

BASIC RESEARCH

Influence of endodontic access cavity design on the effectiveness of different retreatment protocols in mandibular molars obturated with bioceramic or epoxy resin-based sealer: a micro-CT analysis.

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ABSTRACT

Aim: To evaluate the influence of endodontic access cavity design on the volumetric percentage of remaining filling material after different retreatment protocols in mandibular molars, assessed using micro-computed tomography (micro-CT).

Methodology: Sixty-four mandibular molars previously prepared and obturated with either AH Plus (epoxy resin-based) or Bio-C Sealer (bioceramic) were distributed according to access cavity type: traditional (TAC, n=32) or conservative (CAC, n=32), and further subdivided by sealer and complementary retreatment protocol: ProTaper Retreatment + XP-Endo Finisher R (XPFR) or ProTaper Retreatment + Clearsonic Black ultrasonic insert (CLEAR). Micro-CT scans (SkyScan 1276) were performed after obturation, initial filling removal, and complementary filling removal. The volumetric percentages of the remaining filling material were calculated for each root (mesial/distal) and root third (cervical/middle/apical). Three-way ANOVA and Tukey's tests were performed ($\alpha = 0.05$).

Results: TAC exhibited significantly higher initial filling material removal compared to CAC in the cervical and middle thirds of both mesial and distal roots ($p < 0.05$). AH Plus demonstrated greater retreatability than Bio-C Sealer in all groups ($p < 0.05$). The Clearsonic insert outperformed XPFR overall, especially in the distal canals ($p < 0.05$). The apical third showed the lowest removal efficiency, regardless of the protocol.

Conclusions: Initial retreatment efficiency was enhanced through traditional access. AH Plus demonstrated greater retreatability compared to Bio-C Sealer. The Clearsonic insert was particularly effective in removing filling material, especially from the distal canals. No protocol succeeded in achieving complete filling removal.

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KEY WORDS

Retreatment; Access Cavity; Ultrasonics; Root Canal Filling Materials; X-Ray Microtomography

INTRODUCTION

Endodontic failure is frequently associated with residual infection due to incomplete debridement or microleakage of the root filling, requiring nonsurgical retreatment as the first therapeutic option (1). A fundamental step of retreatment is the complete removal of previous root canal filling materials to reestablish proper irrigation, disinfection, and subsequent obturation (2). However, no technique or instrument available today can predictably achieve this goal, and residual filling material invariably remains on the canal walls (3).

Over recent decades, a paradigm shift has occurred in endodontic access cavity preparation, moving from the traditional, fully debrided access to more conservative approaches that preserve pericervical dentin and partial pulp chamber roof (4). Conservative access cavities (CAC) have been shown to enhance fracture resistance; however, their impact on instrumentation quality, canal cleaning, and retreatment efficiency remains controversial (5, 6). While previous extensive coronal destruction may limit conservative access in some retreatment cases, early endodontic failures and well-restored teeth represent clinically significant subsets in which minimally invasive approaches remain feasible. Understanding the impact of access design on retreatability under controlled conditions provides essential evidence for informed case selection and protocol optimization. To date, few studies have assessed the effect of different access cavity designs on retreatment outcomes (7, 8).

Root canal sealers play a critical role in retreatment outcomes. Calcium silicate-based bioceramic sealers have gained widespread clinical use due to their superior biocompatibility, excellent sealing ability, and dimensional stability (9). However, their deep dentinal tubule penetration, chemical bonding to dentin, and the precipitation of hydroxyapatite crystals at the sealer-dentin interface significantly increase resistance to removal (10). Epoxy resin-based sealers, such as AH Plus, are considered the gold standard for comparison, being well-studied and more susceptible to mechanical action during retreatment (11).

To maximize the removal of residual filling, supplementary instruments have been proposed alongside primary retreatment files. The XP-Endo Finisher R (XPFR) is a MaxWire alloy rotary instrument that adopts a spoon-like shape at body temperature, allowing it to reach complex anatomical areas while preserving dentin (12). The Clearsonic Black ultrasonic insert features a lance-shaped tip that mechanically debrides root canal walls, particularly in oval and flattened canal configurations (13).

Micro-computed tomography (micro-CT) is the gold standard for evaluating residual filling material, allowing nondestructive three-dimensional volumetric quantification before and after retreatment (14). Despite the growing body of literature on retreatment protocols, few studies have simultaneously assessed the influence of access cavity design, sealer type, and supplementary instrumentation on retreatment efficiency in mandibular molars using micro-CT imaging.

Therefore, this study aimed to evaluate the influence of access cavity design on the volumetric percentage of remaining filling material after different retreatment protocols in mandibular molars obturated with either AH Plus or Bio-C Sealer. The null hypotheses were as follows: (i) access cavity design does not influence the volume of residual filling material; (ii) sealer type does not influence retreatability; and (iii) supplementary instrument type does not influence residual material after complementary retreatment.

MATERIALS AND METHODS

Sample selection and experimental groups

This study was approved by the local Institutional Research Ethics Committee and used previously prepared and obturated mandibular molars from a prior investigation, also approved by the same Research Ethics Committee. Sixty-four permanent mandibular first molars were included: 32 accessed via traditional access cavity (TAC) and 32 via conservative access cavity (CAC). All teeth had been prepared and obturated using the single-cone technique. Within each access group, 16 teeth were obturated with AH Plus and 16 with Bio-C Sealer. Specimens were stored at 37°C and 100% humidity.

The 64 specimens were distributed according to a factorial design with three independent variables, each at two levels: access cavity design (traditional [TAC] or conservative [CAC]), sealer type (epoxy resin-based [AH Plus] or bioceramic [Bio-C Sealer]), and complementary retreatment protocol (XP-Endo Finisher R [XPFR] or Clearsonic Black ultrasonic insert [CLEAR]). After an initial micro-CT scan, the specimens were matched in pairs based on anatomical similarity and initial filling material volume and were then allocated to balance these characteristics across groups. Within each access cavity group (TAC, $n = 32$; CAC, $n = 32$), the specimens were first divided according to the sealer (AH or BIO, $n = 16$ each) and subsequently according to the complementary protocol (XPFR or CLEAR, $n = 8$ each), resulting in eight experimental groups with eight specimens each: TAC/AH/XPFR, TAC/AH/CLEAR, TAC/BIO/XPFR, TAC/BIO/CLEAR, CAC/AH/XPFR, CAC/AH/CLEAR, CAC/BIO/XPFR, and CAC/BIO/CLEAR.

Initial filling removal

All procedures were performed by a single specialist endodontist with 20 years of clinical experience, under magnification at 8× using a surgical operating microscope. Initial filling removal was performed in all canals using the ProTaper Retreatment system coupled to an X-Smart Plus motor according to the manufacturer's instructions. Between instruments, the canals were irrigated with 10 mL of 2.5% NaOCl using a 30-G NaviTip needle, totaling 30 mL per specimen. Filling material removal was considered complete when no filling material was visible under the microscope, on the files, or in the irrigant. A second micro-CT scan was performed

Complementary filling removal

For the XPFR groups, the canals were filled with 2.5% NaOCl, and XPFR was introduced in continuous rotation to the working length at 1 N/cm torque and 800 rpm, with slow in-and-out movements for 30 s. The procedure was repeated with 2 mL of 17% EDTA and 2 mL of 2.5% NaOCl (three activation cycles each). To maintain the instrument in its austenitic phase, the solutions were preheated to 37°C, and all procedures were performed under temperature-controlled conditions.

For the CLEAR groups, the Clearsonic insert was introduced to a maximum of 2 mm from the working length, directed buccolingually, and activated at 30% power for 30 s with long in-and-out movements, with the same EDTA/NaOCl activation sequence. After both protocols, the canals were irrigated with 5 mL of 2.5% NaOCl and dried with paper points.

Micro-CT imaging

All specimens were scanned at three time points: after obturation, after initial filling removal, and after complementary filling removal, using a micro-CT device (SkyScan 1276, Bruker microCT, Kontich, Belgium). Images were acquired at 90 kV and 200 μ A, with a 1 mm Al+Cu filter, a voxel size of 13 μ m, a rotation step of 0.4°, and 2 frame averaging. Image reconstruction was performed using NRecon v.1.7.1 (Bruker microCT) with the following parameters: smoothing 2, ring artifact reduction 1, and beam hardening correction 20%. Quantitative analysis was performed using CTan v.1.16 (Bruker microCT). Regions of interest were defined separately for mesial and distal roots, and a global threshold was applied to segment the filling material from the surrounding dental tissues. The remaining filling material was calculated for the cervical, middle, and apical thirds as a percentage of the initial obturated volume using the following formula: residual filling (%) = [volume of remaining material (mm³) / initial filling volume (mm³)] $\times$ 100.

Statistical analysis

Data normality and homogeneity of variances were assessed using the Shapiro-Wilk and Levene tests, respectively. The initial filling material volumes were compared within each sealer group using the Mann-Whitney U test to confirm equivalence between subgroups prior to allocation; no significant differences were found between the XPFR and CLEAR subgroups within either the AH Plus or Bio-C Sealer groups ($p > 0.05$). A three-way ANOVA was applied to evaluate the main effects of access cavity design, sealer type, and supplementary instrumentation protocol, as well as their interactions, on the percentage of residual filling material. Tukey's post-hoc test was used for multiple comparisons ($\alpha = 0.05$). Analyses were performed using Jamovi software (version 2.7), separately for each root (mesial and distal) and for each root third (cervical, middle, and apical).

RESULTS

No significant differences were observed in the initial filling material volumes among the experimental groups ($p > 0.05$). The three-way ANOVA revealed significant main effects for access cavity design, sealer type, and complementary instrument ($p < 0.05$), as well as a significant interaction among the three factors ($p < 0.05$).

Effect of access cavity design

The TAC groups presented significantly higher filling material removal than the CAC groups ($p < 0.05$), particularly in the cervical and middle thirds of both the mesial and distal roots (Tables 1–4). After complementary retreatment, all groups achieved removal rates exceeding 85%, markedly reducing the differences between the access designs. In the TAC/AH/CLEAR group, the mean total removal reached $94.90 \pm 4.61\%$ (mesial root) and $96.97 \pm 2.14\%$ (distal root).

Effect of sealer type and complementary retreatment

AH Plus demonstrated greater retreatability than Bio-C Sealer across all groups and root thirds ($p < 0.05$). After complementary retreatment, BIO/XPFR showed the lowest mean removal values in both mesial ($79.59 \pm 13.68\%$) and distal ($80.29 \pm 9.64\%$) roots, with significant differences compared to the other groups in the cervical, middle, and apical thirds. The Clearsonic insert significantly outperformed XPFR in overall filling material removal ($p < 0.05$), with the most pronounced difference in the distal canals (mean removal: CLEAR $96.97 \pm 2.14\%$ vs. XPFR, $80.29 \pm 9.64\%$). In mesial canals, the effect of the instrument was less marked than that of the sealer type, with the instrument-sealer interaction determining outcomes mainly in the apical third.

Table 1. Traditional access group – mesial root: percentage of initial and complementary filling material removal, total and by root thirds (mean $\pm$ standard deviation).

Group	Initial				Complementary			
	Total	Cervical	Middle	Apical	Total	Cervical	Middle	Apical
AH/CLEAR	74.72 $\pm$ 13.13a	82.52 $\pm$ 12.56a	65.37 $\pm$ 19.51a	70.39 $\pm$ 25.84a	94.90 $\pm$ 4.61a	97.94 $\pm$ 1.26a	90.76 $\pm$ 10.90a	90.70 $\pm$ 22.27a
AH/XPFR	63.04 $\pm$ 16.32a	74.45 $\pm$ 18.11a	62.04 $\pm$ 18.30a	44.97 $\pm$ 10.17a	92.57 $\pm$ 6.34a	96.12 $\pm$ 4.38a	89.80 $\pm$ 14.39a	83.31 $\pm$ 19.63a
BIO/CLEAR	77.41 $\pm$ 17.50a	89.40 $\pm$ 13.40a	67.78 $\pm$ 29.21a	52.66 $\pm$ 36.05a	85.05 $\pm$ 9.98a	98.02 $\pm$ 2.39a	73.77 $\pm$ 18.52a	53.81 $\pm$ 35.32b
BIO/XPFR	69.61 $\pm$ 18.46a	83.88 $\pm$ 12.98a	55.76 $\pm$ 36.41a	39.16 $\pm$ 25.49a	79.59 $\pm$ 13.68b	92.47 $\pm$ 6.23a	65.09 $\pm$ 30.31a	55.55 $\pm$ 19.97a

Different lowercase letters in the same column indicate statistically significant differences (Tukey's test, $\alpha = 0.05$).

Table 2. Traditional access group – distal root: percentage of initial and complementary filling material removal, total and by root thirds (mean $\pm$ standard deviation).

Group	Initial				Complementary			
	Total	Cervical	Middle	Apical	Total	Cervical	Middle	Apical
AH/CLEAR	67.50 $\pm$ 24.25a	75.61 $\pm$ 23.43a	60.54 $\pm$ 27.82a	52.02 $\pm$ 39.03a	96.97 $\pm$ 2.14a	99.54 $\pm$ 0.72a	95.72 $\pm$ 3.76a	89.76 $\pm$ 9.19a
AH/XPFR	66.03 $\pm$ 26.92a	78.44 $\pm$ 29.72a	56.68 $\pm$ 30.00a	24.61 $\pm$ 12.23a	93.85 $\pm$ 6.61a	98.93 $\pm$ 1.39a	92.80 $\pm$ 10.14a	76.25 $\pm$ 21.21a
BIO/CLEAR	69.97 $\pm$ 25.93a	74.27 $\pm$ 25.26a	67.00 $\pm$ 30.36a	64.73 $\pm$ 30.90a	91.67 $\pm$ 7.82a	99.04 $\pm$ 1.49a	88.84 $\pm$ 12.06a	55.05 $\pm$ 37.92a
BIO/XPFR	65.95 $\pm$ 18.80a	78.14 $\pm$ 22.27a	54.21 $\pm$ 25.66a	33.90 $\pm$ 26.49a	80.29 $\pm$ 9.64b	92.34 $\pm$ 6.34b	72.29 $\pm$ 18.90b	41.23 $\pm$ 24.42b

Different lowercase letters in the same column indicate statistically significant differences (Tukey's test, $\alpha = 0.05$).

Table 3. Conservative access group – mesial root: percentage of initial and complementary filling material removal, total and by root thirds (mean $\pm$ standard deviation).

Group	Initial deobturation				Complementary deobturation			
	Total	Cervical	Middle	Apical	Total	Cervical	Middle	Apical
AH/CLEAR	61.50 $\pm$ 11.6a	71.80 $\pm$ 13.9a	64.10 $\pm$ 14.13a	48.60 $\pm$ 13.5a	78.50 $\pm$ 8.7a	87.5 $\pm$ 7.8a	81.20 $\pm$ 9.4a	66.30 $\pm$ 12.10a
AH/XPFR	44.8 $\pm$ 13.2b	55.6 $\pm$ 15.2b	47.3 $\pm$ 18.7b	31.4 $\pm$ 16.8b	82.7 $\pm$ 7.1a	91.4 $\pm$ 6.7a	85.3 $\pm$ 7.8a	70.8 $\pm$ 9.4a
BIO/CLEAR	69.1 $\pm$ 10.4a	79.2 $\pm$ 11.5a	72.6 $\pm$ 12.8a	55.4 $\pm$ 11.9a	86.7 $\pm$ 5.0a	95.3 $\pm$ 4.2a	89.8 $\pm$ 5.7a	74.9 $\pm$ 7.6b
BIO/XPFR	53.30 $\pm$ 11.20ab	63.40 $\pm$ 12.4ab	57.10 $\pm$ 13.9ab	39.5 $\pm$ 14.7ab	81.20 $\pm$ 6.4a	90.80 $\pm$ 6.1a	84.6 $\pm$ 7.5a	68.2 $\pm$ 8.9a

Different lowercase letters in the same column indicate statistically significant differences (Tukey's test, $\alpha = 0.05$).

Table 4. Conservative access group – distal root: percentage of initial and complementary filling material removal, total and by root thirds (mean $\pm$ standard deviation).

Group	Initial deobturation				Complementary deobturation			
	Total	Cervical	Middle	Apical	Total	Cervical	Middle	Apical
AH/CLEAR	64.30 $\pm$ 11a	74.3 $\pm$ 12.7a	68.5 $\pm$ 13.1a	50.1 $\pm$ 13a	83.7 $\pm$ 6.8a	93.7 $\pm$ 6.2a	86.8 $\pm$ 7.3a	71.4 $\pm$ 8.7a
AH/XPFR	49.80 $\pm$ 12.6b	59.7 $\pm$ 14.8b	52.4 $\pm$ 15.2b	37.20 $\pm$ 14.10b	79.8 $\pm$ 8.2a	88.9 $\pm$ 7.3a	82.10 $\pm$ 8.6a	68.5 $\pm$ 10.4a
BIO/CLEAR	73.10 $\pm$ 9.8ab	82.6 $\pm$ 10.9ab	76.8 $\pm$ 11.5ab	58.9 $\pm$ 11.7ab	88.7 $\pm$ 4.7a	97.1 $\pm$ 4a	90.9 $\pm$ 5.4a	76.2 $\pm$ 6.9a
BIO/XPFR	58.3 $\pm$ 10.9a	68.9 $\pm$ 12a	61.3 $\pm$ 13.2a	44.7 $\pm$ 13.4a	82.10 $\pm$ 6.2a	92.4 $\pm$ 5.7a	85.5 $\pm$ 7.1a	70.3 $\pm$ 8.2a

Different lowercase letters in the same column indicate statistically significant differences (Tukey's test, $\alpha = 0.05$).

After complementary retreatment, the difference between the instruments became less significant in most groups ($p > 0.05$), although Clearsonic maintained higher mean removal values in the distal canals and cervical third. The apical third consistently exhibited the lowest filling material removal efficiency across all groups and time points. No protocol achieved complete filling removal in any of the root thirds.

Representative 3D reconstructions are presented in Figures 1 and 2.

Figure 1. Representative 3d reconstructions of micro-CT scans - Traditional access group: (a) root canals filled. (b) initial filling removal. (c) complementary filling material removal.

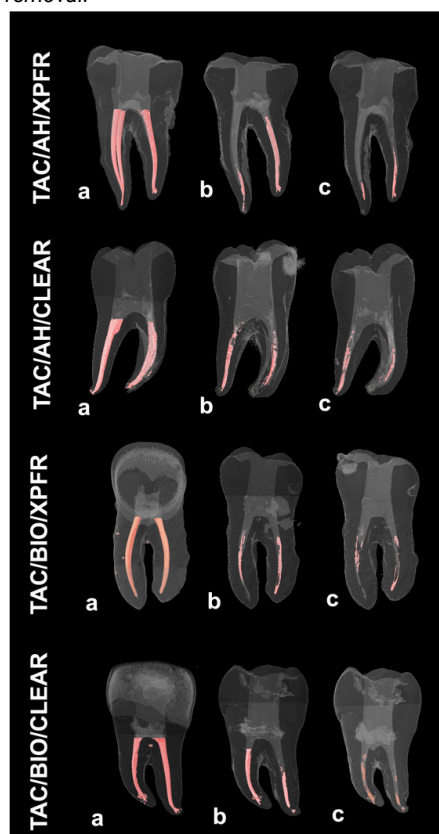
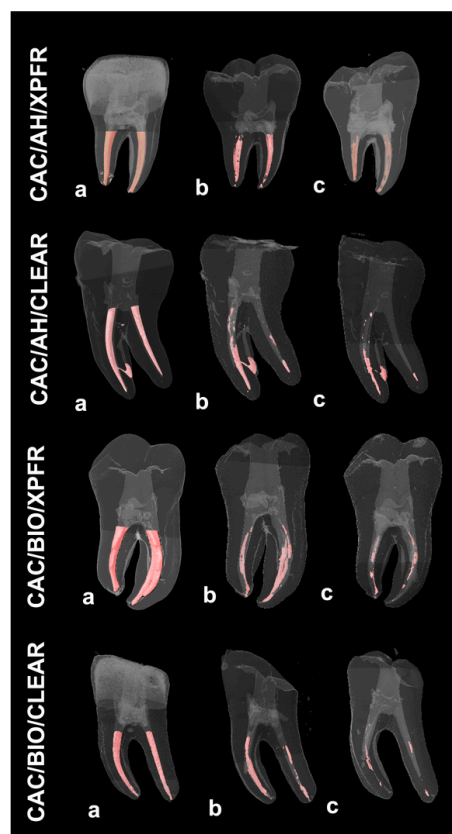


Figure 2. Representative 3d reconstructions of micro-CT scans - Conservative access group: (a) root canals filled. (b) initial filling removal. (c) complementary filling material removal.



DISCUSSION

This study evaluated, using micro-CT, the combined influence of access cavity design, sealer type, and supplementary instruments on retreatment efficiency in mandibular molars, analyzing the mesial and distal roots and the cervical, middle, and apical thirds separately. All three null hypotheses were rejected, as significant effects were identified for each factor, and significant interactions were detected among them.

The traditional access cavity demonstrated superior initial deobturation efficiency, particularly in the cervical and middle thirds of both roots, likely reflecting the more favorable geometry of TAC, which allows greater instrument efficiency, broader movement amplitude, and improved irrigant flow (5, 6). The conservative access restricts insertion angle and instrument motion, which may compromise mechanical contact with dentinal walls during initial retreatment, consistent with previous reports (7, 8). Importantly, after complementary retreatment, these differences were substantially reduced, suggesting that supplementary instrumentation and active irrigation can partially compensate for the limitations of minimally invasive access, supporting case selection of conservative access when the coronal structure permits and fracture resistance is prioritized.

To date, only two studies have evaluated the effect of access cavity design on retreatment outcomes. Fatima et al. (7) assessed uniradicular teeth by two-dimensional microscopy, and Odabaşı Tezer et al. (8) evaluated mandibular premolars by micro-CT; neither found a significant effect of access design on filling material removal. The present study is the first to use micro-CT in mandibular molars, evaluating the mesial and distal roots separately; two anatomically distinct configurations, with the flattened distal root and the narrow, curved mesial canals responding differently to retreatment protocols. This anatomical complexity may explain why access cavity design had a more pronounced effect on initial filling material removal in the present study.

These results reinforce the premise that the sealer is the main determinant of retreatability. AH Plus consistently yielded lower residual volumes than Bio-C Sealer, in agreement with most of the literature, an effect generally attributed to the bioceramic sealer's higher flowability, deeper dentinal tubule penetration, chemical bonding through hydroxyapatite precipitation, and volumetric expansion during setting (9,10,14). A systematic review concluded that the retreatment of canals obturated with bioceramic sealers is feasible, but complete removal has not been achieved by any technique (15). In the present study, Bio-C Sealer left significantly higher residual volumes even after complementary protocols, particularly in the apical third.

Our findings show that none of the protocols completely eliminated residual material from all thirds and roots. Therefore, it is advisable to employ additional methods to improve the removal of fillings (3,17). The Clearsonic insert was superior to XPFR overall, particularly in distal canals, an advantage attributable to its lance-shaped, direct-contact mechanism, which mechanically debrides canal walls including lateral areas; the wider diameter of distal canals likely allows greater freedom for the tip to combine direct mechanical impact with microstreaming (12,18). In mesial canals, the instrument effect was less pronounced, and sealer type predominated, probably because the curved, narrower morphology restricts both full tip contact and XPFR thermal expansion (17,19). Findings in the literature regarding instrument performance remain heterogeneous: some studies report XPFR providing the lowest residual material overall or improved apical patency, particularly when combined with passive ultrasonic irrigation in bioceramic-obturated canals, while others associate the Clearsonic insert, especially when paired with reciprocating systems, with lower residual percentages (20,21,22). A systematic review and meta-analysis confirmed significant residual material reduction with both ultrasonic inserts and XPFR, though no method eradicated filling material completely (3).

In every group, the apical third consistently yielded the least favorable results, reinforcing the known trend of escalating challenges as the apex is approached. The combination of Bio-C Sealer and XPFR proved to be the most problematic, a result that carries significant clinical relevance (13,23). The apical segment concentrates multiple challenges: reduced canal diameter, greater curvature, a higher likelihood of the vapor-lock effect, and greater distance from the access opening, all of which limit irrigant penetration and mechanical instrument reach, even when activation methods are combined (24). These findings reinforce the need for strategies dedicated to the apical third.

The present study agrees with reports in which AH Plus showed superior retreatability and higher apical patency restoration than bioceramic sealer, and in which the apical third showed the worst removal regardless of sealer or protocol (25). Conversely, other studies found bioceramic sealers easier to remove than AH Plus, discrepancies that may reflect differences in canal anatomy, access design, and activation parameters across studies (20,26). The present results add to this body of evidence by demonstrating, in mandibular molars, an additional advantage of the ultrasonic insert particularly in the distal root, and by showing that complementary retreatment significantly increased filling removal across all groups (>85%), reinforcing that supplementary protocols are indispensable for adequate filling removal and may compensate for initial removal deficiencies under conservative access (3,25).

Micro-CT technology facilitated the three-dimensional, volumetric, and nondestructive evaluation of residual filling material at various intervals. This was achieved by matching the initial volumes and conducting separate analyses by root and thirds, thereby broadening the clinical relevance of the results. This approach remains the gold standard for such analyses, as it reduces the biases associated with two-dimensional methods. Similar methodologies have been employed in other micro-CT studies focusing on additional retreatment protocols and the removal of sealers (13,27,28,29).

Limitations of this study include its *ex vivo* design, the inherent anatomical variability of mandibular molars despite experimental control, and segmentation/threshold decisions in micro-CT that, although standardized, may affect absolute volume estimates. Additionally, unlike some studies in the literature that included a re-preparation step with a new mechanized system following initial filling material removal (2,25,27), the present study proceeded directly to supplementary instrumentation after the initial deobturation stage. This may have influenced the absolute percentages of residual filling material reported, particularly in the apical third, as re-instrumentation beyond the original preparation diameter may expose additional canal walls and displace residual filling material. It is noteworthy, however, that Crozeta et al. (2) reported that re-preparation with rotary or reciprocating systems did not significantly improve filling material removal beyond what was achieved with the initial retreatment files alone. Given the heterogeneity of the literature on filling sealers and supplementary filling removal protocols, further research is needed to establish the ideal protocol for endodontic retreatment, particularly regarding the case selection criteria for conservative access cavities.

DISCUSSION

This study evaluated, using micro-CT, the combined influence of access cavity design, sealer type, and supplementary instruments on retreatment efficiency in mandibular molars, analyzing the mesial and distal roots and the cervical, middle, and apical thirds separately. All three null hypotheses were rejected, as significant effects were identified for each factor, and significant interactions were detected among them.

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CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

Traditional access cavities yielded greater initial filling material removal efficiency, especially in the cervical and middle thirds of both mesial and distal roots, while conservative access performed comparably after complementary retreatment.

AH Plus demonstrated superior retreatability compared to Bio-C Sealer, which showed greater resistance to removal, particularly in the apical third.

The Clearsonic Black ultrasonic insert was more effective than the XP-Endo Finisher R in removing filling material, especially in the distal canals.

The apical third showed the lowest retreatment efficiency, regardless of the protocol, access design, or sealer type.

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