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IRRIGATION PROTOCOLS IN THE REMOVAL OF FILLING MATERIALS DURING ENDODONTIC RETREATMENT: SCANNING ELECTRON MICROSCOPY ANALYSIS

PROTOCOLOS DE IRRIGAÇÃO NA REMOÇÃO DE MATERIAIS OBTURADORES DURANTE O RETRATAMENTO ENDODÔNTICO: ANÁLISE POR MICROSCOPIA ELETRÔNICA DE VARREDURA

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IRRIGATION PROTOCOLS IN THE REMOVAL OF FILLING MATERIALS DURING ENDODONTIC RETREATMENT: SCANNING ELECTRON MICROSCOPY ANALYSIS. Bárbara Morsani Mordente ARANHA; Kênia Maria Pereira Soares de TOUBES; Daniel Sousa PARDINI; Stephanie Quadros TONELLI; Idalísio Soares Aranha NETO; Alberto Nogueira da Gama ANTUNES; Frank Ferreira SILVEIRA. JNT Facit Business and Technology Journal. QUALIS B1. ISSN: 2526-4281 - FLUXO CONTÍNUO. 2025 – MÊS DE OUTUBRO - Ed. 67. VOL. 01. Págs. 275-290. http://revistas.faculdadefacit.edu.br. E-mail: jnt@faculdadefacit.edu.br.

ABSTRACT

Endodontic retreatment is often the first choice when initial root canal therapy fails. However, removing filling materials remains a clinical challenge. This study aimed to evaluate, using scanning electron microscopy (SEM), the cleanliness of dentinal tubules in straight canals after retreatment with four different complementary irrigation techniques. Fifty-four single-rooted teeth were instrumented with the ProTaper Next system (X1–X4) and obturated using the single-cone technique with AH Plus sealer. Retreatment was performed using the ProTaper Universal Retreatment system (D1–D3), followed by re-instrumentation with the X5 file. Samples were divided into four groups according to the complementary irrigation method: Ultrasonic tip E1, tip E62, Easy Clean, and XP-Endo Finisher. Roots were sectioned longitudinally, and the most preserved half was selected for SEM analysis to quantify clean and unobstructed dentinal tubule. No statistically significant differences were observed in the degree of dentinal tubule cleanliness among the apical, middle, and cervical thirds within the tested groups ($p > 0.05$). Intergroup analysis revealed significant differences only between the control group and the experimental groups ($p < 0.05$), with no significant differences among the tested irrigation methods ($p > 0.05$). All complementary irrigation techniques contributed to cleaning and dentinal tubule de-obstruction during retreatment. However, none of the protocols were able to completely remove the filling material from the root canal system.

Keywords: Endodontic retreatment. PUI. Easy Clean. XP-Endo Finisher. Scanning electron microscopy.

RESUMO

O retratamento endodôntico é frequentemente a primeira escolha quando a terapia inicial de canal radicular falha. No entanto, a remoção dos materiais obturadores continua sendo um desafio clínico. Este estudo teve como objetivo avaliar, por meio da microscopia eletrônica de varredura (MEV), a limpeza dos túbulos dentinários em canais retos após o retratamento com quatro diferentes técnicas complementares de

irrigação. Cinquenta e quatro dentes unirradiculares foram instrumentados com o sistema ProTaper Next (X1–X4) e obturados utilizando a técnica de cone único com cimento AH Plus. O retratamento foi realizado com o sistema ProTaper Universal Retreatment (D1–D3), seguido de reinstrumentação com a lima X5. As amostras foram divididas em quatro grupos de acordo com o método complementar de irrigação: inserto ultrassônico E1, inserto E62, Easy Clean e XP-Endo Finisher. As raízes foram seccionadas longitudinalmente, e a metade mais preservada foi selecionada para análise em MEV, visando quantificar túbulos dentinários limpos e desobstruídos. Não foram observadas diferenças estatisticamente significativas no grau de limpeza dos túbulos dentinários entre os terços apical, médio e cervical dentro dos grupos testados ($p > 0,05$). A análise entre grupos revelou diferenças significativas apenas entre o grupo controle e os grupos experimentais ($p < 0,05$), sem diferenças significativas entre os métodos de irrigação testados ($p > 0,05$). Todas as técnicas complementares de irrigação contribuíram para a limpeza e desobstrução dos túbulos dentinários durante o retratamento. No entanto, nenhum dos protocolos foi capaz de remover completamente o material obturador do sistema de canais radiculares.

Palavras-chave: Retratamento endodôntico. Irrigação ultrassônica passiva (PUI). Easy Clean. XP-Endo Finisher. Microscopia eletrônica de varredura.

INTRODUCTION

Endodontic treatment failure is primarily attributed to the persistence of infection within the root canal system. In most cases, nonsurgical endodontic retreatment is the preferred approach, involving re-accessing the canal system and removing existing filling materials - such as gutta-percha and sealer - to allow for proper canal disinfection and healing of periapical tissues (Virdee; Thomas, 2017; Rodrigues et al, 2018; Cıkrık et al, 2025).

The removal of obturation materials during non-surgical endodontic retreatment can be performed using manual files, heated instruments, solvents, rotary or reciprocating systems. However, regardless of the technique employed,

complete removal of filling materials—especially in the apical third—remains challenging due to the anatomical complexity of the root canal system (Kato et al., 2016; Tandon et al, 2022; Cıkrık et al, 2025).

To overcome this limitation, supplementary methods involving mechanical or ultrasonic agitation of irrigating solutions have been proposed to enhance the removal of residual materials. Passive ultrasonic irrigation (PUI) is well-established in literature and widely adopted in clinical practice (Kato et al, 2016; Crozeta et al, 2020; Souza et al, 2021; Boutsioukis; Arias-Moliz, 2022). The recommended ultrasonic tips for PUI are delicate, with a small diameter and taper. The E1-Irrisonic tip (Helse Ultrasonic, Santa Rosa de Viterbo, Brazil) has demonstrated efficacy and is supported by several studies (Bernardes et al., 2015; Martins et al., 2017; Crozeta et al, 2020; Alves et al, 2024).

Easy Clean (Easy Bassi, Belo Horizonte, Brazil) is a plastic tip with a 25/.04 configuration, compatible with motors using asymmetric rotation or low-speed movement. Studies have shown that Easy Clean enhances filling material removal during retreatment without compromising canal walls, due to its plastic composition (Kato et al., 2016; Rodrigues et al., 2018; Souza et al, 2021).

The XP-Endo Finisher (FKG, La Chaux-de-Fonds, Switzerland), a nickel-titanium endodontic file, exhibits phase transformation properties due to its thermal treatment during manufacturing. It remains straight in its martensitic phase below 30°C and adopts a spoon-shaped configuration in its austenitic phase at body temperature, expanding up to 10 mm in length and 1.5 mm in depth. This unique design allows it to reach and clean previously inaccessible areas (Alves et al, 2016; Zhang et al., 2016; Hassan et al, 2022;).

One method for assessing dentinal tubule patency is scanning electron microscopy (SEM), which enables visualization and quantification of unobstructed tubules (Bernardes et al, 2015; Vidal et al, 2016). In this context, this study aimed to evaluate the effectiveness of different complementary irrigation techniques, passive ultrasonic irrigation and mechanical agitation, in removing filling materials after endodontic retreatment, using SEM analysis of dentinal tubule exposure.

MATERIALS AND METHODS

Sample Selection

The study was approved by the local Ethics Committee in Research of the Pontifícia Universidade Católica de Minas Gerais (PUC Minas) by protocol number 5.834.473/2023. Fifty-four extracted single rooted human teeth with complete apex formation and no lines of fracture, donated by the PUC Minas biobank with an average length between 21 and 24 mm were selected and stored in a 0.1% thymol solution. The sample size was calculated using G Power analysis and previous study (Vidal et al, 2016).

Sample Preparation

The endodontic access was conventionally performed followed by localization of the canal orifice. A K file #15 (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into the radicular canal until its tip was visualized through the apical foramen. The working length was established at 1 mm short of the previous measurement.

The teeth were endodontically treated using ProTaper Next (Dentsply Maillefer) rotary files X1 (17/.04), X2 (25/.06), X3 (30/.07) and X4 (40/.06) coupled with the X-Smart Plus endodontic motor (Dentsply Maillefer). Speed was set to 300 rpm and torque to 3.0 Ncm^3, according to the manufacturer's recommendation. Crown down instrumentation was performed, introducing the rotary file inside the canal with 3 in and out movements until the file reaches the working length. After each cycle of 3 movements, the files were cleaned with a 70% alcohol-soaked gauze. Apical patency was maintained by introducing a K file #15 beyond the apical foramen between every rotary file used.

Irrigation with 1 ml of 2.5% sodium hypochlorite (NaOCl) (LenzaFarm, Belo Horizonte, Brazil) between every file was accomplished with irrigation syringe and a 30-G Navi Tip needle (Ultradent, South Jordan, EUA) introduced 2 mm short of the working length.

After instrumentation, the canals were irrigated with 2ml of 17% EDTA

(LenzaFarm, Belo Horizonte, Brazil) followed by 2.5% of sodium hypochlorite. Then the canals were dried with absorbent paper points (Dentsply Maillefer) and the obturation was accomplished using standardized ProTaper Next gutta-percha cones and AH Plus endodontic sealer (Dentsply Maillefer) according to the single cone technique. The access opening was cleaned with cotton pellet soaked with 70% alcohol; then temporarily sealed with Coltosol temporary filling material (Coltene/Whaledent AG, Altstätten, Switzerland).

Digital radiographs of all teeth were taken using digital system FIT (Acteon, Merignac, France) to evaluate the quality of the obturation before beginning retreatment procedures. Only the teeth with homogeneous obturation, with no bubbles and good apical sealing were selected in this study.

All teeth had their length standardized to 20 mm. The adjustment was made by grinding the incisal edge with the help of a caliper (Starrett Indústria e Comércio LTDA, São Paulo, Brazil) and a high speed 1557 bur (KG Sorensen, São Paulo, Brazil). The removal of the temporary coronal seal was achieved with a high speed 1557 bur (KG Sorensen).

The endodontic retreatment of all teeth was accomplished without solvent and using the ProTaper Universal retreatment system D1, D2 and D3 (Dentsply Maillefer) respecting the recommended manufacturer's specifications of speed and torque. The instruments were introduced inside the canals with an in and out movement: D1 file was used on the cervical third, D2 file on the middle third and D3 file on the apical third and until reaching working length. After each cycle of 3 movements, the instruments were cleaned with a 70% alcohol-soaked gauze. Irrigation was achieved with 1 ml of 2.5% sodium hypochlorite between every file. Apical patency was maintained with a #15 K file 1 mm beyond the apical foramen. After this procedure, the re-instrumentation with ProTaper Next X5 file (50/.06) was performed.

Group Division

The samples were divided into four groups (n=12) according to the activation method of the solution used during final irrigation and one control group. In groups I and II, ultrasonic agitation of the irrigation solution was performed.

In group I, the irrigation solutions were activated inside the root canal system with E1-Irrisonic ultrasonic tip (Helse Ultrasonic) coupled with ENAC (Osada Eletric Co., Tokyo, Japan) ultrasonic unit.

In group II, the irrigation solutions were agitated with E62 ultrasonic tip (Guilin Woodpecker Medical Instrument, Guilin, China) coupled with Endo 3 ultrasonic unit (Guilin Woodpecker Medical Instrument).

In groups III and IV mechanical methods were employed to agitate the irrigation solutions.

In group III, Easy Clean tip (Easy Bassi) was used in a slow speed motor.

In group IV, XP-Endo Finisher file (XPR; FKG Dentaire) was used with X-Smart Plus endodontic motor.

In the control group (group V), only a final irrigation with 2.5% NaOCl was performed: no irrigation with 17% EDTA was done.

Final irrigation was performed as follows:

1. 3 cycles of 20 seconds each of 2.5% NaOCl
2. 3 cycles of 20 seconds each of 17% EDTA
3. 3 cycles of 20 seconds each of 2.5% NaOCl

Scanning Electron Microscope (SEM) Analysis

After final irrigation, longitudinal cuts were made on the buccal and palatal surfaces of the teeth, using a flexible, double-sided diamond disc (7010, KG Sorensen). With the aid of cutting pliers, the roots were then cleaved along their long axis, being divided into two halves. Thus, the half that remained most preserved was selected and taken to a scanning electron microscopy (JSM – 6510LV, JEOL Ltd., Tokyo, Japan), after gold metallization.

To analyze the presence of unobstructed/clean dentinal tubules in the apical, middle and cervical thirds, in the five groups, areas 5, 10 and 15 millimeters from the apex, in a central position, were marked and analyzed in all teeth, at a magnification of 2000x.

From the selected images, two calibrated examiners counted the unobstructed tubules. The score used will be classified into:

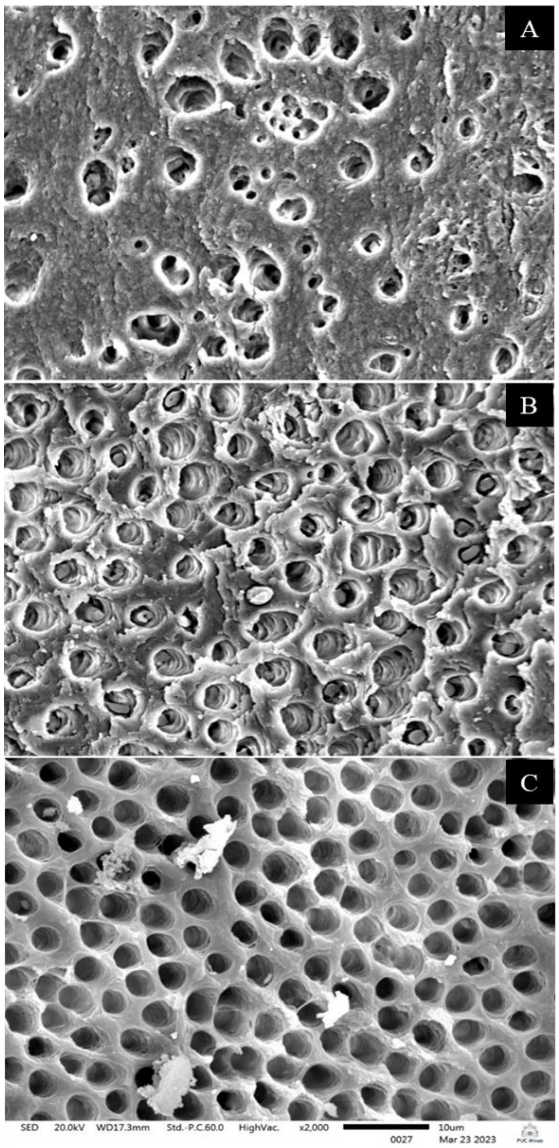
1. Absent (0): tubules completely obstructed; with not visibly clean dentinal tubules;

2. Light (1): tubules slightly unobstructed; with up to 10 clean dentinal tubules;

3. Moderate (2): moderately unobstructed tubules; with the presence of 10 to 20 tubules clean dentinal tubules;

4. Severely (3): intensely unobstructed tubules; with the presence of more than 20 tubules clean dentinal tubules.

Figure 1. SEM images of the (A) apical, (B) middle and (C) cervical thirds.



Source: own authorship (2025).

Statistical Analysis

Data were analyzed by Kruskal-Wallis statistical test followed by the post hoc test of Dunn, seeking to evaluate differences in the variable degree of patency and cleanliness of the dentinal tubules between the 5 groups, and between the thirds of each group.

RESULTS

Intra-group assessment (Table 1) revealed no significant differences in the "degree of desobstruction of dentinal tubules" between the apical, middle and cervical thirds in none of the groups ($p>0.05$).

The inter-group evaluation (Table 1) revealed significant differences only between the control group and the other test groups regarding the "degree of desobstruction of dentinal tubules" in the thirds evaluated ($p<0.05$). Between the test groups (Table 1), no significant differences were found in the "degree of dentinal tubule desobstruction" ($p>0.05$).

Table 1: Medium, minimum, and maximum value of the Score of cleaning tubules in parenthesis.

	Control	Irrisonic	Woodpecker	Easy Clean	XP-Endo Finisher	P value
Apical dentin	0 (0-1) ^{B}	2 (1-3) ^{A}	2 (2-3) ^{A}	3 (1-3) ^{A}	2,5 (0-3) ^{A}	**0,0003**
Medium third	1 (0-2) ^{B}	3 (1-3) ^{A}	3 (1-3) ^{A}	3 (1-3) ^{A}	2 (1-3) ^{A}	**0,0012**
Cervical third	0 (0-1) ^{B}	2,5 (1-3) ^{A}	3 (1-3) ^{A}	3 (1-3) ^{A}	3 (2-3) ^{A}	**< 0.0001**

In the lines, medians followed by the same capital letters show no statistically significant difference ($p>0.05$). P values were obtained by the Kruskal-Wallis test followed by Dunn´s post hoc test to compare the pairs.
Source: own authorship (2025).

DISCUSSION

The removal of root canal filling materials during retreatment remains a clinical challenge due to the anatomical complexity of the root canal system. In the present study, ProTaper Universal retreatment files were used because they are widely adopted and provide favorable conditions for irrigation and decontamination

(Martins et al, 2017). Previous studies have shown that none of the currently available manual, rotary, or reciprocating systems achieve complete removal of gutta-percha and sealers (Vidal et al, 2016). Re-instrumentation with a larger file size, as performed here, is also recommended to reduce residual materials and facilitate irrigant effectiveness (Souza et al, 2021). Moreover, irrigant activation has consistently been reported as an effective strategy to improve canal wall cleanliness by enhancing irrigant access to complex areas (Bernardes et al, 2015; Prado et al, 2018). In agreement with these findings, all activation methods tested in this study were superior to the control group, although no significant differences were found among them in any canal third, confirming the null hypothesis.

Regarding Easy Clean, our findings corroborate those of Rodrigues et al. (2018) and Souza et al. (2021), who also reported no significant differences when comparing it with passive ultrasonic irrigation (PUI). Although originally designed for reciprocating motion, Duque et al. (2016) showed superior performance when Easy Clean was used in continuous rotation, especially in cleaning isthmuses and main canals of mandibular molars, which justifies its use in this study with a slow-speed motor and contra-angle. This approach makes the system an advantageous and low-cost option, especially in undergraduate teaching and general practice. Similarly, the Endo 3 ultrasonic device with the E62 insert showed effective results, supporting the possibility of using PUI with helical tips as an alternative to delicate tips (Bernardes et al, 2015; Crozeta et al, 2020). Despite structural differences between E62 and Irrisonic, no statistically significant differences were observed, indicating that both inserts are clinically viable.

Another device under investigation was the XP-Endo Finisher, which due to its shape-memory alloy and spoon-shaped design upon exposure to body temperature enhances contact with the canal walls and contributes to greater removal of filling materials (Alves et al, 2016; Hassan et al, 2022). Volponi et al. (2020) reported that XP-Endo Finisher was superior to PUI in removing filling material from oval canals, but our findings did not confirm this result, most likely due to methodological differences, particularly the use of micro-CT in their study to quantify remnants.

For assessment of residual filling material, scanning electron microscopy (SEM) was employed, as it provides high-resolution images that allow detailed analysis of dentinal tubule cleanliness (Bernardes et al, 2015). Nevertheless, SEM presents limitations related to its destructive nature and restricted visualization of only selected canal segments (Park et al, 2020). Non-destructive methods such as micro-CT and confocal microscopy have been increasingly used (Silva et al, 2015; Volponi et al, 2020; Santos et al, 2022), but do not fully overcome current methodological limitations, including the inability to evaluate sealer penetration in dentinal tubules.

The present results demonstrated that all activation techniques—PUI with E1 and E62 tips, Easy Clean, and XP-Endo Finisher contributed to additional cleaning after retreatment, but none was able to completely remove obturating materials, particularly in apical and middle thirds, consistent with previous reports (Vidal et al, 2016). Recent studies reinforce these findings. Almohareb et al. (2023) demonstrated that ultrasonic and diode laser activation were more effective than manual irrigation, while Cıkrık and İnce-Yusufoğlu (2025) observed greater efficiency of EDDY for MTA Fillapex removal and Ultra-X for BC sealer. These data and others (Lyngdoh et al, 2024) emphasize that sealer type strongly influences retreatment effectiveness, with bioceramics being more resistant due to their hydrophilic nature and deeper penetration into dentinal tubules.

Other aspects should be clinically considered. Alves et al. (2024) demonstrated by micro-CT that both Easy Clean and PUI may lead to dentin wear in the apical third, with Easy Clean causing greater loss of dentin. This finding highlights the need to balance cleanliness with dentin preservation, particularly in narrow or curved roots. With respect to postoperative outcomes, İnce-Yusufoğlu et al. (2023) reported less pain with manual dynamic agitation compared to EDDY, suggesting that more aggressive systems may cause greater early postoperative discomfort due to debris extrusion, although differences subside after seven days. Furthermore, irrigant penetration represents another limiting factor, as Gunes et al. (2024) found deeper NaOCl penetration into dentinal tubules in the middle and coronal thirds with PUI and

XPR, but significantly lower effectiveness in apical thirds, which is consistent with our findings and reinforces the influence of root anatomy.

In view of the constant development of new irrigant activation methods, further studies are necessary to validate their effectiveness, assess their impact on dentin structure and postoperative outcomes, and provide clinical protocols supported by evidence. Within the limitations of this study, it can be concluded that the activation of irrigation contributes significantly to the cleaning of root canals during retreatment, although none of the evaluated techniques achieved complete removal of filling materials.

CONCLUSION

Based on the results of the present study, it can be concluded that:

1. All irrigation activation protocols tested were effective in enhancing the cleanliness of the root canal system during endodontic retreatment.
2. None of the protocols, however, were able to achieve complete removal of the obturating materials, particularly in the apical and middle thirds.
3. Irrigant agitation can be effectively achieved using alternative methods that do not require ultrasonic devices, which may represent a clinically accessible option.

The authors declare no conflicts of interest.

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