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Efficacy of XP-endo finisher files in the removal of calcium hydroxide paste from artificial standardized grooves in the apical third of oval root canals

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Abstract

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Aim To compare the efficacy of the XP-endo finisher file (XP) (FKG Dentaire, La Chaux de Fonds, Switzerland) to that of passive ultrasonic irrigation (PUI) and conventional syringe and needle irrigation (SNI) in the removal of calcium hydroxide paste from an artificial standardized groove in the apical third of root canals.

Methodology The root canals of 68 mandibular incisors with single oval canals were prepared using Mtwo instruments (VDW GmbH, Munich, Germany) up to size 40, .04 taper. Each tooth was split longitudinally, and in one half of the root, a standardized groove was prepared in the apical part of the specimen. The grooves were filled with $Ca(OH)_2$, and the root halves were reassembled. The roots were randomly divided into two control groups ($n = 4$) and three experimental groups ($n = 20$) according to the $Ca(OH)_2$ methods used: XP, PUI and SNI. The amount of remaining medicament was evaluated under X25 magnification using a 4-grade scoring system. Kappa values were calculated for intra- and interobserver agreement evaluation. The differences in the $Ca(OH)_2$ scores amongst the different groups were analysed using the Kruskal–Wallis test.

Results None of the tested methods could completely clean the $Ca(OH)_2$ from the artificial standardized groove in the apical third of the root canals. XP and PUI removed significantly more $Ca(OH)_2$ than SNI ($P < 0.001$), with no significant differences between them ($P = 0.238$).

Conclusions XP and PUI were more effective in removing $Ca(OH)_2$ from artificial standardized grooves in the apical third of root canals than SNI.

Keywords: artificial groove, calcium hydroxide removal, oval canals, passive ultrasonic irrigation, XP-endo finisher file.

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Introduction

Calcium hydroxide paste ($Ca(OH)_2$) has been extensively studied and used as an intracanal medicament, and its benefits are well documented. However, there are clinical concerns regarding the inability to completely remove the paste from the root canal system (Kenee *et al.* 2006, van der Sluis *et al.* 2007, Rödig *et al.* 2011, Taşdemir *et al.* 2011, Capar *et al.* 2014). Residual $Ca(OH)_2$ may interfere with the ability of endodontic sealers to adapt to the canal wall and to enter the dentinal tubules, thus potentially allowing increased leakage (Lambrianidis *et al.* 1999, Kim & Kim 2002, Barbizam *et al.* 2008). Therefore, complete

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removal of $Ca(OH)_2$ paste prior to filling of the root canal system is desired.

Previous studies have shown that no existing mechanical preparation methods or irrigation solutions render the main canal completely free of residual $Ca(OH)_2$ (Kenee *et al.* 2006, van der Sluis *et al.* 2007, Rödig *et al.* 2011, Taşdemir *et al.* 2011, Capar *et al.* 2014, Alturaiki *et al.* 2015). $Ca(OH)_2$ remaining in canal irregularities in the apical third of the root canal may be inaccessible to hand files, rotary file systems or copious irrigation with sodium hypochlorite (NaOCl) or ethylenediaminetetraacetic acid (EDTA) (Salgado *et al.* 2009, Capar *et al.* 2014, Topçuoğlu *et al.* 2015). Even passive ultrasonic irrigation (PUI), which has been revealed to be a superior technique for removing $Ca(OH)_2$ from an artificial standardized groove in the apical part of the root canal, leaves $Ca(OH)_2$ residues in such irregularities (Kenee *et al.* 2006, van der Sluis *et al.* 2007, Rödig *et al.* 2011, Taşdemir *et al.* 2011, Capar *et al.* 2014).

XP-endo finisher (XP) (FKG Dentaire, La Chaux de Fonds, Switzerland) is a file based on the shape-memory principles of NiTi alloy, with a small core size 25 and no taper; it was designed to be used following any root canal preparation of size 25 or more (http://www.fkg.ch/) to clean highly complex morphologies and difficult-to-reach areas.

The aim of this study was to compare the efficacy of XP, PUI and conventional syringe and needle irrigation in the removal of $Ca(OH)_2$ from mechanically unreachable regions in the apical third of straight root canals. The null hypothesis tested was that there would be no differences in $Ca(OH)_2$ removal efficacy amongst the different techniques.

Materials and methods

The study design was based on the studies of Lee *et al.* (2004), van der Sluis *et al.* (2007), Rödig *et al.* (2011) and Capar *et al.* (2014).

Preparation of specimens

Sixty-eight extracted human mandibular incisors with intact apices, a minimum tooth length of 18 mm and no previous root canal treatment were selected. Radiographs of all teeth were obtained from buccolingual and mesiodistal projections and were used to select only teeth with a single oval-shaped root canal, with a long:short canal diameter ratio of ≥ 2.5 at 5 mm from the apex (De-Deus *et al.* 2008).

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

All root canals were prepared by an endodontic expert (RW) using Mtwo rotary NiTi instruments (VDW) to a size 40, .04 taper at WL. Between each file, the root canals were rinsed with 5 mL 4% NaOCl delivered with a syringe and a 30-gauge needle (NaviTip; Ultradent, South Jordan, UT, USA). After completion of mechanical preparation, the root canals were irrigated with 5 mL 17% EDTA followed by 5 mL 4% NaOCl and dried with paper points.

All specimens were fixed in Plexiglas tubes containing silicon impression material (Coltene/Whaledent, Langenau, Germany). The teeth were then removed from these moulds, and two grooves were cut along the long axis of each root using a diamond-coated disc (Horico, Berlin, Germany) under copious water irrigation, avoiding penetration into the root canal. The roots were then split longitudinally into two halves using a chisel and a mallet.

A longitudinal groove, 3 mm in length, 0.2 mm in width and 0.5 mm in depth was then cut in the root canal dentine of one half of each specimen at a distance of 2 mm from the apex. This was performed with a size 20 file (Mani Inc., Utsunomiya, Japan) that was coupled to the file-holding adapter of the handpiece of a Satalec P5 Newtron ultrasonic system (Acteon Group, Merignac, France). The groove was intended to simulate an uninstrumented irregular canal recess in the apical part of the root canal, in which intracanal medications may accumulate (Rödig *et al.* 2011). A toothbrush was used to remove debris from the root halves and grooves. $Ca(OH)_2$ was then mixed with saline solution to a creamy consistency, and the grooves were filled using paper points (Rödig *et al.* 2011). This technique was intended to simulate a situation in which $Ca(OH)_2$ remains in an uninstrumented natural canal recess (van der Sluis *et al.* 2007). The root halves were then re-assembled, and the specimens were 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 with 100% humidity for

1 week to simulate interappointment dressing. All further procedures were also carried out by a single operator who is an endodontic expert (RW).

$Ca(OH)_2$ removal procedures

After storage for 1 week, the specimens were allocated into 3 equal groups (De-Deus *et al.* 2011) ($n = 20$) (Capar *et al.* 2014). The technique to be used to remove $Ca(OH)_2$ in each of the groups was then randomly decided by a flip of coin. Additionally, two control groups were formed: the negative control group ($n = 4$), in which $Ca(OH)_2$ was not applied, and the positive control group ($n = 4$), in which $Ca(OH)_2$ was applied but not subsequently removed.

Conventional syringe and needle irrigation (SNI) group

The root canals were rinsed with 10 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}.

Passive ultrasonic irrigation (PUI) group

Passive ultrasonic irrigation was performed using a Satalec P5 Newtron ultrasonic system and an IrriSafe size 20, .00 taper file (Acteon) in an endo power setting using 30% power. The specimens were rinsed with 2.5 mL 4% NaOCl using a syringe and 30G needle placed 1 mm from the WL with a flow rate of approximately 5 mL min^{-1}. Then, the 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 2.5 mL 4% NaOCl at a flow rate of approximately 5 mL min^{-1}. A total irrigant volume of 10 mL was used and was activated for a total of 1 min. The file was kept as centred as possible to minimize contact with the canal walls, as any contact with the canal wall could dampen the oscillatory motion of the file (Jiang *et al.* 2011).

XP-endo finisher (XP) group

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

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

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 grooves. Digital photographs of each groove 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 photographs 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 using a four-grade scoring system described by Lee *et al.* (2004) and recently used by Capar *et al.* (2014) (Fig. 1). Calibration of the evaluators was carried out by examination and scoring of 100 samples from a previous similar study. 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 filled/covered with $Ca(OH)_2$ (Fig. 1a–d).

Statistical analysis

Kappa values were calculated for intra- and interobserver agreement evaluation. The differences in the $Ca(OH)_2$ scores amongst the different groups were analysed using the Kruskal–Wallis test ($P < 0.05$). All statistical analyses were performed using SPSS 20.0 software (SPSS, Chicago, IL, USA).

Results

During the complete scoring procedure, the intra- and interobserver differences in scoring never exceeded one score. The kappa values were 0.895 and 0.951

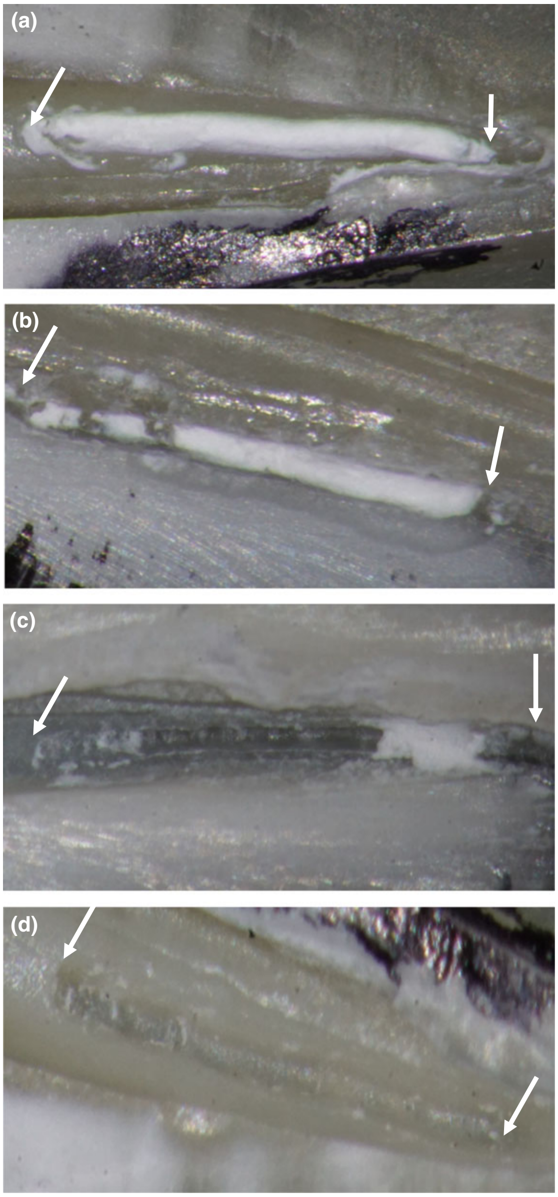

Figure 1 Score system for evaluation of removal of $Ca(OH)_2$ from the artificial groove. (a) Score 3: the groove is completely filled/covered with $Ca(OH)_2$. (b) Score 2: more than half of the groove surface is covered with $Ca(OH)_2$ (c) Score 1: less than half the groove surface is covered with $Ca(OH)_2$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

for the first and second observers, respectively, and 0.914 between the observers. Figure 2 presents the distribution of the scores for the removal of the $Ca(OH)_2$. None of the tested methods could completely remove the $Ca(OH)_2$ (Score 0) from the artificial standardized grooves. XP and PUI removed significantly more $Ca(OH)_2$ than SNI ($P < 0.001$), with no significant differences between them. A score of 3, namely a groove completely filled/covered with $Ca(OH)_2$, was given in 95% of the canals cleaned with SNI, whilst in those cleaned with XP or PUI, it was given in only 20% and 15%, respectively (Fig. 2).

Discussion

A large number of studies have been published regarding the removal of $Ca(OH)_2$ from the root canal system (Kenee *et al.* 2006, van der Sluis *et al.* 2007, Salgado *et al.* 2009, Rödig *et al.* 2011, Taşdemir *et al.* 2011, Capar *et al.* 2014, Ethem Yaylali *et al.* 2015). Some studies have evaluated the potential of different irrigation solutions (Capar *et al.* 2014, Ethem Yaylali *et al.* 2015), and others have assessed the effectiveness of different devices (van der Sluis *et al.* 2007, Salgado *et al.* 2009, Rödig *et al.* 2011, Taşdemir *et al.* 2011, Capar *et al.* 2014, Ethem Yaylali *et al.* 2015). All of the studies have found that it is difficult to remove $Ca(OH)_2$ from the apical third of the root canal system (van der Sluis *et al.* 2007, Salgado *et al.* 2009, Rödig *et al.* 2011, Taşdemir *et al.* 2011, Capar *et al.* 2014, Ethem Yaylali *et al.* 2015). A systematic review of the literature recently published by Ethem Yaylali *et al.* (2015) stated that ultrasonically activated irrigation was superior to SNI and apical negative-pressure irrigation, but insufficient evidence was found to indicate its superiority over the other irrigation techniques, such as sonically activated irrigation, the Self-Adjusting File (ReDent-Nova, Ra'anana, Israel) and the RinsEndo (Dürr Dental, Bietigheim, Germany). Therefore, it is necessary to search for new methods of $Ca(OH)_2$ removal. Previous studies have used the artificial standardized groove model design in the evaluation of $Ca(OH)_2$ removal (Lee *et al.* 2004, van der Sluis *et al.* 2007, Rödig *et al.* 2011, Capar *et al.* 2014). This model allows for standardization of the size and location of the grooves and the volumes of medicament used (Lee *et al.* 2004, van der Sluis *et al.* 2007, Rödig *et al.* 2011, Capar *et al.* 2014). A drawback of this artificial standardized groove design is that it does not represent the complexity of physiological root canal anatomy (Rödig *et al.* 2011, Capar *et al.* 2014).

The new XP-endo finisher file was tested in the present study as a potential tool for cleaning highly complex morphologies and inaccessible irregularities,

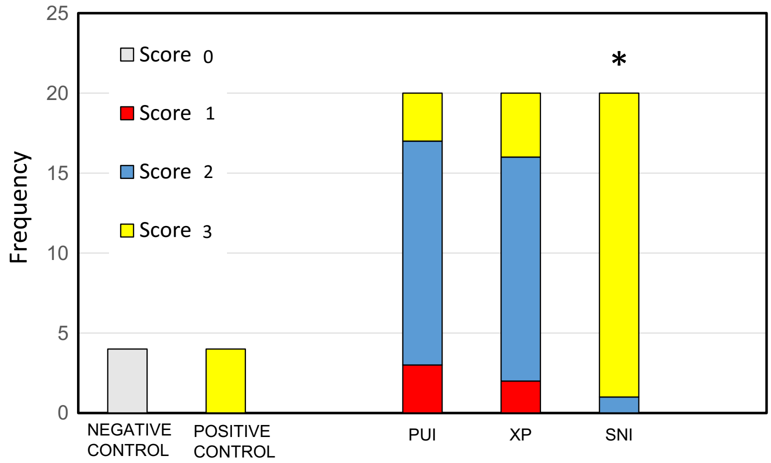

Figure 2 Frequency of scores in the three experimental groups. Score 0 was not found in any of the experimental groups. *indicates significant difference between this group (SNI) and the other groups ($P < 0.001$). PUI, Passive ultrasonic irrigation; XP, XP-endo finisher file; SNI, Syringe and needle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

as the manufacturer claims that this tool is specially effective in cleaning inaccessible recesses of root canals (FKG Dentaire). The results of the current study show that the complete removal of $Ca(OH)_2$ from artificial standardized grooves in the root canals was not obtained, and the null hypothesis that there is no difference between the various techniques was rejected because XP and PUI removed significantly more $Ca(OH)_2$ than SNI, with no significant differences between them. In the SNI group, 95% of the grooves were left completely filled/covered with $Ca(OH)_2$ following irrigation, whilst only 20% and 15% of the grooves in the XP and PUI groups, respectively, were completely filled/covered with $Ca(OH)_2$. $Ca(OH)_2$ covered more than half of the groove area in the remaining 5% treated with SNI and in 70% of the specimens treated with XP or PUI. These results were not surprising for the SNI group because irrigation without additional activation has been demonstrated to be ineffective (Rödig *et al.* 2011, Taşdemir *et al.* 2011, Capar *et al.* 2014, Ethem Yaylali *et al.* 2015). Furthermore, the PUI group results were also expected because previous studies have demonstrated its additional effect on $Ca(OH)_2$ removal (Taşdemir *et al.* 2011, Capar *et al.* 2014, Ethem Yaylali *et al.* 2015). The XP group scores were surprising because according to the manufacturer, XP is very flexible and can expand its reach to 6 mm in diameter or 100-fold greater than an equivalent-sized file, thus is claimed to allow the mechanical cleaning of the canal in areas previously impossible to reach (FKG). The file design is based on the shape-memory principles of the NiTi alloy; it is straight in its M-phase, which is achieved when it is cooled, and changes its molecular memory to the A-phase when it is exposed to the canal temperature. The idea behind this is that in rotation mode, the A-phase shape will allow the file to contract and expand according to the root canal anatomy, accessing and cleaning areas that are otherwise impossible to reach with standard instruments (FKG). This expectation was not realized in the present study in terms of $Ca(OH)_2$ paste.

One possible shortcoming is that the operator has little influence on the amount of time the file will actually contact a certain irregular area because the only factor influenced by the operator is the working time. Because the 1-min operation time, suggested by the manufacturer, was not sufficient for the effective removal of $Ca(OH)_2$ from the artificial groove in this study, longer operation periods should be tested to clarify this issue before final, more comprehensive, conclusions can be reached.

Conclusions

None of the methods tested was able to effectively remove the $Ca(OH)_2$ from an artificial standardized groove in the apical third of root canals. 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 groove.

Conflict of interest

The authors have stated explicitly that there is no conflict of interest in connection with this article.

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