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ORIGINAL RESEARCH

Efficacy of self-adjusting file, XP-endo finisher and passive ultrasonic irrigation on the removal of calcium hydroxide paste from an artificial standardized groove

Anda Kfir, DMD[1]; Nuphar Blau-Venezia, DMD[1]; Tomer Goldberger, DMD[1]; Itzhak Abramovitz, DMD[2]; and Ronald Wigler, DMD[1,*]

1 Department of Endodontology, The Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel
2 Department of Endodontics, Hebrew University-Hadassah School of Dental Medicine, Jerusalem, Israel

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artificial standardised groove, calcium hydroxide removal, passive ultrasonic irrigation, self-adjusting file, XP-endo finisher.

Correspondence
Ronald Wigler, Department of Endodontology, Tel Aviv University, Tel Aviv 69978, Israel.
Email: dr.wigler@gmail.com

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Abstract

The purpose of this study was to compare the effectiveness of self-adjusting file (SAF), XP-endo finisher (XP), passive ultrasonic irrigation (PUI) and conventional syringe and needle irrigation (SNI) in the removal of $Ca(OH)_2$ from an artificial groove. Eighty mandibular incisors with single oval canals were prepared to size 40/0.04 and split longitudinally. A standardised groove was prepared in the apical third and filled with $Ca(OH)_2$. The root halves were reassembled and divided into two control groups ($n = 4$) and four experimental groups ($n = 18$) according to the removal methods used. The amount of residual $Ca(OH)_2$ was evaluated using a four-grade scoring system. The differences among the groups were analysed using the Kruskal–Wallis test ($P < 0.05$). SAF, XP and PUI removed significantly more $Ca(OH)_2$ than SNI ($P < 0.001$), although there were no significant differences among them ($P = 0.209$). None of the tested methods could completely clean $Ca(OH)_2$ from the groove.

Introduction

The ultimate goals of endodontic treatment are complete removal of bacteria, their by-products and pulpal remnants from infected root canals and the complete sealing of the disinfected root canals (1). The root canal system is a highly complex space, which impairs cleaning and disinfection procedures as well as the removal of root canal dressing (2). Calcium hydroxide dressing [$Ca(OH)_2$] has been used in dentistry for almost a century, and its advantages and disadvantages are well documented (3–5). One major concern is the inability to completely remove this dressing material from the root canal system (6–10). Residual $Ca(OH)_2$ may interfere with the ability of endodontic sealers to adapt to the entire canal wall and to enter the dentinal tubules, potentially allowing increased leakage (11,12). Therefore, the complete removal of $Ca(OH)_2$ paste prior to obturation of the root canal system is desired.

The Self Adjusting File (SAF) (ReDent Nova, Ra'anana, Israel) is a coreless, compressible nickel-titanium (NiTi) instrument designed to adapt itself to the canal walls to promote the cleaning and shaping of root canals with varied anatomy (13,14). Lin *et al.* (15) demonstrated its capabilities in reducing bacterial biofilm from artificial apical groove. Capar *et al.* (10) showed the SAF and passive ultrasonic irrigation technique (PUI) effectiveness in removing $Ca(OH)_2$ from an artificial standardised groove in the apical part of the root canals compared to EndoVac (Discus Dental, Culver City, CA) and conventional syringe and needle irrigation (SNI) systems. However, none render the groove completely free of residual $Ca(OH)_2$ (10).

A recent study by Wigler *et al.* (16) examined the efficacy of PUI and the XP-endo finisher file (XP) (FKG Dentaire, La Chaux de Fonds, Switzerland) in the removal of $Ca(OH)_2$ paste from an artificial standardised groove in the apical third of root canals. XP is a new file with a small core, size 25 and no taper, made of a proprietary alloy (Martensite-Austenite Electropolish-FleX) that when exposed to body temperature changes its shape to the austenite phase, allowing the file to expand its reach to 6 mm in diameter, when rotating, to clean highly complex morphologies and difficult-to-reach areas (17–19). In their study, PUI and XP were shown to be more effective than the SNI technique, although none completely removed $Ca(OH)_2$ from the artificial grooves (16).

The aim of this study was to compare the efficacy of SAF, XP, PUI and SNI in the removal of $Ca(OH)_2$ from artificial standardised grooves in the apical third of root canals. The null hypothesis tested was that there would be no differences in $Ca(OH)_2$ removal efficacy among the different techniques.

Materials and methods

The study design was based on the work of Lee *et al.* (20), van der Sluis & Wesselink (7), Rödig *et al.* (8), Ḉapar *et al.* (10) and Wigler *et al.* (16).

Preparation of specimens

Eighty extracted human mandibular incisors with intact apices, a minimum tooth length of 18 mm and no previous treatments were selected from a random collection of recently extracted teeth. Radiographs of all teeth were obtained from bucco-lingual and mesio-distal projections and used to select teeth with a single oval-shaped canal, that is, a long:short canal diameter ratio of ≥2.5 at 5 mm from the apex (21).

An endodontic access cavity was prepared, and apical patency was established using a size 10 file (Mani, Utsunomiya, Japan). The canal length was determined by introducing the file until the tip of the instrument was just visible at the apical foramen under an operating microscope (Karl Kaps, Asslar, Germany) at fivefold magnification. The incisal edges of all teeth were ground to obtain a standardised length of 17 mm with a working length (WL) of 16 mm.

All root canals were prepared by an endodontic specialist (RW), using Mtwo rotary NiTi instruments (VDW, Munich, Germany), to size 40/0.04 WL. During the mechanical preparation, the root canal was irrigated with 5 mL 4% NaOCl solution after each instrument. After completion of the mechanical preparation, a final flush was applied using 5 mL 17% EDTA followed by 5 mL 4% NaOCl, and the canal was dried with paper points.

The specimens were fixed in Plexiglas tubes containing silicon impression material (Coltene/Whaledent, Langenau, Germany). After removal from these moulds, all the roots were grooved longitudinally on the buccal and lingual surfaces using a diamond-coated disc (Horico, Berlin, Germany) under copious water irrigation, avoiding penetration into the root canal. The roots were then split into two halves using a chisel and a mallet.

A size 20 file (Mani, Utsunomiya, Japan) coupled to a file-holding adapter of the handpiece of a Satalec P5 Newtron ultrasonic system (Acteon Group, Merignac, France) was used to cut a longitudinal groove 3 mm in length, 0.2 mm in width and 0.5 mm in depth in the root canal dentinal wall of one half of each specimen, at a distance of 2–5 mm from the apex, to simulate an uninstrumented canal recess in the apical part of the root canal. A toothbrush was used to remove debris from the root halves and grooves. $Ca(OH)_2$ (Sultan Healthcare Inc., York, PA) was then mixed with saline solution to a creamy consistency, and the grooves were filled using paper points to simulate $Ca(OH)_2$ remnants in an uninstrumented natural canal recess (7,8). The root halves were then re-assembled and remounted in the Plexiglas tube moulds. The access cavities were temporarily sealed with a cotton pellet and Cavit (3M ESPE, Seefeld, Germany) and stored at 37°C and 100% humidity for 1 week to simulate inter-appointment dressing. All further procedures were done with the root tightly set within the mould, thus the apical foramen in all specimens was close during the procedures.

$Ca(OH)_2$ removal procedures

After storage for 1 week, the specimens were randomly allocated into four experimental groups (n = 18), according to the technique used to remove $Ca(OH)_2$ (see below) and two control groups: the positive control group (n = 4), in which $Ca(OH)_2$ was applied but not subsequently removed, and the negative control group (n = 4), in which $Ca(OH)_2$ was not applied.

Self-adjusting file (SAF) group

The SAF (2.0 mm diameter and 25 mm length) was passively introduced into the canal to the WL and activated for 4 min at a frequency of 5000 in-and-out vibrations/min and an amplitude of 0.4 mm, using an RDT3 handpiece head (Re-Dent-Nova, Ra'anana, Israel). Pecking motions were applied, by the operator, to the WL. A total of 20 mL 4% NaOCl irrigant was continuously provided by a VATEA peristaltic pump (ReDent-Nova), at a rate of 5 mL min^{-1}.

Passive ultrasonic irrigation (PUI) group

PUI was performed using a Satalec P5 Newtron ultrasonic system and an IrriSafe #20/0.00 file (Acteon, Viry-Châtillon, France) in an endo power setting using 30% power. The specimens were rinsed with 5 mL 4% NaOCl using a syringe and a 30G needle placed 1 mm from the WL with a flow rate of approximately 5 mL min^{-1}. Then, the

IrriSafe file was inserted into the canal 1 mm short of the WL, and the irrigant was ultrasonically activated for 20 s. This sequence was repeated two more times, followed by a final flush with 5 mL 4% NaOCl at a flow rate of approximately 5 mL min^{-1}. A total irrigant volume of 20 mL was used, and it was activated by the ultrasonic file for a total of 1 min.

XP-endo finisher (XP) group

The specimens were rinsed with 10 mL 4% NaOCl using a syringe and 30G needle (NaviTip; Ultradent, South Jordan, UT, USA) placed 1 mm from the WL with a flow rate of approximately 5 mL min^{-1}.

The XP file was used with an endodontic motor (X-Smart, Dentsply-Maillefer, Ballaigues, Switzerland) at 800 rpm and 1 Ncm. The WL was fixed by using the plastic tube to adjust the rubber stopper, while the file was cooled inside the tube using a cold spray (Endo-Ice, Whaledent, Mahwah, NJ, USA), which made the file straight. The file was then inserted into the WL, the access cavity was filled with irrigant and the file was operated for 60 s using slow and gentle 7–8 mm lengthwise in-and-out movements. This process was followed by a final flush with 10 mL 4% NaOCl with a flow rate of approximately 5 mL min^{-1}. A total irrigation volume of 20 mL was used.

In all groups, the 4% NaOCl solution was warmed to 37°C prior to application to allow the XP to work optimally when in the austenite phase (17–19).

Conventional syringe & needle irrigation (SNI) group

The specimens were rinsed with 20 mL 4% NaOCl using 10 mL syringes with 30G needles (NaviTip; Ultradent) placed 1 mm from the WL with a flow rate of approximately 5 mL min^{-1}.

Cleaning efficacy assessment

The root canals were dried with paper points, and the specimens were disassembled to evaluate the removal of the $Ca(OH)_2$ paste from the artificial grooves. Digital photographs of the grooves were taken before the placement of the $Ca(OH)_2$ and after its removal using a microscope (Karl Kaps) at 24× magnification and a digital camera (Sony alpha A6000, Sony Inc., New York, USA). The images were coded to prevent the identification of the specimen by the evaluators. The amount of $Ca(OH)_2$ remaining in the grooves was scored by two calibrated endodontic specialists. One hundred samples from a previous study were initially examined and scored by the examiners for calibration purposes. The four-grade scoring system described by Lee *et al.* (22) was used (Figure 1). Score 0: the groove is empty; score 1: $Ca(OH)_2$ is present in less than half of the groove area; score 2: $Ca(OH)_2$ covers more than half of the groove area; and score 3, the groove is completely covered with $Ca(OH)_2$. Any disagreement between the observers was settled by discussion.

Statistical analysis

Kappa values were calculated to evaluate intra- and inter-observer agreement. The differences in the $Ca(OH)_2$ scores among the different groups were analysed using the Kruskal–Wallis test at a 95% confidence level ($P < 0.05$). All statistical analyses were performed using the SPSS 20.0 software (SPSS, Chicago, IL, USA).

Results

During the entire scoring procedure, the intra- and inter-observer differences in scoring never exceeded one score. The intra-observer kappa values were 0.933 and 0.968 for the first and second observers, respectively, and the kappa value between the observers was 0.945.

Figure 2 presents the distribution of the scores for the removal of $Ca(OH)_2$. None of the tested methods could completely clean the $Ca(OH)_2$ from the artificial standardised grooves (Score 0). SAF, XP and PUI removed significantly more $Ca(OH)_2$ than SNI ($P < 0.001$), with no significant differences among these three groups ($P = 0.209$). SNI was the least efficient method of $Ca(OH)_2$ removal, leaving 89% of the grooves completely covered with $Ca(OH)_2$ (Score 3), while only 22%, 17% and 17% of grooves in the SAF, XP and PUI groups, respectively, received this score (Figure 2).

Discussion

The aim of this study was to compare the efficacy of SAF, XP, PUI and SNI in the removal of $Ca(OH)_2$ from artificial grooves in the apical third of root canals. SNI is the traditional method to deliver different irrigant solutions into the root canal space. However, studies have shown that using solely this method results in ineffective debridement and smear layer removal, particularly at the apical third of root canals (23–27). Root canal cleanliness benefits from solutions activation in comparison with no activation; Sonic activation systems, ultrasonic activation systems, laser systems and apical negative pressure irrigation device have been reported to provide deeper penetration of irrigants to the endodontic space and more effective cleaning of debris and removal of smear layer (23–30). When $Ca(OH)_2$ paste is used as intracanal

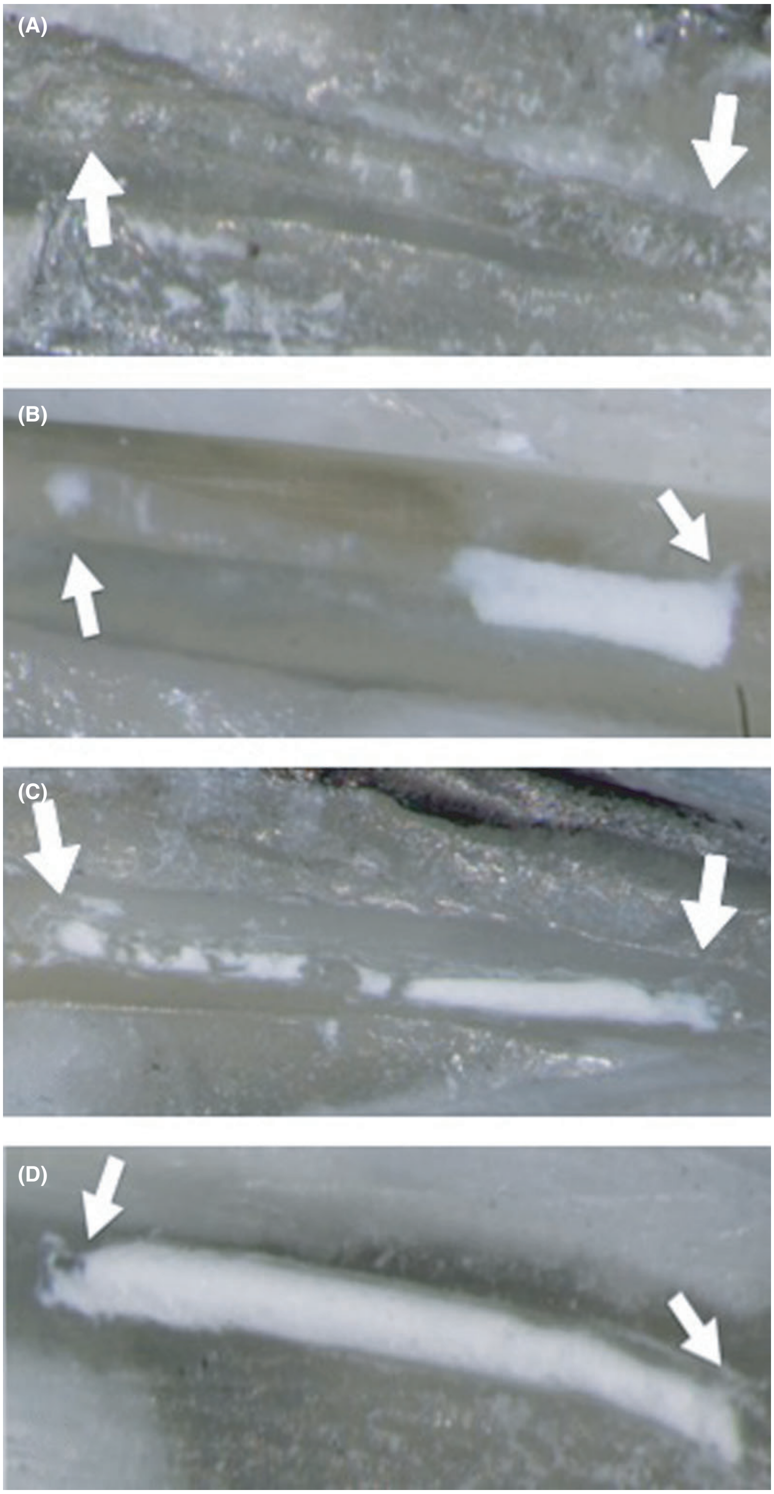

Figure 1 Score system for evaluation of removal of $Ca(OH)_2$ from the artificial groove. White arrows indicate the coronal and apical ends of the grooves. (a) Score 0: the groove is clean of any $Ca(OH)_2$ residue. (b) Score 1: less than half the groove surface is covered with $Ca(OH)_2$. (c) Score 2: more than half of the groove surface is covered with $Ca(OH)_2$. (d) Score 3: the groove is completely covered with $Ca(OH)_2$.

medicament between treatment visits, it should be completely removed prior to obturation (6–12). No irrigation technique thus far, however, has proven capable of achieving this goal (7–10). Even the PUI technique, shown by several previous studies to be superior for removing $Ca(OH)_2$ from artificial grooves, leaves $Ca(OH)_2$ residues in such irregularities (6–10). In this study, PUI was superior only to SNI (Figure 2), which was consistent with previous studies (7,9,10), and performed similarly to XP and SAF. This result is also consistent with

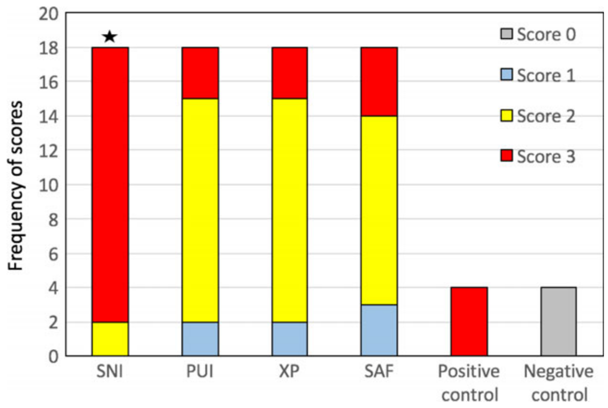

Figure 2 Frequency of scores in the four experimental groups. Score 0 was not found in any of the experimental groups. SNI-Syringe and needle irrigation. PUI – Passive ultrasonic irrigation. XP – XP-endo finisher file. SAF – Self-adjusting file. *Indicates significant difference between this group (SNI) and the other groups ($P < 0.001$).

the results of Wigler *et al.* (16), which indicated that XP and PUI were more effective than SNI in removing $Ca(OH)_2$ from artificial standardised grooves. It is important to note that the XP was designed, to begin with, as a ***finisher file,*** aimed to clean already shaped root canals, while the SAF was designed to clean and shape the root canals, and not as a finisher file following root canal preparation. The SAF was tested in this study for its potential ability to clean the $Ca(OH)_2$ from the groove mainly because a study by Lin *et al.* (15) indicated that the SAF was very effective in removal of bacterial biofilm from a similar artificial groove. The use of the SAF as a finisher file in this study was thus an exploration out of the "envelope" of its manufacturer instructions, similar to the use in Capar *et al.* (10) and Türker *et al.* (22) studies. They reported that the SAF system was significantly better than SNI, and as effective as PUI (10) and EndVac (22), although it was not able to completely clean $Ca(OH)_2$ residues. (10,22). The results of this study are in agreement with these two previous publications.

The apparent contradiction between the results of this study and the two above mentioned ones, and the results of Lin *et al.* (15), may be explained by the size of the enlarged canals. In Lin *et al.* (15) study, the canals were initially enlarged to size 20 and the SAF was used to clean and shape the canals and artificial grooves, while in this study, and two above-mentioned studies, the canals were initially enlarged to size 40, and the SAF was used as a finisher file. It should be kept in mind that in order to adapt into oval canals or canal recesses, the SAF has to be compressed (31). This may not occur in a canal that has already been enlarged to size 40, and in which the SAF is used as a finisher.

The present results support the notion that to allow an effective use of the SAF, clinicians should limit its use to what is indicated in its manufacturer instructions. This includes the use of the SAF for 4 min, which is according to its manufacturer's instruction. Although the SAF cleaned the $Ca(OH)_2$ paste significantly better than SNI, the expectation that it will perform better than PUI did not materialise.

The XP, which was designed to begin with as a finisher file, and used in this study according to the manufacturer instructions, also failed to completely clean the $Ca(OH)_2$ from the artificial standardised grooves. This might be due to lack of contact time, between the file and the groove, in the 1 min operation time indicated by the manufacturer (16). It might be worthwhile to test the XP with longer operation times to reveal whether it might better perform.

The null hypothesis of this study was rejected because SAF, XP and PUI all removed significantly more $Ca(OH)_2$ than SNI. Nevertheless, none of these methods could render the grooves free of $Ca(OH)_2$.

Further studies should be conducted to seek an irrigation technique that can effectively render the grooves free of $Ca(OH)_2$ paste remnants.

Conclusions

Within the limitations of this study, none of the tested methods was able to effectively remove all the $Ca(OH)_2$ from the artificial standardised groove in the apical third of root canals. SAF, XP and PUI were more effective than the SNI technique but did not differ from each other in their ability to clean $Ca(OH)_2$ from the grooves.

Authorship declaration

All authors have contributed significantly, and are in agreement with the manuscript.

Disclosure statement

The authors deny any conflicts of interest.

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