http://dx.doi.org/10.1590/1981-86372020000572021 0021

| ORIGINAL

Ex vivo evaluation of the effectiveness of XP-endo Finisher on the removal of smear layer from the root canal

Avaliação ex vivo da eficácia do XP-endo Finisher na remoção de smear layer do canal radicular

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ABSTRACT

Objective: The aim of this study was to evaluate the effectiveness of XP-endo Finisher (XP) on removal of the smear layer in root canals by comparing different irrigation protocols. **Methods**: Seventy-two human single-rooted teeth were similarly instrumented using R25 Reciproc files (VDW, Munich, Germany) applied in reciprocating mode with a VDW GOLD endo motor (VDW, Munich, Germany). The working length was determined at 1 mm short of the apical foramen. The canals were irrigated with 5 mL of 2.5% sodium hypochlorite during instrumentation. The teeth were divided at random into six groups (n=12). A control group, which was not submitted to the final irrigation protocol, and five experimental groups with different irrigants and agitation techniques: EDTA/File, EDTA/XP, EDTA/Passive Ultrasonic Irrigation (PUI), Distilled Water (DW)/XP, and DW/PUI). Smear layer removal quality scores were assessed in the apical, middle, and cervical thirds of the root canal based on images obtained by scanning electron microscopy. Data were analyzed using the Kruskal-Wallis test, followed by two-by-two comparisons with the Dunn test (α=5%). **Results**: EDTA/File, EDTA/PUI, and EDTA/XP groups demonstrated significantly lower scores than the other groups (P<0.05) in all thirds evaluated. No significant difference was observed between the groups in which distilled water was used and the control group in all thirds evaluated (P> 0.05). **Conclusion**: The XP-endo Finisher file did not increase the efficiency of EDTA in removal of the smear layer in root canals.

Indexing terms: Root canal irrigants. Smear layer. Scanning electron microscopy. Ultrasonics.

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How to cite this article

Pereira SM, Carvalho CN, Tavarez RR, Nelson-Filho P, Silva LAB, Maia Filho EM. Ex vivo evaluation of the effectiveness of XP-endo Finisher on the removal of smear layer from the root canal. RGO, Rev Gaúch Odontol. 2022;70:e20220057. http://dx.doi.org/10.1590/1981-86372020000572021 0021

RESUMO

***Objetivo**: Avaliar a eficácia do XP-endo Finisher (XP) na remoção da smear layer em canais radiculares, comparando diferentes protocolos de irrigação. **Métodos**: Setenta e dois dentes humanos unirradiculares foram similarmente instrumentados usando limas R25 (VDW, Munich, Germany) aplicadas no modo reciprocrantes em um motor endodôntico VDW GOLD (VDW, Munich, Germany). O comprimento de trabalho foi determinado a 1 mm aquém do forame apical. Os canais foram irrigados com 5 mL de hipoclorito de sódio 2,5% durante a instrumentação. Os dentes foram divididos aleatoriamente em seis grupos (n=12). Um grupo controle, que não foi submetido ao protocolo final de irrigação, e cinco grupos experimentais com diferentes irrigantes e técnicas de agitação: EDTA/Lima, EDTA/XP, EDTA/Irrigação Ultrassônica Passiva (IUP), Água destilada (AD)/XP, e AD/IUP). Os escores de qualidade de remoção da camada de smear layer foram avaliados nos terços apical, médio e cervical do canal radicular com base em imagens obtidas por microscopia eletrônica de varredura. Os dados foram analisados pelo teste de Kruskal-Wallis, seguido de comparações dois a dois pelo teste de Dunn (α = 5%). Resultados: Os grupos EDTA/lima, EDTA/PUI e EDTA/XP demonstraram escores significativamente menores que os outros grupos (P <0,05). Não foi observada diferença entre os grupos que utilizaram água destilada e o grupo controle em todos os terços avaliados (P> 0.05). **Conclusão**: A lima XP-endo Finisher não aumentou a eficiência do EDTA na remoção da smear layer em canais radiculares.*

Termos de indexação: *Irrigantes do canal radicular. Camada de esfregaço. Tomografia com microscopia eletrônica. Ultrassom.*

INTRODUCTION

Successful endodontic treatment depends on effective control of the infection during the treatment. In this regard, chemo-mechanical preparation plays an essential role in the elimination or reduction of bacteria [1]. However, it has been shown that large areas of the root canal walls remain untouched after instrumentation [2] and that bacteria remained inside the root canals, irrespective of the instrumentation technique employed [3]. Accordingly, a irrigation becomes essential to ensure cleanliness in areas that have not been subjected to mechanical instrumentation [4] and direct contact of the irrigant solution with the entire wall of the root canal is essential for effective action [5], and removal of the smear layer is essential for the irrigant to be able to permeate the whole root canal system.

Using the conventional irrigation method, with syringe and needle, is insufficient for complete cleaning of the root canal system (lateral, isthmus, and accessory canals) [6]. In addition, air trapped in the apical third of the root canal can hinder the action of the irrigant and its effectiveness in debridement [7]. Agitation of irrigants using endodontic files, sonic, ultrasonic or laser devices has been associated with improvement in cleaning and disinfection of the root canal system [8]. Passive ultrasonic irrigation (PUI) comprises activation of the solution using fine-gauge instruments with ultrasonic oscillation after root canal instrumentation [8]. PUI has been considered more effective than conventional irrigation with manual agitation [6]. However, the use of PUI is limited in canals with complex anatomies, considering that direct physical contact of the instrument with walls of the root canal is essential, thereby reducing its cleaning potential [8].

A rotary nickel-titanium file named XP-endo Finisher (XP-FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) was developed, produced with a highly flexible Martensite-Austenite alloy. The file is straight when cooled (Martensitic phase) and the shape changes on contact (Austenitic phase) based on changes in body temperature. Accordingly, the instrument expands in the last 10 mm, allowing an expansion of 6 mm in diameter or 100 times a file of the corresponding size. According to the manufacturer, this feature aids in removal of the smear layer present in the root canal, even in canals with extremely complex morphologies [9]. Moreover, the file has been shown to be effective in removing debris [10], filling materials [11], and root canal disinfection [12].

The aim of this study was to evaluate the effectiveness of the XP-endo Finisher (XP) in removal of the smear layer in root canals by comparing different irrigation protocols.

METHODS

This study was approved by the Ethics Committee of Ceuma University for research on human subjects (CAAE 57876616.1.0000.5084), and the procedures used met the protocols stipulated in the ethical guidelines in the Declaration of Helsinki.

Selection of the specimens and instrumentation

Seventy-two mandibular incisors and single-rooted canines extracted from humans were used in this study. Organic material was removed from the root surface using curettes. The teeth were stored in 0.1% thymol at 4°C and subsequently radiographed in the mesiodistal direction. Teeth with internal resorption, curved roots, presence of diffuse or localized calcification in the root canal, endodontic treatment, and root length less than 13 mm were excluded.

The selected teeth were sectioned at the cemento-enamel junction leaving the specimens with an average length of 13 mm. Longitudinal orientation grooves were made on the external root surface with a diamond disk (Vortex, São Paulo, SP, Brazil), to facilitate subsequent root cleavage. The root apex was sealed with utility wax (NewWax, Rio de Janeiro, RJ, Brazil) to prevent leakage of irrigating solution.

Following this, the specimens were fixed with dense condensation silicone (Clonage, DFL, Rio de Janeiro, RJ, Brazil) and placed at the center of a metal muffle. Root canal preparation was done using R25 Reciproc files (VDW, Munich, Germany).

The files were driven under reciprocating movement, using VDW Gold engine in Reciproc All mode (VDW, Munich, Germany). The working length (WL) was determined at 1 mm short of the apical foramen. The canals were irrigated with 5 mL of 2.5% sodium hypochlorite during instrumentation. Irrigation was performed 2 mm short of the WL using 30G needles with side and apical opening (Navitip, Ultradent, South Jordan, UT, USA) attached to the luer lock type disposable syringe, followed by aspiration with suction cannula.

Irrigant activation protocols

After instrumentation and drying of the root canals with absorbent paper tips, the teeth were randomly allocated into five experimental groups and one control group (n=12 specimens/group). No final irrigation procedure was performed in the control group, and the specimens were only instrumented and dried. The other groups were submitted to the final irrigation by changing the irrigant (17% EDTA - Biodinâmica, Ibiporã, Paraná, Brazil, or distilled water - DW) and the irrigant activation technique (manual agitation, PUI, or XP) giving rise to the five experimental groups: EDTA/File, EDTA/XP, EDTA/PUI, Distilled water/XP, and Distilled water /PUI.

For the agitation technique using files, the irrigants were injected into the root canal using 30G needles 1 mm short of the WL. Manual agitation was performed with a K-File #20 (Dentsply, Maillefer, Ballaigues, Switzerland) for 3 min with up and down movements, without touching the walls of the root canal. The root canals were irrigated with 2.5 mL EDTA solution before and after agitation with the file.

PUI was performed with a 21 mm IrriSafeTM instrument (IrriSafeTM # 20, taper 00 - IrriSafe, Acteon, Merignac, France), driven by an EMS PM100 ultrasound unit (EMS Company, Nyon, Switzerland). The instrument was introduced 2 mm short of CT with upward and downward movements for 20 s, without touching the dentin walls. After aspiration of the solution, the protocol was repeated two more times, using a total of 5 mL of the solution, during an activation time of 60 s, divided into three cycles of 20 s each.

To use the XP-endo Finisher, it was attached to a contra-angle dental handpiece (VDW GmbH) and cooled (Endo-Frost; Roeko, Lanhenau, Germany), as recommended by the manufacturer. The root canal was filled with 1 mL of the irrigant according to the group. The XP was inserted into the root canal and activated in slow longitudinal movements (800 rpm, 1 Ncm torque) for 60 s until the WL was reached. The instrument was removed, and the root canal was irrigated with 4 mL of the irrigating solution.

After the final irrigation protocols, irrigants were aspirated using capillary tips (Ultradent, São Paulo, Brazil) and the root canals were dried with absorbent paper tips. Subsequently, the specimens were stored in Eppendorf tubes.

Scanning Electron Microscope (SEM) Analyses

The teeth were cleaved in two sections using a chisel inserted in the previously made longitudinal grooves (SS White Duflex, Rio de Janeiro, Brazil). For each sample, one section was randomly selected and the other was discarded. Each specimen was coated with gold (Desk II, Denton Vacuum, Moorestown, NJ, USA) and evaluated under a SEM (JSM5410, Jeol Ltd., Tokyo, Japan) by an examiner blinded to the group to which each sample belonged, and who selected a representative image for each third.

The smear layer was evaluated on representative images of the apical, middle, and cervical thirds of each specimen under 1000× magnification.

The images were analyzed by two blinded examiners, previously calibrated and evaluated by the intra and inter-examiner Kappa test.

The presence of smear layer was evaluated based on the scores previously reported by Nelson-Filho et al. [13].

Score 0 - Surface free of debris and visible openings of fully exposed dentinal tubules;

Score 1 - Root surface partially covered with debris;

Score 2 - Root surface completely covered with debris, without visible openings of the dentinal tubules.

Statistical Analyses

Smear layer removal scores in the experimental groups were analyzed in each third by the Kruskal-Wallis non-parametric test, followed by two-by-two comparison analysis using the Dunn test. The data were imported to the statistical software SPSS 26.0 (IBM, Armonk, NY, USA) for statistical analyses (α>0.05).

RESULTS

The result of the Kappa test for intra-examiner reliability ranged from 0.679 to 1.

The smear layer scores of the different groups are presented in table 1. Figure 1 shows the percentage values of each score in the groups. Figure 2 shows representative MEV of each group, in the cervical, middle, and apical thirds of the root canal.

EDTA/File, EDTA/PUI, and EDTA/XP groups demonstrated significantly lower scores than the other groups (P<0.05) in all thirds evaluated, with no significant difference between them (P>0.05). No significant difference was observed between the groups in which distilled water was used and the control group in all thirds evaluated (P> 0.05).

Table 1. Median value ranking (Mean rank) of the scores in the groups evaluated.

Thirds	Groups					
	Control	EDTA			DW	
		File	PUI	XP	PUI	XP
Cervical	1.5 (44.25)	0 (25.92) ^{a*}	0 (21.75)^{a*}	0 (29.25)^{a*}	2 (50.00)^{b}	1.5 (44.25)^{b}
Middle	1.5 (47.00)	0 (22.50) ^{a*}	0 (24.25)^{a*}	0 (24.25)^{a*}	2 (51.10)^{b}	2 (46.50)^{b}
Apical	2 (49.58)	0 (18.38) ^{a*}	0.5 (25.63)^{a*}	0 (23.83)^{a*}	2 (43.70)^{b}	2 (53.25)^{b}

Note: Different horizontal letters = significant statistical difference (p<0.05). *Significant difference compared to the control group (p<0.05)

DISCUSSION

In this study, the effectiveness of the XP-endo Finisher instrument in removal of the smear layer in root canals after biomechanical preparation was compared with different irrigation protocols using SEM. SEM is a

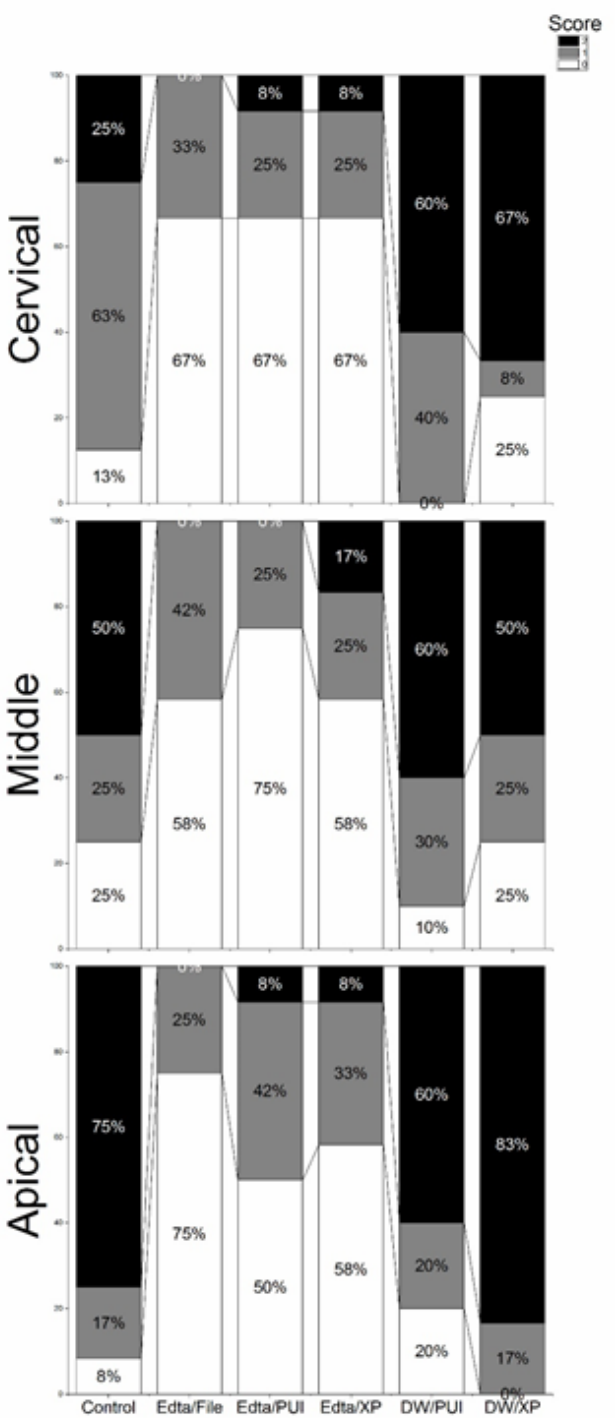

Figure 1. Percentage values of each score in the groups based on the root thirds evaluated.

valuable tool in assessment of the cleanliness of the root canal wall, since it allows numerical evaluation of the smear layer [14].

Given its bactericidal effect, sodium hypochlorite (NaOCl) is the most commonly used irrigating solution in endodontics. However, it is ineffective in the removal of the smear layer [15]. Thus, EDTA has been recommended and subjected to different studies to evaluate the efficiency of different concentrations and activation methods. Generally, EDTA is considered as an effective solution in removal of the smear layer during final irrigation [16].

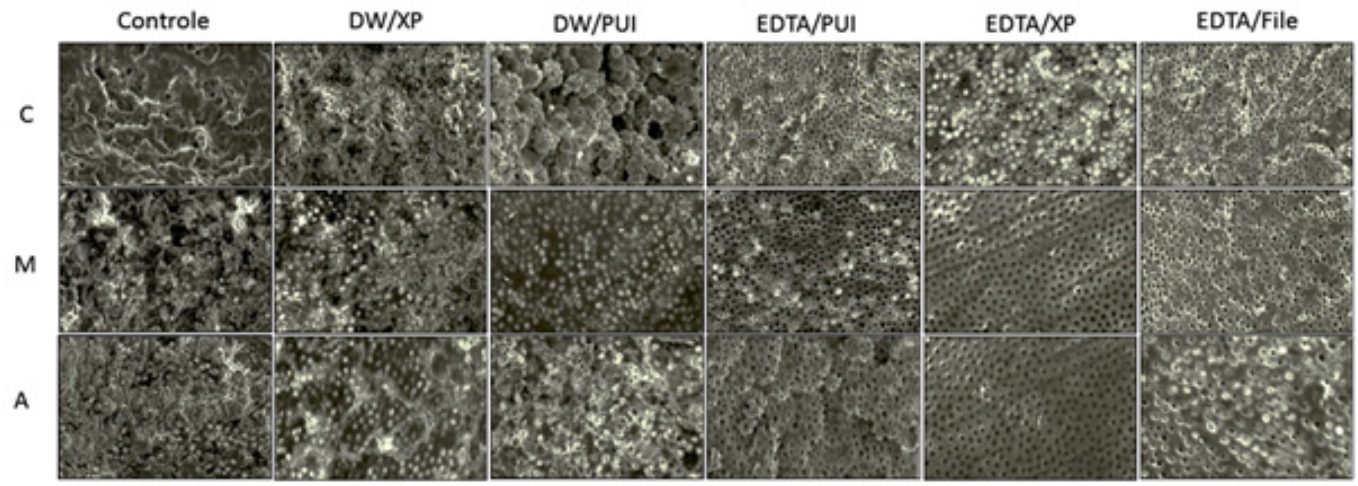

Figure 2. SEM at 1000× in the cervical (C), middle (M), and apical (A) thirds that represent the root surfaces in the control, DW/XP, DW/PUI, EDTA/PUI, EDTA/XP, and EDTA/File group samples.

The smear layer is removed by PUI due to impact of the wave produced against the walls of the root canal, which is the result of the energy of a freely oscillating instrument transmitted to the irrigant inside the root canal. This energy results in an acoustic flow, change in hydrostatic pressure, as well as production of bubbles that explode and increase the temperature and pressure [17]. Direct physical contact of the instrument with the walls of the root canal reduces acoustic flow, thus reducing the effects of PUI [8]. Therefore, short activation periods are important for the success of PUI, since they facilitate maintenance of the ultrasound tip at the center of the canal, preventing its contact with the dentin wall. This justifies the choice of the PUI protocol in the present study.

XP has proved to be an efficient instrument for agitation of irrigating solutions. The efficacy of XP can be explained by the small diameter of the instrument (ISO 25, taper zero), made with a highly flexible nickel-titanium alloy to maintain fatigue resistance. In addition, the turbulence provoked results in a large surface area of the canal coming in contact with the irrigating solution, which potentiates better cleaning of the root canals [12]. Currently, the XP instrument is one of the alternatives to potentiate the effect of irrigating solutions [18,19], enabling the removal of calcium hydroxide [20,21] and root canal filling materials [11,22,23] and disinfection of root canals [24]. The proposition of this study was to evaluate if XP possesses a synergic effect on the removal of the smear layer. Neither the XP instrument nor the technique of PUI were capable of significantly increasing the removal of the smear layer from the root canals. The results of this study are in agreement with previous study [18], which demonstrated that the most effective protocol for elimination of the smear layer might be related to final irrigation with EDTA solution. Without EDTA, the smear layer was found to cover the root canal surface in the apical, middle, and cervical thirds, regardless of the use of activation methods. Moreover, Alakshar et al. [25] demonstrated that the use of XP in an irrigation protocol failed to achieve a dentine surface free from debris in the apical portion of the majority of root canals. Similarly, Azimian et al. [26] showed that XP fared no better than the standard protocol (EDTA + NaOCl) with the removal of debris and smear layer. In view of this, there is no justification for increasing the clinical arsenal with an instrument that has not proved effective in the removal of the smear layer.

Straight canals were considered in the present study, wherein XP demonstrated results similar to PUI and manual agitation with a file in removal of the smear layer. However, other studies have demonstrated significant positive results of XP in canals with more complex anatomies as an adjuvant in the removal of obturating materials [11], and has been associated with lower levels of accumulated debris compared to conventional irrigation [27].

Satisfactory cleaning of the walls was not achieved in some cases, despite better scores in the groups where EDTA was used. Similar findings were reported in a study, which highlighted the need for advancement in the search for protocols to achieve better results [7].

CONCLUSION

The XP-endo Finisher instrument did not increase the efficiency of EDTA in removal of the smear layer in straight root canals compared to PUI and manual agitation with endodontic hand files.

Collaborators

SM Pereira, performed all experimental part. CN Carvalho, responsible for writing. RR Tavarez, responsible for the design and writing. P Nelson-Filho, performed the SEM analyses. LAB Silva, responsible for writing. EM Maia Filho, responsible for the statistical analysis.

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Received on: 26/3/2021
Final version resubmitted on: 22/11/2021
Approved on: 21/12/2021

Assistant editor: Fabiana Mantovani Gomes França