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Removal of bioceramic cement evaluation after root canal retreatment using two complementary irrigant cleaning and activation systems

Adriana Licet Verdugo Balcázar[1], Karol Jazmín Carrillo Rengifo[2]
[1] Graduated in Endodontics, Department of Endodontics, University Hemisferios, Quito, Ecuador
[2] Specialist in Endodontics, Department of endodontics, Professor of the postgraduate program in Endodontics at the University of Los Hemisferios, Quito, Ecuador

Abstract
The introduction of bioceramic sealer has enabled the development of properties such as biocompatibility, bioactivity, and sealing ability, due to the interaction between the sealer and radicular dentin, which results in the formation of hydroxyapatite as a byproduct. Therefore, the ability of the cement to penetrate dentinal tubules is a key factor to consider during retreatment, along with the need for effective retreatment strategies to adequately address these clinical challenges. This study aims to evaluate the efficacy of two different cleaning and irrigant activation techniques (XP-Endo Finisher and AF Max 1) for the removal of the bioceramic cement Neosealer flo (ZARC) during root canal retreatment, analyzed using scanning electron microscopy (SEM). Materials and method: an *in vitro* study was conducted using 25 single-rooted premolar roots. After disinfection, instrumentation was performed with RECIPROC BLUE 25 files, and obturation was carried out using the hydraulic technique with a single cone and NeoSealer Flo (ZARC) bioceramic cement. After three weeks, retreatment was performed using AF Retreatment Rotary files (FANTA, Shanghai, China), and specimens were randomly divided into two groups of 12 roots and one group of a single root. Group 1 (Negative control): no complementary system used, group 2: XP-Endo Finisher used, group 3: AF Max 1 used. The specimens were examined by thirds using SEM. Statistical analysis was performed in RStudio using the Kruskal–Wallis and Mann–Whitney tests. Results: Kruskal–Wallis test (C vs XP vs AF) by canal third: cervical: $H = 5.882$, $p = 0.053$, $\varepsilon^2 = 0.176$, middle: $H = 3.710$, $p = 0.156$, $\varepsilon^2 = 0.078$, apical: $H = 0.474$, $p = 0.789$, $\varepsilon^2 \approx 0$, Mann–Whitney comparisons (XP vs AF) by third: cervical: $p = 0.080$, middle: $p = 0.218$ (XP tends to perform better), apical: $p = 0.799$. No statistically significant differences were detected between techniques by canal third; however, a trend favoring XP was observed in the cervical third. Conclusion: complementary cleaning techniques enhanced the removal of bioceramic cement. Nevertheless, none of the techniques completely eliminated the residual filling material from the root canal.

Keywords: Bioceramic sealer, retreatment, xp-endo finisher, af max 1

Introduction

Primary endodontic treatment has a high success rate of 97% (Salehrabi R, Rotstein I, 2004) [13]; however, failures may occur in 14–16% of cases (Torabinejad, Corr, Handysides, & Shabahang, 2009) [21]. The persistence of necrotic tissue or the presence of microorganisms within residual filling material in the root canal system can compromise the prognosis and lead to endodontic treatment failure (Tabassum & Khan, 2016) [19].

Endodontic retreatment has proven beneficial, showing success rates comparable to those of primary root canal therapy (Alakam H, Kim H-C, Jeong JW, 2024) [9]. A favorable retreatment prognosis is influenced by several factors, including the presence and size of periapical radiolucency (Farzaneh M, Abitbol S, Friedman S, 2004) [7], removal of the coronal restoration, and elimination of root canal filling materials (Stabholz A, Friedman S, 1988) [18]. The obturation techniques used during initial treatment affect the amount of remaining filling material, which in turn influences the time required for retreatment (Athkuri S, Mandava J, Chalasani U, Ravi RC, Munagapati VK, Chennareddy AR, 2019) [2].

Calcium silicate-based sealers used for obturation form hydroxyapatite crystals at the dentin–sealer interface, making dentinal wall removal challenging. Although dentin penetration is not a drawback, the depth of bioceramic cement infiltration and the blockage of dentinal tubules can complicate retreatment procedures (Hyunsuk, Euiseong, Seung-Jong, & Su-Jung, 2015).

Bioceramic sealers in endodontics have emerged as materials that are not sensitive to moisture or blood contamination, and therefore are less technique-sensitive. They are dimensionally stable and exhibit slight expansion (Debelian & Trope, 2016) [5]. The first article of the 20th century introducing hydraulic ceramics for dentistry described a material known as MT aggregate, later referred to as MTA, composed of a hydrophilic powder containing "tricalcium silicate, tricalcium aluminate, tricalcium oxide, silicate oxide, and other mineral oxides" (Primus, Tay, & Niu, 2019) [10]. Calcium silicate-based cements are also valued for their biocompatibility and bioactivity (Yuan *et al*., 2023). NeoSealer Flo (Avalon Biomed, Houston, TX, USA) is a premixed bioceramic sealer composed of tricalcium silicate (<25%) and dicalcium silicate (<10–15%) as bioactive components, along with calcium aluminate (<25%), calcium and aluminum oxide (grossite) (<6%), tricalcium aluminate (<5%), and tantalite (50%) as a radiopacifier, with trace amounts of calcium sulfate (<1%) (Zamparini, F, *et al*., 2022) [25]. According to the manufacturer, it exhibits dimensional stability with <0.1% expansion, a film thickness of <50 µm, and radiopacity equivalent to 6 mm of aluminum. The physical strength of set calcium silicate-based sealers is a critical factor determining their retrievability during retreatment, which varies among brands due to differences in setting properties (Alakam H, Kim H-C, Jeong JW, 2024) [9]. Soft-set calcium silicate sealers are easier to retrieve compared to hard-set ones. Among sealers such as EndoSequence BC, EdgeBioceramic, and NeoSealer Flo (NEO), apical permeability was significantly higher in NEO (Carrillo *et al*., 2022) [4].

Complete removal of root canal filling material is essential during retreatment to ensure proper cleaning and shaping of the canal system. Therefore, it is also necessary to identify instrumentation systems that provide clean, debris-free root canals (Agrawal P *et al*., 2019). Nickel–Titanium (NiTi) files designed for root canal preparation can be used effectively and safely to remove filling materials (Özlek E, Gündüz H, 2021). Currently, several dental manufacturers have introduced rotary NiTi retreatment systems. One such system is the AF Retreatment Rotary System (FANTA, Shanghai, China), which, according to the manufacturer, is specifically designed for the removal of obturation materials. It includes three files: D1 20.07, D2 25.08, and D3 30.09, each with a square cross-section.

The XP-Endo Finisher (XPF) (FKG Dentaire, Switzerland) is a non-tapered file made from NiTi MaxWire alloy (Martensitic–Austenitic Electropolish File X). It has an ISO tip size of 25/.00 and can expand up to 100 times its core size. At temperatures below 30 °C, the file remains straight (in the martensitic "M" phase), but when placed inside the root canal at body temperature, it transforms into the austenitic phase. In this phase, the file reaches a depth of approximately 1.5 mm. During canal insertion, the phase transformation and shape memory enhance its ability to contact and displace residual obturation materials (Farrayeh A, 2023) [6].

Askel, Sucukkaya Eren, and Celik (2019) [1] compared the removal of root canal fillings using the universal ProTaper retreatment system followed by supplementary preparation with the XP-Endo Finisher. They concluded that additional preparation with the XP-Endo Finisher after retreatment improved the removal of filling materials. The combination of complementary protocols—such as sonic and ultrasonic activation, ultrasonic inserts, and XP-Endo Finisher instruments used after obturation material removal—optimizes debris elimination and enhances root canal cleaning and disinfection (Freitas da Rosa *et al*., 2024) [8].

The AF Max 1 instrument (FANTA, Shanghai, China), according to manufacturer specifications, is designed for efficient smear layer removal, rotary cleaning, and maximum dentin preservation. It operates with a pecking motion (inward and outward) to a depth of 3 mm until reaching working length. The file rotates at 800 rpm with a torque of 1 N.

Based on the above, this study aims to evaluate the effectiveness of two different irrigant cleaning and activation techniques for the removal of bioceramic cement during root canal retreatment, analyzed using scanning electron microscopy (SEM).

Methodology

An *in vitro* experimental and comparative study was designed, using a non-probabilistic convenience sampling method. A total of 25 uniradicular lower premolar roots were selected, following the methodology described by De-Deus, G. *et al*., 2019.

Inclusion Criteria: Lower uniradicular premolars extracted for orthodontic or prosthetic reasons; permanent teeth with fully formed apices and apical patency.

Exclusion Criteria: Teeth with root curvatures greater than 5° (Schneider, 1971), assessed using the method proposed by Schneider (1971), which involves measuring the root curvature based on the angle formed by the intersection of two straight lines—one drawn along the tooth's longitudinal axis, and the other from the apical foramen intersecting the first at the point where the canal begins to deviate from its straight path. Also excluded were teeth with root resorption, calcified canals, or previous endodontic treatment.

The specimens were divided into three groups according to the complementary cleaning approach:

- **G1:** Negative control group, 1 canal, no complementary cleaning system used.
- **G2:** 12 canals treated with XP-Endo Finisher as the complementary cleaning system.
- **G3:** 12 canals treated with AF Max 1 as the complementary cleaning system.

Each group was labeled on the vestibular surface of the root using a black permanent marker:

- **G1:** Negative control group labeled as C1
- **G2:** XP-Endo Finisher group labeled as XP1 XP2, XP3, XP4, XP5, XP6, XP7, XP8, XP9, XP10, XP11, XP12.
- **G3:** AF Max 1 group labeled as AF, AF1, AF2, AF3, AF4, AF5, AF6, AF7, AF8, AF9, AF10, AF11, AF12.

Specimen Preparation

Disinfection of the lower premolars began with the removal of soft tissue and calculus using a periodontal curette. The teeth were then immersed in a 5.25% sodium hypochlorite solution for 15 minutes to eliminate organic residues. Once disinfected, the crowns were sectioned at the cementoenamel junction using diamond discs (FGM), operated with a low-speed handpiece (NSK, Japan) under irrigation, yielding standardized root samples of 13 mm.

Root canal patency was confirmed using K-files #10 and #15 (Dentsply Maillefer, Ballaigues, Switzerland), until the tip of the instrument was visible at the apical foramen. The canals were prepared using Reciproc Blue instruments (VDW, Munich, Germany) following the R25 file sequence, with pecking motions until reaching the working length, powered by the Endo Smart A motor (Woodpecker, China). Irrigation was performed with 15 ml of 2.5% sodium hypochlorite using a NaviTip 30-G needle (Ultradent, South Jordan, UT), positioned 2 mm short of the working length. Patency was verified with a K-file #10 (Dentsply Maillefer, Switzerland). Sodium hypochlorite (NaOCl) is considered the most widely used irrigant in endodontics. However, there is no consensus regarding the optimal recommended concentration. The use and concentration of these irrigants alter dentin composition and, consequently, its microhardness. A study by Haiping *et al*. (2022) reported that 2.5% sodium hypochlorite significantly reduced fracture resistance. Agarwal *et al*. (2024) noted that 2.5%

NaOCl significantly decreased dentin microhardness after 15 minutes, while the 5% solution caused the greatest reduction within 5 minutes, affecting the clinical behavior of endodontically treated teeth.
Final instrumentation and obturation protocol upon completion of canal instrumentation, an R25 gutta-percha cone was placed at 13 mm to verify the presence of tug-back (apical binding). To remove the smear layer, final irrigation was performed with 2 ml of 17% EDTA, activated ultrasonically (Ultra X, Eighteeth, China) in one cycle of 20 seconds for 1 minute. This was followed by 3 ml of 2.5% NaOCl with prior activation, and a final rinse with 2 ml of saline solution to eliminate residual irrigants and enhance sealer contact with the canal walls. An R25 paper point (VDW, Munich, Germany) was then inserted.
Canals were obturated using NeoSealer Flo bioceramic cement (ZARC, Spain) via the hydraulic single-cone technique, employing R25 gutta-percha cones (VDW, Munich, Germany). According to the manufacturer's instructions, the sealer was dispensed directly from the syringe into the canal, 4 mm short of the working length. The gutta-percha cone was then slowly inserted to full working length and sectioned at the cervical level using a heat carrier (Woodpecker). Prior to obturation, the apical foramen was sealed with composite resin.
A light-cured glass ionomer restorative material was placed at the cervical level. Digital periapical radiographs were taken to confirm the absence of underfilling, overfilling, or voids in the obturation. Once root canal obturation was completed, a notch was made on the vestibular and lingual surfaces of the roots using diamond discs (FGM), and the samples were subsequently sectioned. The obturated roots were fixed into heavy-body silicone placed in multiwell plates designed for cell culture. Water was added to each well to maintain a humid environment, and the samples were stored in an incubator at 37°C with 100% humidity for 20 days to ensure complete sealer setting.

Retreatment Procedure

All samples were retreated using the AF Retreatment Rotary system (FANTA, Shanghai, China), which consists of three instruments. First, the 30/09 instrument was introduced 3–4 mm into the root canal to achieve coronal third removal, activated at 300 RPM with 2 N torque. Then, the 25/08 file was inserted with pecking motions until engaging the gutta-percha, followed by gentle pressure to reach the working length, powered by the Endo Smart A motor (Woodpecker, China).
After each instrument, the canal was irrigated with 1 ml of NaOCl using a NaviTip 30G needle (Ultradent, South Jordan, UT). Removal of filling material was confirmed when no remnants were visible on the active portion of the instrument. Canal patency was verified using a K-file #15 (Dentsply Maillefer, Ballaigues, Switzerland).
Subsequently, the roots were randomly divided into four groups of 12 roots for each complementary approach and one root for the negative control group. Each sample was labeled with a black permanent marker according to its group:

- **G1: Negative Control Group**

No complementary approach was used after retreatment with the AF Retreatment Rotary system.

- **G2: XP-Endo Finisher Group**

The XP-Endo Finisher file (FKG, Switzerland) was used as a complementary instrument. The file was cooled, removed from its plastic tube, inserted into the canal, and activated. Slow movements with pressure against the canal walls were performed until reaching the working length, powered by the Endo Smart A motor (Woodpecker, China) at 1000 RPM and 1 N/cm torque.

Irrigation protocol:

2 ml of 2.5% NaOCl activated in 3 cycles of 20 seconds
Canal dried with paper points
3 ml of saline solution
2 ml of 17% EDTA activated in 1 cycle of 20 seconds for 1 minute
Final rinse with 3 ml of saline and canal dried with paper points

G3: AF Max 1 Group

The AF Max 1 25.00 file (FANTA, Shanghai, China) was used, activated by the Endo Smart A motor (Woodpecker, China) at 800 RPM and 1 N/cm torque. The file was operated with in-and-out pecking motions to a depth of 3 mm until reaching the working length.

Irrigation protocol

2 ml of 2.5% NaOCl activated in 3 cycles of 20 seconds
Canal dried with paper points
3 ml of saline solution
2 ml of 17% EDTA activated in 1 cycle of 20 seconds for 1 minute
Final rinse with 3 ml of saline and canal dried with paper points
After completing the retreatment procedures with the complementary approaches, the samples were split in half using a straight elevator, applying gentle pressure and leveraging the previously made notch. The specimens were then analyzed using a Scanning Electron Microscope (SEM) at the Nano Instrumentos laboratory located in Quito.

Preparation samples for Scanning Electron Microscopy (SEM)

The samples were longitudinally sectioned, and the half with the sharpest cut was selected and placed in labeled test tubes.
Observations were conducted using the Phenom XL G2 Scanning Electron Microscope (SEM), with an adjustable electron beam ranging from 4.8 kV to 20.5 kV. Each sample was mounted on a double-sided carbon tape affixed to an SEM specimen holder. The samples were then gold-coated using a sputter coater (Quorum Q105R) under the following parameters: 15 mA and 80 Torr for 30 seconds, producing a gold layer approximately 20 nm thick. SEM observations were performed at 10 kV.
Microphotographs were taken of the cervical, middle, and apical thirds, allowing visualization of bioceramic sealer removal at a magnification of 2500×. The cleanliness of dentinal tubules was evaluated based on SEM image scoring, following the criteria established by Torabinejad (2003) [21]:

- **No smear layer:** No smear layer on the canal surface; tubules are clean and open.

- **Moderate smear layer:** No smear layer on the canal surface, but tubules contain debris.
- **Heavy smear layer:** Smear layer covers the canal surface and dentinal tubules.

The data obtained were tabulated in an Excel 2016 spreadsheet and subsequently exported as a database to RStudio for statistical analysis.

Results

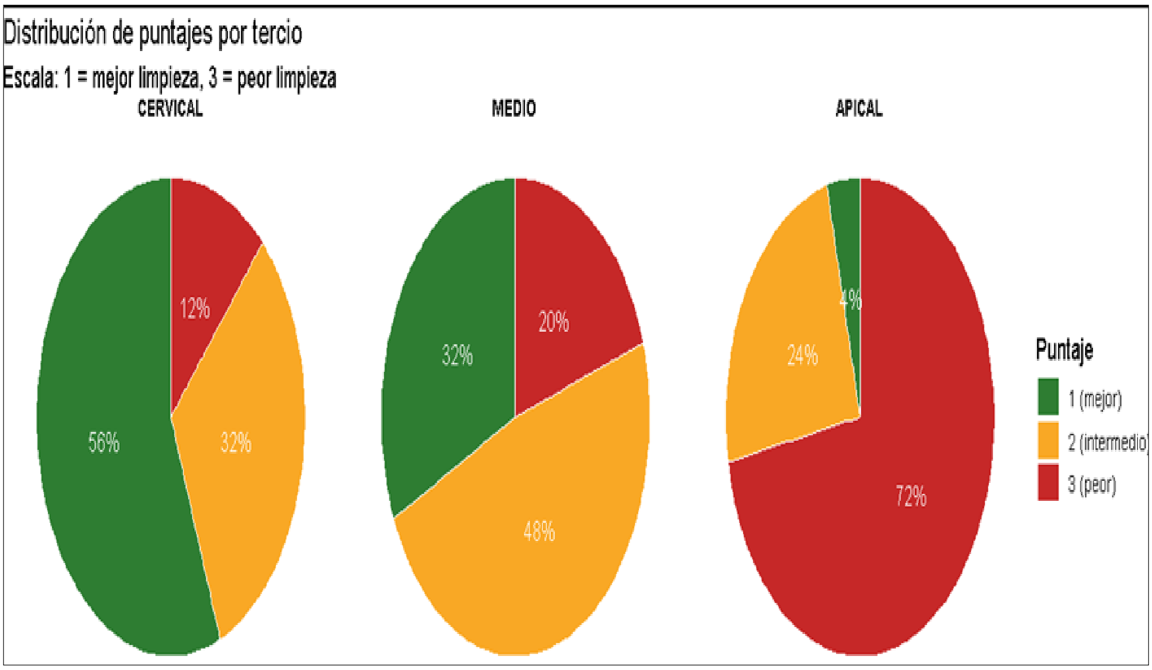

Fig 2: Overview of canal cleanliness by thirds (Cervical, Middle, and Apical)

For each canal third, the proportion of scores observed across all samples (Groups C, XP, and AF) is presented. The scoring scale is as follows: 1 = best cleanliness, 3 = poorest cleanliness.

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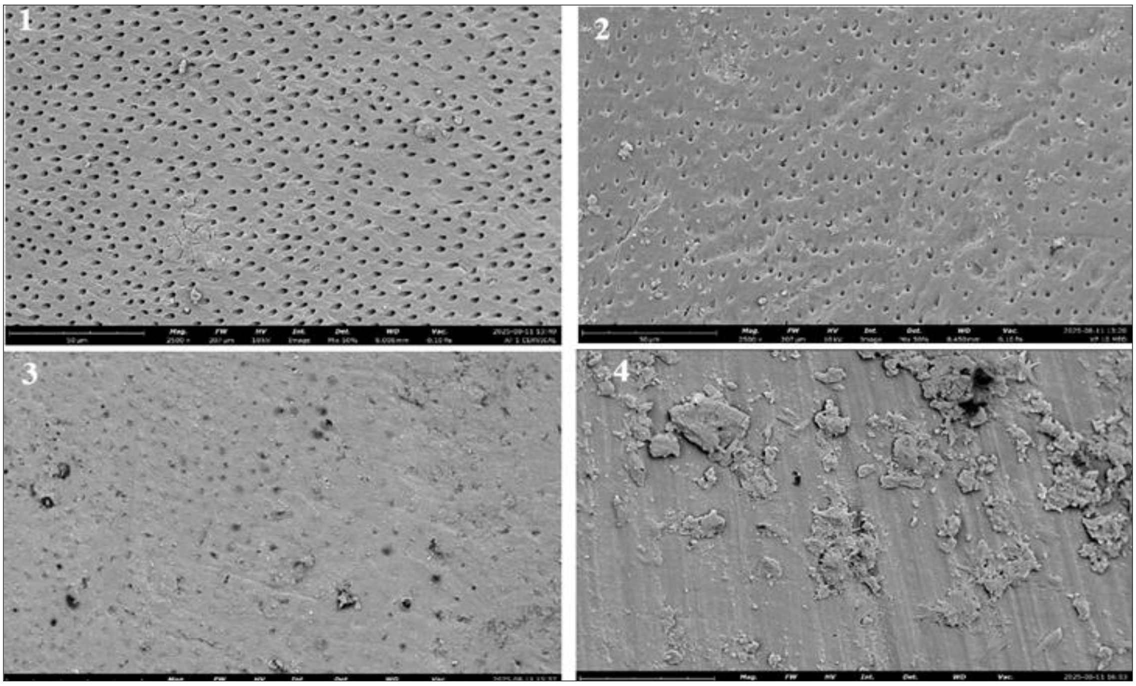


Fig 3: Scores Assigned to SEM Images

1: No smear layer — No smear layer on the canal surface; dentinal tubules are clean and open. 2: Moderate smear layer — No smear layer on the canal surface, but tubules contain debris. 3: Heavy smear layer — Smear layer covers the canal surface and dentinal tubules. 4: Control — Untreated reference sample.

Basic descriptive analysis by group and canal third

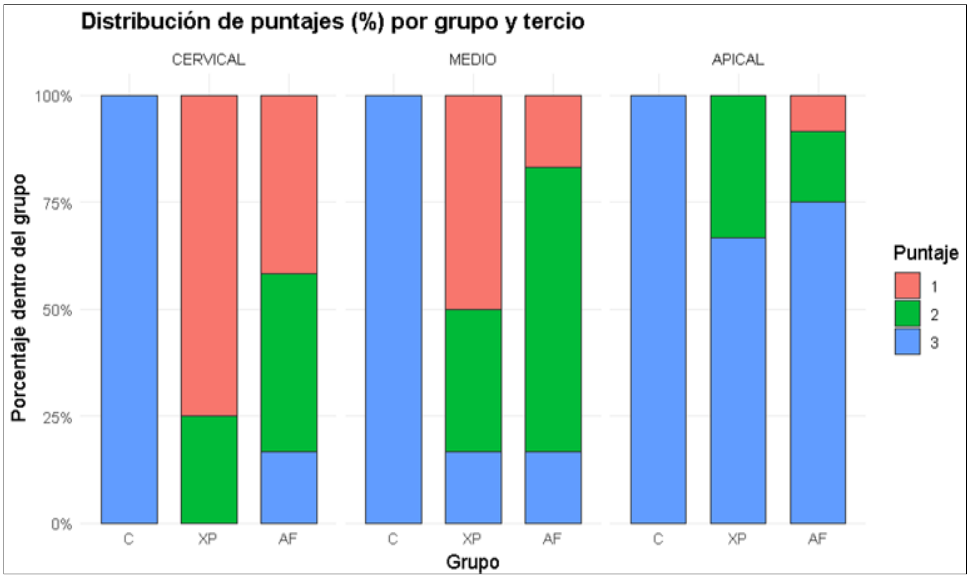
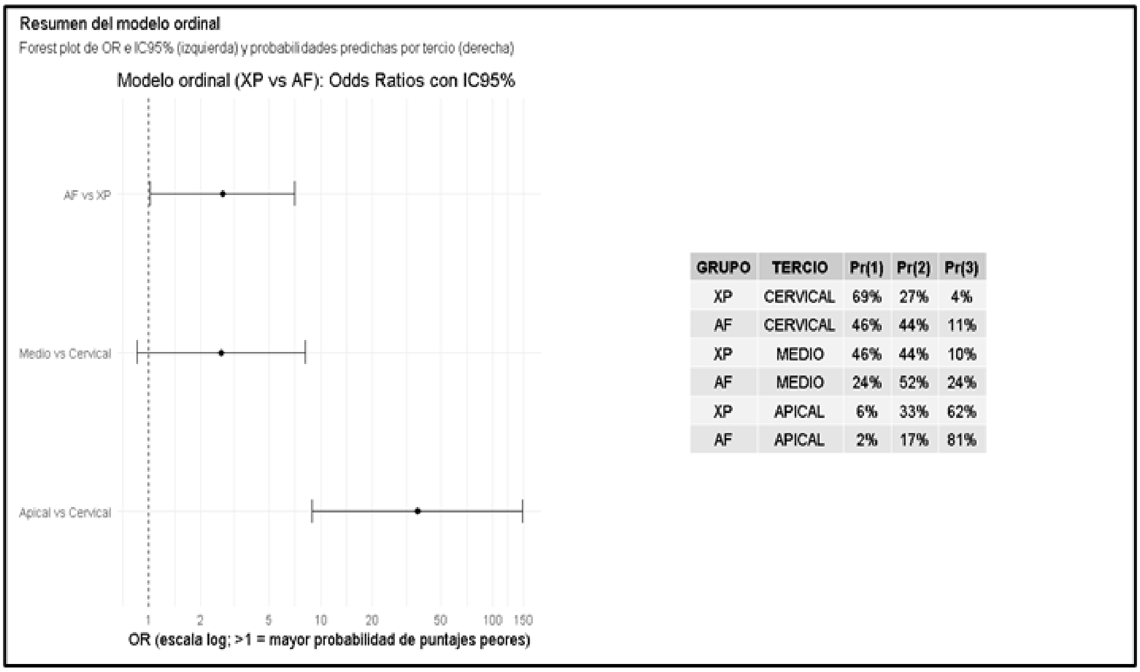


Fig 4: Stacked Bar Chart (%)

- In the cervical third, XP shows 75% of samples with score 1, in contrast to AF, which is distributed across scores 1, 2, and 3.
- In the middle third, AF stands out with 67% of samples scoring 2, while XP maintains 50% at score 1 and 33% at score 2.
- In the apical third, both groups concentrate in score 3 (XP 67%, AF 75%), indicating lower cleaning effectiveness in this region.

The visualization confirms that XP-Endo achieves better results in the cervical and middle thirds, but shows no significant advantage in the apical third.



GRUPO	TERCIO	Pr(1)	Pr(2)	Pr(3)
XP	CERVICAL	69%	27%	4%
AF	CERVICAL	46%	44%	11%
XP	MEDIO	46%	44%	10%
AF	MEDIO	24%	52%	24%
XP	APICAL	6%	33%	62%
AF	APICAL	2%	17%	81%

Fig 5: Ordinal Model (Ordinal Logistic Regression)

An ordinal logistic regression model was applied to compare cleaning scores (1 = best, 3 = poorest) between the XP-Endo Finisher and AF Max 1 techniques across the three canal thirds (cervical, middle, apical).

The left-hand chart displays the odds ratios (OR) with their 95% confidence intervals (IC95%).

OR > 1 indicates a higher likelihood of poorer scores; OR < 1 indicates a higher likelihood of better scores.

Technique Comparison:

AF Max 1 vs XP-Endo Finisher yielded an OR = 2.68 (95% CI: 1.02–7.06; p = 0.046).

Using AF Max 1 results in approximately 2.7 times greater odds of obtaining poorer cleaning scores compared to XP-Endo Finisher.

Comparison by Canal Thirds (reference: cervical):

- Middle vs Cervical: OR = 2.65 (95% CI: 0.86–8.16; p = 0.091) → trend toward poorer results in the middle third, though not statistically conclusive.
- Apical vs Cervical: OR = 36.45 (95% CI: 8.92–148.97; p < 0.001) → the apical third is clearly the most difficult to clean, with significantly worse outcomes than the cervical third.

The right-hand table presents predicted probabilities by canal third:
- Cervical: XP-Endo Finisher shows a 69% probability of score 1 (best), compared to 46% with AF Max 1.
- Middle: XP-Endo Finisher has a 46% probability of score 1 vs 24% with AF Max 1 (AF shows higher concentration in scores 2–3).
- Apical: Both techniques perform worse, but AF is more unfavorable (Pr (score 3) = 81% vs 62% with XP).

XP-Endo Finisher demonstrates superior performance in the cervical and middle thirds. The apical third consistently yields the poorest scores for both techniques, particularly with AF Max 1.

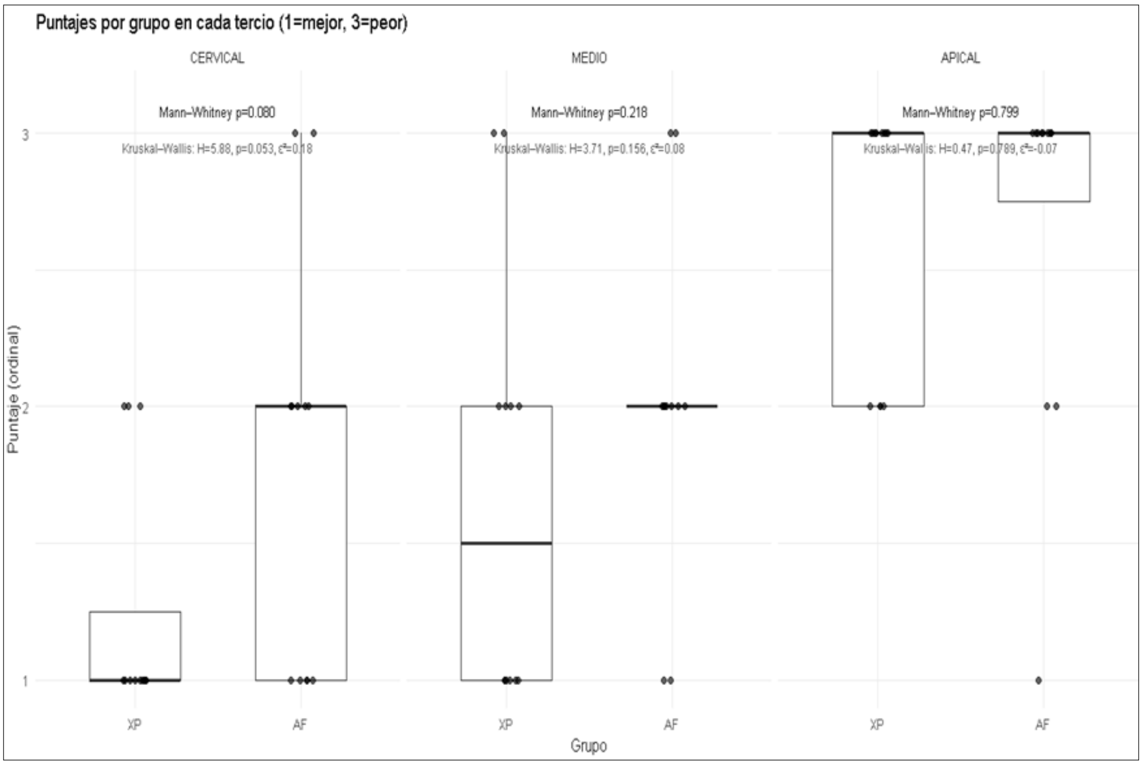


Fig 6: Kruskal-Wallis Test

The Kruskal–Walli's test was applied within each canal third (cervical, middle, apical) to compare the three groups: Control, XP-Endo Finisher, and AF Max 1. Since the control group included only one sample per third, the primary comparison between techniques was supplemented with Mann–Whitney U tests (XP vs AF) within each third. When appropriate, post-hoc Dunn tests with Holm adjustment were performed to identify specific pairwise differences

Kruskal–Wallis (C vs XP vs AF, - By canal third).

- **Cervical:** H = 5.882, p = 0.053, ε^2 = 0.176 → trend toward significance (not statistically significant).
- **Middle:** H = 3.710, p = 0.156, ε^2 = 0.078 → not significant.
- **Apical:** H = 0.474, p = 0.789, $\varepsilon^2 \approx 0$ → not significant.

Post-hoc Dunn tests with Holm adjustment revealed no statistically significant pairwise comparisons.

Mann–Whitney (XP vs AF, By canal third).

Cervical: p = 0.080 → trend toward better scores with XP.
Middle: p = 0.218 → no statistically significant differences (XP tends to perform better).
Apical: p = 0.799 → no differences; both groups show a concentration of higher (poorer) scores.

By canal third, no statistically significant differences were detected between techniques. However, the cervical third shows a trend favoring XP-Endo Finisher. In the apical third, no differences were observed, and both groups predominantly exhibited poorer scores

Discussion

The primary objective of this study was to evaluate the effectiveness of two different cleaning and irrigant activation techniques—XP-Endo Finisher and AF Max 1—for the removal of the bioceramic sealer NeoSealer Flo (ZARC) during root canal retreatment, analyzed using scanning electron microscopy (SEM).

Currently, there is a growing trend in the use of bioactive materials in endodontics, leading to the emergence of new generations of bioceramic sealers and complementary retreatment instruments such as XP-Endo files (Silva *et al*., 2018) [16] and AF Max 1. Due to the interaction between hydroxyapatite crystals at the dentin–sealer interface, removing material from the dentinal wall can be challenging (Hyunsuk, Euiseong, Seung-Jong, & Su-Jung, 2015). Therefore, the use of complementary systems for bioceramic sealer removal should be considered.

The findings of this study show that both complementary techniques promoted bioceramic sealer removal; however, the XP-Endo Finisher group demonstrated more efficient cleaning than both the Control and AF Max 1 groups. These results align with Agarwal *et al*. (2024), who evaluated the cleaning efficacy and debris extrusion of supplementary XP-Endo systems during retreatment. Their study found that XP-Endo Finisher was more effective than XP-Endo Finisher R, possibly due to its narrower tip diameter (#25 vs #30), allowing greater flexibility and improved cleaning. A known limitation of rotary retreatment files is their difficulty in reaching all areas of the root canal.

This study revealed no statistically significant differences between XP-Endo Finisher and AF Max 1, although a trend favoring XP was observed in the cervical third. This contrasts with the findings of Valponi *et al*. (2020), who used micro-CT to evaluate complementary cleaning techniques for bioceramic sealer and gutta-percha removal in oval canals, showing that XP-Endo Finisher significantly reduced residual filling material compared to other techniques.

Similarly, Shim *et al*. (2025) [15] evaluated the removal of residual mineral deposits from two calcium silicate-based sealers compared to AH Plus Jet. Their results showed that additional use of XP-Endo Finisher improved material removal and may be a viable option for retreatment—findings consistent with this study, which concluded that both complementary techniques improved bioceramic sealer removal, particularly in the cervical and middle thirds.

Bincelli *et al*. (2022) [3] demonstrated that XP-Endo Finisher R combined with passive ultrasonic irrigation effectively removed bioceramic root canal filling materials. However, no technique achieved complete removal (Sinsareekul & Hiran-Us, 2022) [17], which is consistent with the present study, where residual material remained regardless of the technique used.

This study assessed cleaning efficiency using a numerical analysis of SEM images focused on the coronal, middle, and apical thirds of the canals. Results showed: Cervical: XP-Endo Finisher achieved the best cleaning (75% score 1); AF Max 1 was distributed between scores 1 and 2 (~42% each); Control group scored 3 in 100%. Middle: XP-Endo Finisher maintained a relative advantage (50% score 1), while AF Max 1 showed a majority of score 2 (~67%), indicating intermediate cleaning. Apical: Both groups shifted toward poorer scores, with AF Max 1 reaching 75% score 3 and XP-Endo Finisher 66.7%, confirming the apical third as the most difficult to clean.

The complex anatomy and limited access in the apical third explain the accumulation of debris and persistence of the smear layer. These findings are consistent with Hyunsuk *et al*. (2015), who reported significant residual material on canal walls in both groups based on SEM imaging.

As bioceramic retreatment remains an emerging field, the limited number of studies and variability among them is understandable. Nevertheless, available research indicates that none of the evaluated techniques—complementary or otherwise—achieves complete canal cleanliness. Therefore, further research, preferably *in vivo*, is essential to better understand the biological behavior of these endodontic materials.

Conclusions

Complementary cleaning techniques enhanced the removal of bioceramic sealer; however, none of the methods achieved complete elimination of residual filling material from the root canal.

The most favorable cleaning distributions were observed with XP-Endo Finisher in the cervical and middle thirds, while the apical third showed the poorest results with both techniques, more pronounced in the AF Max 1 group.

Cleaning efficacy progressively decreased from the cervical to the apical third, with the apical region being the most challenging to clean, regardless of the complementary system used.

Complementary activation using XP-Endo Finisher and AF Max 1 improved bioceramic sealer removal.

The greater cleaning difficulty observed in the control group supports the need for complementary systems during root canal retreatment, particularly in the cervical and middle thirds, while the apical third continues to present limitations across all evaluated systems.

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