





Bioceramic and Resin-Based Sealers Removal Using XP-Endo Finisher: A Scanning Electron Microscopy Study

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Abstract

Objectives The aim of this study was to evaluate remaining filling materials of a bioceramic sealer (TotalFill BC sealer) and an epoxy resin sealer (AH Plus) after retreatment using a supplementary instrumentation (XP-endo Finisher).

Materials and Methods Forty single-rooted teeth were selected for the study. The teeth were instrumented using ProTaper system and randomly divided into two groups ($n = 20$). Then they were obturated with either TotalFill BC/gutta-percha or AH Plus/gutta-percha using lateral compaction technique. Canals were retreated using ProTaper retreatment files and a solvent. The groups were subdivided ($n = 10$) according to the application or not of the XP-endo Finisher as a final step of retreatment. All roots were cleaved longitudinally and examined under scanning electron microscope to evaluate root canal filling remnants. A scoring system was utilized to quantify the amount of residual filling material at the three predetermined portions of each root canal.

Statistical analysis was performed using IBM SPSS.25 with a significant value $p < 0.05$. Data were compared using the Mann-Whitney test and Kruskal-Wallis test.

Results There was no statistically significant difference in the remaining filling materials for each third of the root canal after initial retreatment procedure between the TotalFill group and AH Plus group. Similar results were observed among the TotalFill groups with or without the application of XP-endo Finisher supplementary step. However, the remaining filling materials of AH Plus in the middle third of root canal were significantly less after the XP-endo Finisher application ($p = 0.015$).

Conclusion No retreatment protocol tested in this study allowed the total elimination of root canal filling materials. The residual root canal filling materials is similar for the bioceramic and resinous sealers. The XP-endo Finisher is not effective in improving the removal of bioceramic root canal filling material while it is able to improve the removal of resinous cement.

Keywords

- ▶ epoxy resin-based root canal sealer
- ▶ retreatment
- ▶ root canal filling materials
- ▶ scanning electron microscopy
- ▶ tricalcium silicate
- ▶ XP-endo Finisher

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Introduction

The key role of root canal sealer is the filling of the space between the core obturation material and the walls of the root canal, as well as lateral and accessory canals. AH Plus is an epoxy resin-based sealer, with higher physical properties than other root canal sealers (bond strengths to dentin, low solubility, and adequate dimensional stability). But this sealer presents no bioactive properties or osteogenic potential.¹ In this context, the utilization of bioceramic materials as root canal sealers is served by two major advantages: their biocompatibility and the presence of calcium phosphate. The composition and crystalline structure closely resemble those of tooth and bone apatite materials, thus enhancing bonding to root canal dentin.^{2,3} Nonetheless, a significant drawback associated with bioceramic materials is the challenge encountered when extracting them from the root canal during retreatment or postspace preparation. In fact, conventional retreatment techniques are not effective in removing bioceramic sealer.^{4,5}

Notwithstanding, one of the ideal root-filling material properties proves to be easily removable from the canal if endodontic revision becomes necessary.⁶ Gutta-percha is well dissolved by organic solvents, but the sealers are more resistant to chemical removal. As none of the systems could be effective in removing the bioceramic material, supplementary techniques should be employed to enhance root canal cleansing.⁷ The utilization of XP-endo Finisher (XPEF) and XP-Endo Finisher R (XPEF R) proves advantageous in effectively removing root canal filling materials.^{8,9}

The objective of this research was to assess the remaining filling materials (RFMs) of a bioceramic sealer, specifically TotalFill, and an epoxy resin-based sealer (AH Plus) after retreatment with a supplementary instrumentation using XPEF.

The initial assumption posited that there were no substantial disparities in the quantity of residual debris following retreatment, whether the XPEF file was employed or not, for both types of sealers.

Materials and Methods

Specimen Selection and Preparation

Forty human teeth with closed apices and a single root were selected and numbered for the study. Two radiographs for each tooth were taken in the B°L and M°D direction to ensure the absence of calcifications, obstructions, or internal resorption and the presence of a single canal (type I). The teeth were examined using a stereomicroscope to verify the absence of cracks. The angle of curvature of each canal was calculated according to the Schneider technique. For this study, only the canals with a curvature angle of less than 20 degrees were chosen. Then, it underwent a thoroughly meticulous cleaning to remove any residual tissues or calcification on their root surfaces, after which they were preserved in a 0.5% sodium hypochlorite solution. Flattening of the incisal edge/canine tip was done with a diamond disc to standardize the lengths to 17 ± 1 mm and to have a

reproducible coronary mark. The endodontic access cavities have been prepared.

Canal Preparation and Obturation

Manual K files no 10, 15, and 20 were used for canal patency. The working length (WL) was established visually (leaving a gap of 0.5 mm before the file tip emerged onto the root surface). Root canal instrumentation was conducted using nickel-titanium rotary ProTaper system (Dentsply Maillefer) and the Endus Duo motor (Gnatus) with a constant speed of 250 revolutions per minute (rpm), to a major apical file of 30.09 (F3) for all teeth. Each instrument sequence was used for 10 canals and then replaced. Throughout the instrumentation procedure, 2.5% sodium hypochlorite irrigation using a 27-gauge needle with lateral opening was used with a cumulative volume of 20 mL per canal. A final rinse step was performed by flushing each canal with 2 mL ethylenediaminetetraacetic acid (17%) for 2 minutes, then concluding by 2 mL of saline solution.

Sterile paper points were utilized to dry the canals and, subsequently, the teeth were randomly split into two equal groups. ($n = 20$). G1: Canals were filled with gutta-percha (TotalFill BC points, FKG) with bioceramic canal-sealing cement (TotalFill, FKG). The root canals were filled employing cold lateral compaction technique. G2: obturation with gutta-percha associated to epoxy resin-based sealer (AH Plus, Dentsply) by cold lateral compaction technique. The coronal obturation was achieved with the application of glass ionomer cement (3M).

All specimens were kept in gauze that had been dampened with sterile normal saline solution and maintained at a temperature of 37°C in a humidified chamber (100% humidity and 37°C) for 1 month to ensure a full setting of the sealer.

Retreatment

The initial retreatment protocol was standardized for all groups; Glidden Gates (no. 3 to 4) were employed to extract root canal-filling materials from the 3 first mm of the coronal parts. Before instrumentation using the ProTaper retreatment system (500 tr/min), 0.1 mL of chloroform was introduced into the canal for 30 seconds and Gentle apical pressure with brushing movements against the canal walls was applied. In case of blockage, an absorbent paper cone soaked in solvent was placed in the canal. After each use, the instrument was cleaned with a compress and the canal was irrigated with sodium hypochlorite. The initial instrumentation was considered complete when the instruments completed WL and no gutta-percha or sealant residue could be noted in its spires. Each file sequence was used in only 5 teeth.

Additional instrumentation was suggested to be employed following the initial removal of filling material by mechanical systems. The roots of each group were randomly divided into two subgroups (A and B) ($n = 10$) depending on the retreatment protocol (with or without supplementary final step with XPEF file). The groups (Gr1A and Gr2A) retreated without the use of XPEF were considered as the control groups. The XPEF (FKG, Switzerland) was utilized up to the WL, at a rotation

speed of 800 rpm. It was used for 4 canals with an irrigation solution heated to 37°C, and then replaced. To minimize any variations due to the operator, a single individual performed all of the instrumentation. Subsequently, scanning electron microscopy was employed for observation.

Scanning Electron Microscopy Observation: Evaluation of Root Canal-Filling Remnants

After retreatment, teeth were longitudinally sectioned. To prevent the penetration of debris into the canal space, cotton was used to block the access cavity. Two longitudinal buccal and lingual grooves were made with a diamond disc. After that, root surface was cleaned using a microbrush, then the root was cleaved into two halves. The more undamaged half was identified as the elected sample for the evaluation under scanning electron microscope (SEM). Samples were prepared before SEM analysis. They were dehydrated by placing them in alcohol at increasing concentrations (30, 50, 70, and 100%) for 5 minutes each time, and then dried. Then the intern surface of the root canal walls was gold-coated before examination under an SEM

(FEI Quanta 250 SEM, Netherlands). Images of each third were digitally captured at magnifications of $\times 33$, $\times 50$, and $\times 1000$. A scoring system was employed to assess the degree of RFM that covered the dentinal surface in each third of the root canal¹⁰ (► Fig. 1).

- Score 0: 0 to 25% of dentinal surface hidden with remaining debris.
- Score 1: 25 to 50% of dentinal surface hidden with remaining debris.
- Score 2: 50 to 75% of dentinal surface hidden with remaining debris.
- Score 3: 75 to 100% of dentinal surface hidden with remaining debris.

This evaluation was done by a blinded observer. There was no effort made to differentiate between gutta-percha and sealer residues.

Statistical Analysis

The statistical analysis was conducted using IBM SPSS.25 with a significant value $p < 0.05$. The Mann-Whitney test

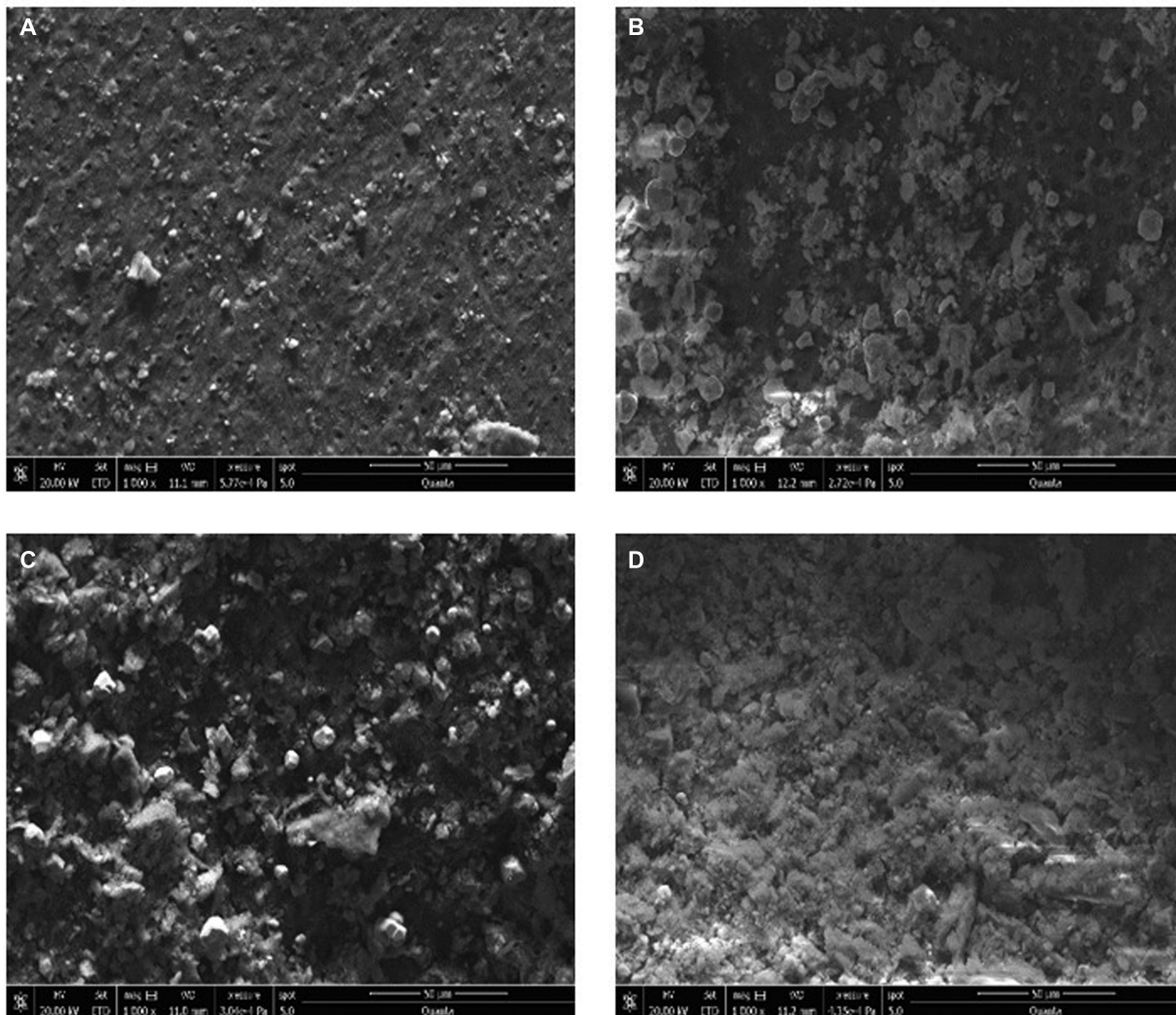


Fig. 1 A scoring system was utilized to assess dentinal surface covered with residual filling material at the three predetermined portion of each root canal: Score 0 (A), Score 1 (B), Score 2 (C), and Score 3 (D).

was utilized to assess the disparities in the quantity of RFMs between various groups.

Additionally, the Kruskal–Wallis test was utilized to examine variations in the quantity of residual filling materials within each group across the sectional thirds.

Results

All specimens exhibited RFM after all retreatment steps (–Fig. 2).

There was no statistically significant distinction noted in the quantity of RFM for each third of the root canal following the initial retreatment procedure between the TotalFill group (G1A) and the AH Plus group (G2A) ($p > 0.05$). Comparable findings were identified within the TotalFill groups (G1A and G1B) with or without the application of XPEF supplementary step ($p > 0.05$). Nonetheless, it is worth mentioning that the amount of RFM within the middle third of the canal was significantly lower

following the application of XPEF when using AH Plus ($p = 0.015$). On the other hand, there were no statistically significant variances to be observed in the coronal and apical thirds for the AH Plus group (G2B). Additionally, the middle sections of the canal in the AH Plus group (G2B) exhibited significantly less residual filling materials after using XPEF compared with the TotalFill group (G1B) ($p = 0.019$) (–Table 1).

Discussion

The comprehensive elimination of the RFM and the establishment of patency during endodontic retreatment are essential for the thorough disinfection of the root canal system, particularly when dealing with persistent periapical disease.^{11,12} We investigated the elimination of TotalFill BC sealer and AH Plus root canal sealer with mechanical instrumentation using the ProTaper retreatment system, followed by additional preparation using the XPEF (FKG). This

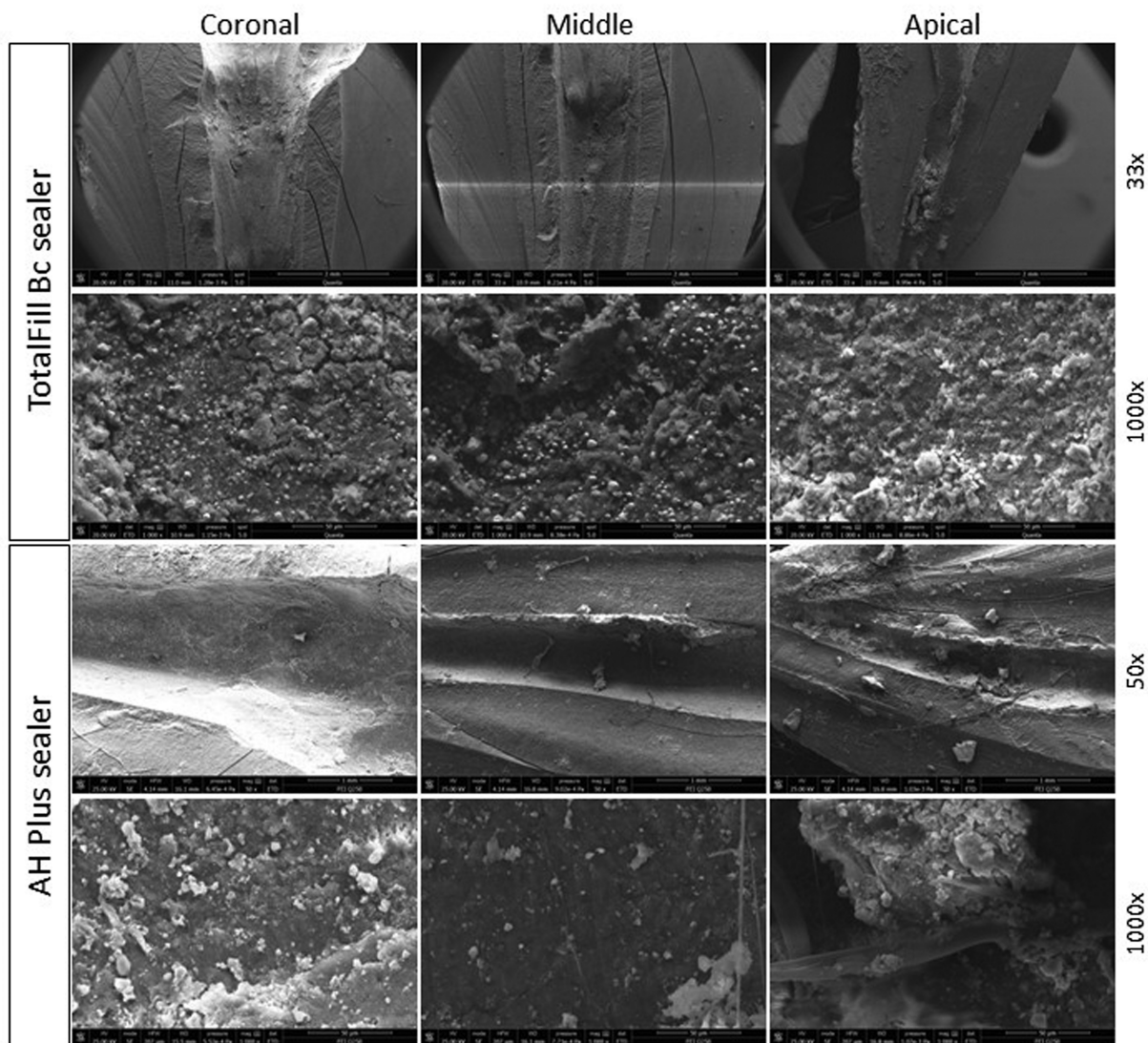


Fig. 2 Representative scanning electron microscope (SEM) images of the remaining filling materials in the coronal, middle, and apical thirds of the root canal, at $\times 33$, $\times 50$, and $\times 1000$ magnification.

Table 1 Scores of remaining filling materials evaluated by means of SEM analysis for the different groups at the coronal, middle, and apical thirds

		TotalFill		AH Plus	
		Without XPEF G1A	With XPEF G1B	Without XPEF G2A	With XPEF G2B
Coronal	Score 0	4	1	3	5
	Score 1	2	2	2	1
	Score 2	1	0	1	1
	Score 3	3	7	4	3
Middle	Score 0	1	2	2	7
	Score 1	1	1	1	1
	Score 2	2	2	1	1
	Score 3	6	5	6	1
Apical	Score 0	3	3	3	2
	Score 1	3	2	1	4
	Score 2	0	2	1	0
	Score 3	4	3	5	4

Abbreviations: SEM, scanning electron microscope; XPEF, XP-endo Finisher.

procedure was specifically applied to straight canals with an angle of less than 20 degrees.

The present study revealed that TotalFill BC sealer showed equal difficulty on reestablishment of patency as for AH Plus. After initial retreatment, residuals were similarly recorded in TotalFill and AH Plus groups. XPEF file did not significantly improve removal for TotalFill BC sealer. It was effective for AH Plus only.

Bioceramic sealers, also referred to as tricalcium silicate-based sealers, had been investigated for both their biological and physicochemical characteristics. These sealers exhibited a superior depth of penetration into dentinal tubules compared with AH Plus sealer.¹³ The setting reaction of these sealers can lead to the formation of hydroxyapatite on their surface, generating tag-like structures inside the dentinal tubules.¹⁴ Utilizing a matched-taper bioceramic gutta-percha point improved the dentinal tubule penetration of the tricalcium silicate-based sealer.¹⁵ The manufacturer of TotalFill BC sealer recommends the use of TotalFill BC point, which is crafted from gutta-percha that is impregnated and coated with bioceramic nanoparticles. This fact promotes the sealing of bioceramic sealers but constitute a further challenge in their removal.

The initial retreatment procedure, employing the ProTaper retreatment system, effectively eliminated a substantial quantity of filling material from both types of sealers. It exhibited comparable efficiency for both sealers. Earlier research indicated that the ProTaper retreatment system files can efficiently eliminate filling materials, demonstrating effectiveness comparable to other NiTi rotary files.^{16,17} In the current study, a noteworthy quantity of filling material was extracted, regardless of the sealer type employed.

Roggendorf et al also documented in their research, that enlarging canals by up to two sizes beyond the preretreatment dimension helped reduce the residual sealer amount.^{18,19} In this study, further apical preparation was conducted using the ProTaper (F3 file). Following the initial retreatment procedure with ProTaper retreatment, the quantity of RFM was comparable among the groups, which is very likely due to the similar adhesive characteristics of the sealers.²⁰ Several studies had previously documented resembling removal of both AH Plus sealer and Endosequence BC sealer.²¹⁻²³ Simsek et al found that there was no difference among the sealers including AH Plus and iRoot SP in terms of retreatment effectiveness.²⁴ On the contrary, in previous studies, it was observed that there was a larger quantity of RFM when using Endosequence BC sealer in comparison to AH Plus.^{25,26}

There were no statistically significant distinctions identified among the sectional thirds within each group. These findings align with the results of the Colmenar et al study, which also indicated that AH Plus and Endosequence BC sealers exhibited similar removability at all levels within the root canal.²¹ Uzunoglu et al compared the elimination of iRoot SP, AH Plus, and MTA Fillapex. The quantity of RFM in the middle and lower third was comparable and greater than in the coronal thirds.²⁷

Chloroform was used as solvent in the present study. It has been reported that its application facilitates patency reestablishment in root canal sealed with bioceramic sealers.²⁵

The variations in methodologies among the studies contribute to significant differences in the reported results. This difference could be attributed to the selection of specimens and the utilization of various retreatment protocols for root-filling removal.

Following the initial root canal retreatment procedure, the random allocation of samples into the groups was performed to minimize any anatomical biases. Different instrumentation techniques have been assessed for the elimination of these sealers from dentinal walls. Nevertheless, only a few have explored additional removal techniques.²⁸ The XPEF files were found effective in debris and smear layer removal,²⁹ in the removal of triple antibiotic paste,³⁰ and in the removal of calcium hydroxide paste.³¹ The additional preparation involving XPEF files has the potential of enhancing the dissolvement of sealers by activating the irrigation solutions.⁷

In this study, we used the XPEF file. It possessed a diameter of 0.25 mm, whereas the XPEF R file had a diameter of 0.30 mm. Each of these instruments was crafted from a highly flexible NiTi Max Wire alloy and feature a uniform taper. Silva et al's study has concluded that XP-endo files both, demonstrated equal efficacy in eliminating residual filling material from straight oval-shaped canals.⁸

In our findings, additional preparation using the XPEF file did not prove effective in improving the removal of the material from straight circular cross-section root canal sealed with TotalFill BC sealer. However, this file did significantly enhance the elimination of AH Plus sealer in the canal median third. This is in concordance with the results of other

studies, where XPEF R file has improved removal limited to the AH Plus group, but not in the bioceramic group.^{32,33} Conversely, a significant improvement in the removal was obtained in the residual filling material from the oval-shaped canal after additional cleaning with XPEF R.^{34,35} The conflicting results may be due to the different types of teeth included in the studies and the difference in root canal anatomy.³⁶

In our study, the results were different from those of Aksel et al who concluded that XPEF enhanced the elimination of filling materials, with no regard to the type of sealer, including bioceramic sealers.³⁷ This difference may be due to the selection of the samples. The primary extraneous variable affecting the similarity of the groups is the internal canal anatomy. In this current investigation, the angle of curvature of each canal was calculated according to the Schneider technique, employing radiographic images to establish a dependable anatomical reference point.² Only the canals with an angle of curvature inferior to than 20 degrees and a round cross-section were selected for this study. Contrariwise, moderate mesiobuccal root canal curvature (20- to 30-degree angle) was selected, in the study of Aksel et al.

Conclusion

No retreatment protocol tested in this study allowed the total elimination of root canal filling materials. The RFMs were comparable for both bioceramic and resinous sealers. The XPEF does not enhance the elimination of bioceramic root canal-filling material, but demonstrates efficacy in enhancing the removal of resinous cement.

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Conflict of Interest

None declared.

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