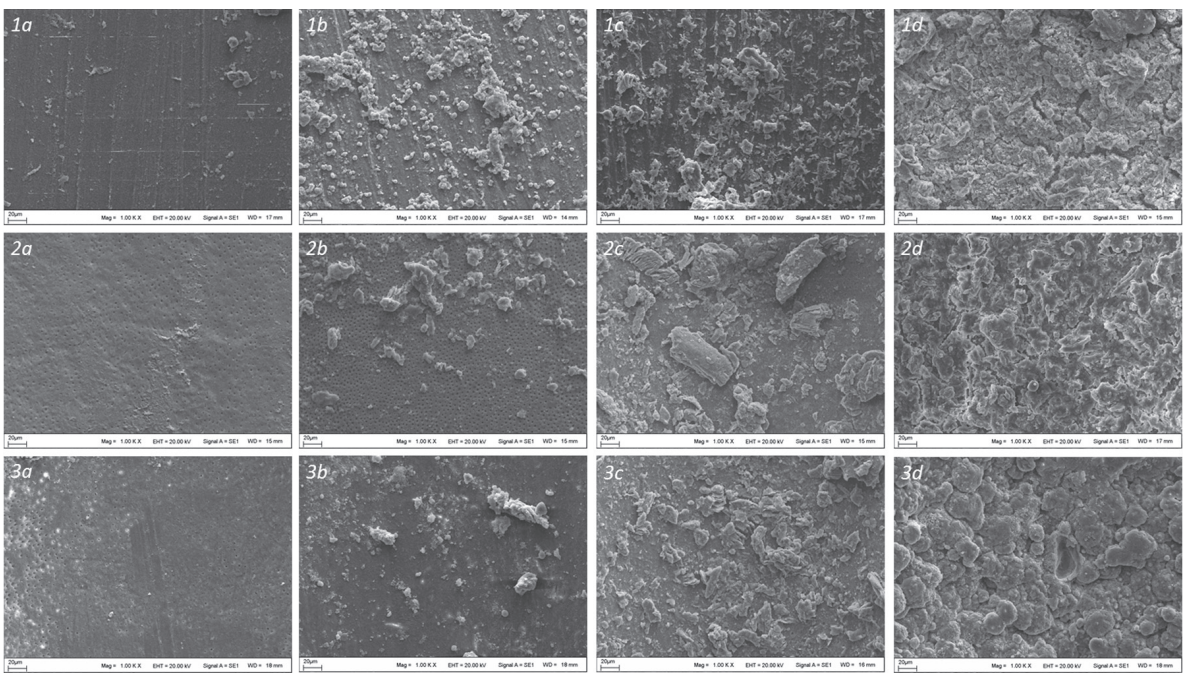



Fig. 1 Representative SEM images of all thirds of SAF group (Row 1), PUI group (Row 2), and CI group (Row 3). (a) Score 0, (b) Score 1, (c) Score 2, and (d) Score 3.

Table 1 Distributions of the scores and percentage values of residual CH at coronal, middle, and apical thirds of the root canal

| Groups | | Score 0 | Score 1 | Score 2 | Score 3 |
|---|---|---|---|---|---|
| 1 | Coronal | 0 | 4 (26.66) | 5 (30) | 6 (40) |
| | Middle | 1 (6.66) | 2 (13.33) | 6 (40) | 6 (40) |
| | Apical | 0 | 3 (20) | 6 (40) | 6 (40) |
| 2 | Coronal | 1 (6.66) | 10 (66.66) | 3 (20) | 1 (6.66) |
| | Middle | 6 (40) | 3 (20) | 4 (26.66) | 2 (13.33) |
| | Apical | 2 (13.33) | 8 (53.33) | 3 (13.33) | 2 (13.33) |
| 3 | Coronal | 5 (30) | 7 (46.66) | 1 (6.66) | 2 (13.33) |
| | Middle | 2 (13.33) | 3 (20) | 6 (40) | 4 (26.66) |
| | Apical | 0 | 3 (20) | 8 (53.33) | 4 (26.66) |

Percentage values are given in parentheses.

Table 2 Median and minimum-maximum values of coronal, middle, and apical thirds of all experimental groups

| | Coronal | | Middle | | Apical | |
|---|---|---|---|---|---|---|
| Group | Median | Min–Max. | Median | Min–Max. | Median | Min–Max. |
| 1 | 2 | 1–3 | 2 | 0–3 | 2 | 1–3 |
| 2 | 1 | 0–3 | 1 | 0–3 | 1 | 0–3 |
| 3 | 1 | 0–3 | 2 | 0–3 | 2 | 0–3 |

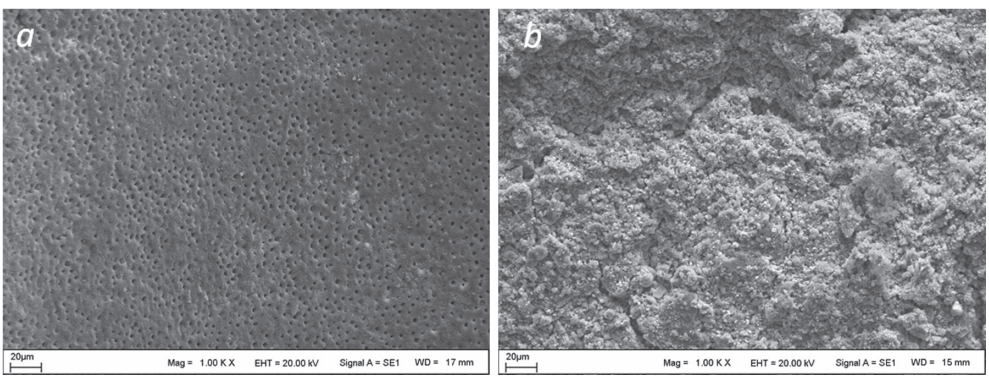



Fig. 2 Representative SEM images of: (a) Negative Control group; and (b) Positive Control group.

Groups 1 to 3 showed significantly different CH removal results from the positive and negative control groups ($p<0.05$). The positive control group showed canal walls completely covered with densely packed CH residues, which was in stark contrast to the clear view of dentinal tubules showed by the negative control group (Fig. 2).

## DISCUSSION

CH is the most widely used and investigated intracanal dressing material in endodontics. Its removal prior to the final filling is very important because CH residues may adversely affect the sealing ability of sealers by preventing their penetration into the dentin tubules[4]. Different techniques have been used to remove CH from root canals such as CI with/without files, PUI, sonic activated irrigation, or laser irridation. However, the complete removal of CH from root canal walls is a vital task that remains unaccomplished.

PUI is based on the transmission of energy from an ultrasonically oscillating instrument to the irrigation solution inside the root canal[15]. The term "passive" relates to the "non-cutting" action of the ultrasonically activated file, and hence no simultaneous canal shaping during PUI[16]. Compared with traditional syringe irrigation, PUI can be an important supplement for cleaning the root canal system as it removes more organic tissue, planktonic bacteria, and dentin debris from the root canal[16]. Compared with sonic activated irrigation PUI is more effective in removing dentin debris[16] and CH residues[17]. Tasdemir *et al.*[9] evaluated the efficiency of several irrigation techniques in removing CH, namely, NaOCl, EDTA+NaOCl, NaOCl+CanalBrush (a flexible microbrush), and NaOCl+PUI. None of the techniques removed CH completely, but NaOCl in combination with CanalBrush or PUI were significantly more effective than irrigant-only techniques. Similarly, van der Sluis *et al.*[15] demonstrated that PUI of NaOCl was more effective in removing CH from artificial root canal grooves than irrigant-only techniques. However, Balvedi *et al.*[18] found that neither syringe irrigation nor PUI was efficient in removing CH from root canals, especially at the apical third.

A newly developed SAF system consists of a hollow file, built as a pointed cylinder, made of a thin NiTi lattice. The compressible file adapts itself three-dimensionally to the oval-shaped canal as it cleans, while its abrasive NiTi lattices are pressed against the walls to enlarge, shape, and debride the root canal by their sandpaper-like effects[19]. Recent studies have shown that it is able to touch all canal walls evenly[20-22], generating more complete root canal shapes than with rotary instrumentation. On debridement efficacy, histological comparisons by De-Deus *et al.*[23] showed that SAF was more efficient than rotary NiTi files for pulpal debridement in oval-shaped root canals. Similarly, del Melo Ribeiro *et al.*[22] showed that SAF removed more debris than rotary instrumentation in the apical third of mandibular incisors, while a recent study[24] showed that the use of SAF system after rotary

instrumentation resulted in a significantly reduced amount of filling residue in the curved canals of mandibular molars.

The hollow design of SAF system also allows for simultaneous continuous irrigation during instrumentation to facilitate debris and bacteria removal[12]. Metzger *et al.*[21] found that when the operation of the SAF system with continuous irrigation was coupled with the use of alternating irrigants, clean and mostly smear layer-free dentin surfaces were obtained in all parts of the root canal.

Cleanliness of root canal walls or amount of residual CH on root canal walls has been assessed in varied ways. Cleaning efficacy assessment methods span from measuring the surface areas covered by CH residues based on digital images to calculating the volumes of CH residues by spiral computed tomography (CT)[7-10,14,25]. In the present study, a scoring index was used by calibrated examiners to independently evaluate the presence of CH residues in longitudinally sectioned root halves based on digitally recorded SEM images.

According to the results, none of the tested techniques (SAF, PUI, and CI) completely removed CH from the canal walls. PUI was superior to SAF in removing CH at all parts of the root canal system. PUI was superior to CI at middle and apical thirds. The high-velocity jets and higher volume of irrigant flow rendered by PUI[26] might explain its efficiency in flushing out loose CH from root canals[17]. Therefore, the null hypothesis was rejected.

For SAF and PUI, intra-group differences among coronal, middle, and apical thirds of the root canal system were not statistically different. However, for CI, cleaning efficacy at coronal-third was superior to the middle and apical thirds. These results were comparable with the findings of previous studies[7,15,25].

Paranjpe *et al.*[27] reported that the SAF system presented uncontrolled apical instrumentation and inadequate apical irrigation. It was also commented that the SAF is not a penetrating instrument and is too flexible to accomplish the task of removing the bulk of root filling materials and CH residues[24]. In the present study, CH deposits on root canal walls cleaned by the SAF were typically round-shaped (Fig. 1-1b) or crystalline/worm-shaped (Fig. 1-1c). This was probably due to the filing movement of the SAF system. Streaks observed on the dentin surfaces were formed in coronal-apical direction, indicating that the SAF indeed cleaned and debrided the root canal system to remove CH but that complete CH removal could not be achieved. Another reason for incomplete CH removal could be inadequate irrigation solution or inability of the irrigant to reach the environment.

## CONCLUSION

According to the findings of the present study, none of the tested techniques completely removed the CH intracanal dressing material from the root canals. But, PUI technique was significantly more effective than SAF and CI.

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