Frontiers in Dentistry

Retrieval of AH Plus, MTA Fillapex, and Endoseal MTA in Endodontic Retreatment: An in Vitro Cone-Beam Computed Tomography Study

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Article Info

Article type:
Original Article

Article History:
Received: 20 Aug 2024
Accepted: 29 Mar 2025
Published: 20 Sep 2025

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A B S T R A C T

Objectives: Retrievability is an important characteristic for an endodontic sealer. This study compared the retrieval of Endoseal MTA, AH Plus, and MTA Fillapex in endodontic retreatment using cone-beam computed tomography (CBCT).

Materials and Methods: This in vitro study was conducted on 45 radiographically confirmed single-rooted and single-canal mandibular premolars. The root canals were instrumented by the Denco Universal rotary system up to size F3, and randomly divided into 3 groups for the application of either AH Plus, Endoseal MTA, or MTA Fillapex and subsequent root canal obturation. Next, the root filling materials were removed using chloroform solvent and Denco Universal retreatment rotary system. The roots then underwent CBCT with the Gaussian and nonlinear diffusion filters for noise reduction. The residual sealer volume on the root canal walls was quantified on axial CBCT sections using MATLAB R2012 version 14 software. Data were analyzed by the Kruskal-Wallis and Dunn tests (alpha=0.05).

Results: The residual sealer volume was significantly different among the three groups (P<0.001) and was the highest in Endoseal MTA (2.70±2.41mm^3). The residual volume of Endoseal MTA sealer was significantly greater than MTA Fillapex (P=0.009). However, the difference between AH Plus and Endoseal MTA (P=0.592), or AH Plus and MTA Fillapex (P=0.352) was not significant.

Conclusion: Within the limitations of this in vitro study and considering the residual sealer volume, retrieval of Endoseal MTA was comparable to that of AH Plus, and lower than that of MTA Fillapex in endodontic retreatment.

Keywords: Epoxy Resin-Based Root Canal Sealer; Cone-Beam Computed Tomography; Retreatment

➢ **Cite this article as:** Omidi S, Rahmanirad S, Jafari A, Moosazadeh M, Abbaspourrokni H, Alimohammadi M. Retrieval of AH Plus, MTA Fillapex, and Endoseal MTA in Endodontic Retreatment: An In Vitro Cone-Beam Computed Tomography Study. *Front Dent*. 2025:22:38. http://doi.org/10.18502/fid.v22i38.19801

INTRODUCTION

Non-surgical endodontic retreatment is the first and most popular treatment option for a failed primary endodontic treatment. As part of this procedure, the root filling material is completely removed, and the

canal is biochemically cleaned, disinfected, and obturated again [1]. It is essential to remove all the root filling material with no or minimal residues during the retreatment process to avoid periapical inflammation. The new root filling material's sealing ability is also decreased by residual components. Root filling materials can be successfully removed by various methods developed for this purpose; however, such methods cannot completely remove the entire root filling material and may leave some residues. Thus, the clinicians should take into account both the optimal sealability and also the retrievability of root filling materials as well as the quality of their retrieval based on the logic, complexity, and necessity for retreatment. [2-4].

The lateral compaction technique in combination with a sealer is one of the most commonly used techniques for root canal obturation. Sealer is crucial for long-term sealing because it helps the gutta-percha to adhere to the canal walls and fill the gaps between the gutta-percha points and the canal walls [5, 6]. An optimal sealer should have sufficient adhesion, biocompatibility, antibacterial property, radiopacity, and insolubility in liquids [7-9]; however, it is difficult to find a sealer with all these characteristics [10].

AH Plus sealer is a modified form of AH26, an epoxy resin-based sealer with optimal water resistance and dimensional stability [11, 12]. MTA Fillapex is a recently introduced biocompatible calcium silicate-based sealer. Its biological characteristics are similar to those of MTA, except for difficult removal of its residues from the canal walls during retreatment [9, 13]. Endoseal MTA, another recently introduced sealer, has favorable physical properties, low discoloration potential, optimal biocompatibility, high resistance to bacterial microleakage, and the potential to biomineralize the dentinal tubules [14]. When MTA-based sealers, like Endoseal MTA, are exposed to physiological fluids that include phosphate, they show their bioactivity potential and produce an apatite layer. Such distinctive qualities of MTA seem to be crucial for biomineralization of dentinal tubules for improved root canal sealing [15].

Cone-beam computed tomography (CBCT), which has a lower radiation dose than computed tomography (CT), is an easy method to obtain three-dimensional images without superimposition of anatomical structures, and is increasingly used in the field of endodontics [16]. Since the recent CBCT scanners have higher resolution and reduced radiation dose, the obtained radiographs can be potentially used as the first option for endodontic treatment planning and evaluation of the treatment results [17].

Proper and thorough removal of sealer from the root canal walls has a significant effect on success of root canal retreatment. Endoseal MTA sealer was recently introduced to the market and to the best of the authors' knowledge, the retrievability of AH plus, MTA Fillapex and Endoseal MTA sealers has not been previously investigated in the literature using CBCT. Thus, this study investigated the retrieval of the sealers mentioned above by calculating the residual sealer volume in the root canal system using CBCT.

MATERIALS AND METHODS

This in vitro study was ethically approved by the Research Ethics Committee of Mazandaran University of Medical Sciences (IR.MAZUMS.REC.1399.42).

The sample size was determined to be 15 in each group using the formula below and according to a study by Neelakantan et al [18]:

$$n = \frac{\left(z_{1-\frac{\alpha}{2}} + z_{1-\beta}\right)^2 (\sigma_1^2 + \sigma_2^2)}{(\mu_1 - \mu_2)^2}$$

A total of 45 single-rooted and single-canal mandibular premolar teeth (confirmed by two different parallel radiographs taken in mesiodistal and buccolingual dimensions) were collected. The calculus was removed with a curette, and the soft tissue residues were cleaned by soaking the teeth in 5.25% NaOCl for 10 minutes, followed by their immersion in 0.09% saline as instructed by

Neelakantan et al [20]. Teeth with cracks, fractures, caries, or canals with more than 15% curvature were excluded from the study [18, 19].

Root canal preparation:

Patency was obtained by inserting a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) into the canal up to 1mm beyond the anatomical apex. Then, the working length was determined by reducing 2mm from this length [20]. The root canals were prepared by using Denco Universal rotary system (Denco Super Files III, Guangdong, China) up to size F3 according to the manufacturer's instructions. Each file was discarded after use in 5 canals. After using each file, the canal was rinsed with 1ml of 5.25% NaOCl. To remove the smear layer, 17% ethylenediaminetetraacetic acid (EDTA; CinaBartar Co., Tehran, Iran) and 5.25% NaOCl were used according to the Crumpton's method. 1ml of 17% EDTA solution was left in the canal for one minute, and then, 3ml of 5.25% NaOCl solution was used for irrigation. A final rinse with 3ml of distilled water was also performed. This was followed by drying the canals with paper points (Meta Biomed Co. Ltd., Chungcheongbuk-do, Korea) [21].

Root canal obturation:

The samples were randomly divided into 3 groups (n= 15) and obturated as follows:

First group: gutta-percha with AH Plus sealer (Dentsply, De Trey, Konstanz, Germany)

Second group: gutta-percha with MTA Fillapex sealer (Angelus, Londrina, PR, Brazil)

Third group: gutta-percha and Endoseal MTA sealer (Maruchi, Wonju, Korea)

Due to its optimal efficacy, AH Plus epoxy resin sealer was selected as the gold standard (control group) for the purpose of comparison with other sealers based on previous studies [18, 22]. The root canals were dried with size 30 paper points (Meta Biomed Co. Ltd., Cheongju City, Chungbuk, Korea) and obturated with gutta-percha points and the respective sealer using the single-cone technique. The gutta-percha point was dipped in sealer, and inserted into the canal to the working length. A heated instrument was used to cut the gutta-percha point at the cementoenamel junction, and the root filling materials were condensed vertically with an endodontic plugger [23]. To avoid technical errors due to inter-individual differences, all root canals were cleaned and obturated by the same operator [24]. The access cavity of the teeth was filled with glass ionomer (GC Fuji II LC, GC Co., Tokyo, Japan) and the teeth were incubated at 37°C temperature and 100% humidity for 6 weeks to simulate the clinical setting.

Retreatment technique:

Denco Universal retreatment system (Denco Super Files III, Guangdong, China) was used with a speed of 300rpm and the crown-down technique to remove the filling material from the root canals. Three drops of chloroform solvent (Morvabon, Iran) were injected into each canal, one drop in each of the apical, middle, and coronal thirds by using an insulin syringe [25]. A D1 Denco file (size 30 with 0.09 taper) was used for removal of the filling material from the coronal third of the canal. Apical preparation was done with F1 Denco file (size 20 with 0.07 taper), followed by F2 (size 25 with 0.08 taper) and then F3 file (size 30 with 0.09 taper). The canals were irrigated with 5.25% NaOCl after using each file. Final irrigation was performed with 5mL of 5.25% NaOCl and then by 5mL of saline; finally, the canals were dried with paper points.

CBCT:

After root canal preparation, all teeth underwent CBCT by using NewTom CBCT scanner (NewTom, Giano, Italy) with 100µm voxel size, 0.5mm slice thickness, and 0.5mm slice interval. The CBCT scans were evaluated using NNT software version 10 in axial and coronal sections and saved in DICOM format. MATLAB R2012 version 14 software was utilized to quantify the remaining sealer volume in each canal. Initially, the axial section radiograph of the teeth was entered the MATLAB software. Next, noise removal and thresholding of the images were done. The Gaussian and nonlinear diffusion filters were used for noise reduction. By applying the threshold, the residual sealers were cropped and separated from other parts of the image [26]. The remaining sealer had a gray level

above the threshold and the number one was assigned to it. Then, on each image, the volume of the sealer was quantified, and finally, the volume of the remaining sealer in each root canal was calculated and reported in cubic millimeters (mm^3).

Statistical analysis:

The three sealers were compared using the Kruskal-Wallis test. Pairwise comparisons were performed by the Dunn test. All statistical analyses were performed using SPSS version 24 (SPSS Inc., IL, USA) at 0.05 level of significance.

RESULTS

The Kruskal-Wallis test demonstrated a significant difference in the remaining sealer volume among the three sealer types (P<0.001). The highest and the lowest volume of the remaining sealer was observed in the Endoseal MTA and MTA Fillapex groups, respectively (Figs 1-3, Table 1).

Pairwise comparisons of the groups were subsequently performed by using the Dunn test (Table 2). As shown, the residual volume of Endoseal MTA sealer was significantly greater than MTA Fillapex (P=0.009). However, the remaining volume of AH Plus and Endoseal MTA sealers was not significantly different (P=0.592). Also, there was no significant difference between the residual volume of AH Plus sealer and MTA Fillapex sealer in the root canal (P=0.352).

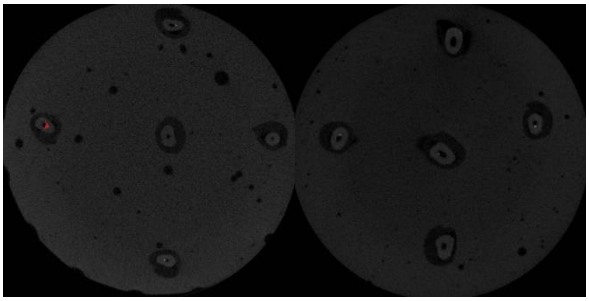

Fig 1. Axial CBCT section of the teeth in the AH Plus sealer group

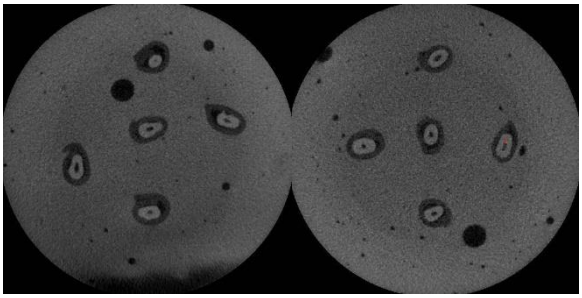

Fig 2. Axial CBCT section of the teeth in the MTA Fillapex sealer group

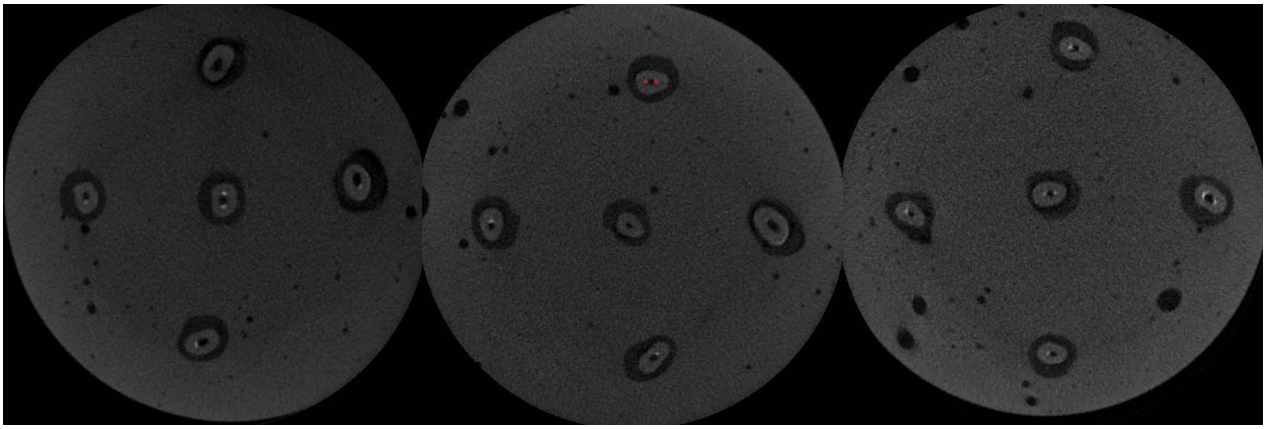

Fig 3. Axial CBCT section of the teeth in the Endoseal MTA sealer group

Table 1. Comparison of the remaining volume of AH Plus, Endoseal MTA, and MTA Fillapex sealers in the root canals

Sealers	Number	Mean	Standard Deviation	Mean rank	Chi-Square	P-value*
AH Plus	15	1.604	2.843	22.17		
Endoseal MTA	15	2.702	2.414	32.40	14.205	0.001
MTA Fillapex	15	0.409	0.919	14.43		

* Kruskal-Wallis test

Table 2. Pairwise comparisons of the sealers regarding the residual sealer volume

Sealers		Mean difference	P-value*
AH Plus	**Endoseal MTA**	1.098mm^3	0.592
AH Plus	**MTA Fillapex**	1.194mm^3	0.352
MTA Fillapex	**Endoseal MTA**	2.292mm^3	0.009

* Dunn test

DISCUSSION

The current study assessed the retrieval of AH Plus, MTA Fillapex, and Endoseal MTA sealers in endodontic retreatment using CBCT. According to previous studies, after a root canal procedure, inflammation and pain in the periapical tissue are caused by the residues of root filling materials, causing tissue necrosis. Therefore, for optimal periapical healing, it is crucial to completely remove the root filling material from the root canal walls. The retrievability of sealers during endodontic retreatment is also an essential parameter to consider when comparing their efficacy [3, 27].

Previous studies evaluated the retrievability of obturation materials during endodontic retreatment by various methods such as the clearing technique, longitudinal sectioning of the tooth and subsequent digital imaging analysis of the surface, or scanning electron microscopy [28]. However, these techniques are two-dimensional and involve tooth destruction; thus, the exact amount of residual filling material in the root canal system cannot be accurately estimated. Micro-CT, which has a high resolution, can also be used for this purpose, but CBCT has easier clinical application [16, 18]. Previous studies showed higher accuracy of CBCT than other types of CT such as peripheral quantitative CT and spiral CT. High resolution, low dose, and short scanning time contribute to the superiority of CBCT. As a non-invasive tool, it provides a three-dimensional view of the root and reveals details of the root canal system [29].

The findings of the current study demonstrated that the residual volume of Endoseal MTA sealer in the root canal (2.70±2.41mm^3) was slightly higher than AH Plus sealer (2.84±1.60mm^3), but significantly higher than MTA Fillapex sealer (0.91±0.40mm^3). Kim K et al quantified the residual EndoSequence BC and Endoseal MTA bioceramic sealers remaining in the canal in comparison with AH Plus epoxy resin-based sealer following endodontic retreatment using micro-CT. According to their results, the percentage of remaining sealer in the root canals of single-rooted teeth was not significantly different among the three sealers, but the highest amount of remaining sealer was seen in the Endoseal MTA group, which was in line with the findings of the present study [2]. Kim SR et al compared the efficacy of root canal obturation processes (continuous wave of condensation method with AH Plus sealer versus the single-cone technique with Endoseal MTA) and retrieval of AH Plus, Endoseal MTA, MTA Fillapex, and EndoSequence BC in endodontic retreatment. Similar to the present results, they found no significant difference in the volume of residual sealer in the canals following retreatment between AH Plus and Endoseal MTA sealers [19].

High bond strength, which is considered a favorable property of sealers, makes root canal cleaning difficult during retreatment procedures as a greater amount of sealer remains in the canals [30]. MTA is a bioactive material, which forms chemical bonds, hydroxyapatite, and carbonated apatite in contact with physiological fluids. MTA-based materials stimulate biomineralization and improve sealing [15]. The potential of these sealers for use in endodontic retreatment needs to be investigated considering the existing challenges with respect to the setting of MTA-based materials [18, 31].

Based on the findings of the present study, the retrieval of Endoseal MTA was comparable to that of AH Plus, and lower than that of MTA Fillapex. In a study by Kim et al [19] there was

no significant difference between the residual amounts of AH Plus and Endoseal MTA, which was in line with the current findings.

The present results showed that the remaining volume of AH Plus and MTA Fillapex was almost the same. However, the residual volume of AH Plus was slightly higher than MTA Fillapex. Donyavi et al [26] assessed the retreatability of teeth obturated with fluoride varnish in comparison with AH26 and MTA Fillapex sealers using CBCT. According to the findings, the amount of remaining material after retreatment in the MTA Fillapex sealer group was lower than that in the AH26 resin-based sealer group, which was in agreement with the current findings. Donnermeyer et al [13] investigated the retreatability of three calcium silicate-based sealers (BioRoot, MTA Fillapex, Endo CPM) and one epoxy resin-based sealer (AH Plus). According to their findings, the retreatability of calcium silicate-based sealers (such as MTA Fillapex) was more favorable than AH Plus sealer due to less residual material and less time required for retreatment, which was in line with the current findings. Some studies have reported similar efficacy of bioceramic and resin-based sealers including a study conducted by Kim H et al [32] that compared the retreatability and the amount of residual sealers in the dentinal tubules of canals treated with AH Plus and EndoSequence BC utilizing scanning electron microscopy. They found no significant difference in retreatability between EndoSequence BC and AH Plus sealers, and these two sealers showed similar characteristics in the retreatment process. The same results were also reported by Colmenar et al [30].

Sealers with a lower film thickness or greater flow easily penetrate into the dentinal tubules and accessory canals. In this regard, the high concentration of MTA-based sealers results in their poor adaptation to the dentinal walls [33]. This characteristic can be the reason for the lower amount of the remaining MTA Fillapex sealer compared with AH Plus in the present study. Adhesion to dentinal walls is another characteristic that affects sealer retrieval from the root canal system. Resin-based sealers such as AH Plus are harder to remove from the root canal walls due to penetration into the dentinal tubules and creating a mono-block [34]. Also, the bond strength and the quality of the hybrid layer formed between the sealer and root canal dentin in resin-based sealers are considerably greater than those in sealers such as MTA Fillapex [35]. On the other hand, the impact of the examined sealers on CBCT artifacts due to their different radiopacities might have influenced the present results [24]. In previous studies, AH Plus sealer caused greater artifacts on CT scans compared with MTA Fillapex [36] and Endoseal MTA [37], which can adversely affect the image quality and complicate the diagnosis.

The questionable biomineralization of MTA Fillapex sealer and the weak bond strength of MTA Fillapex to root canal dentinal walls may both be responsible for lower amount of MTA Fillapex remaining in the canal after retreatment [38]. The classification of MTA Fillapex as a true calcium silicate-based sealer is dubious because this sealer includes a large percentage of resin components despite having bioaggregate and bioceramic properties [39]. Likewise, MTA forms a chemical bond to root canal dentinal walls. Many sealer tags have been observed on dentinal walls of the canals obturated with Endoseal MTA. Therefore, its higher bond strength results in its lower retrievability. But MTA Fillapex is mainly comprised of resin and silica, and has a low percentage of MTA, which causes lower bond strength and less leakage than AH Plus and Endoseal MTA [31, 33].

The present results demonstrated slightly greater residual volume of Endoseal MTA than AH Plus in the root canals, but a significant difference was observed between the two MTA-based sealers i.e., MTA Fillapex and Endoseal MTA. Considering the biocompatibility and high bond strength of Endoseal MTA, it may be preferred for use as an endodontic sealer; nevertheless, other aspects such as canal morphology and the possibility of retreatment should also be considered.

CONCLUSION

According to the findings of the present study, AH plus, MTA Fillapex, and Endoseal MTA

sealer had the lowest to the highest volume of residual sealer in root canal. Greater volume of residual sealer demonstrates that a thorough root canal retreatment will be more chalenging and the obturation materials including sealer will be more removed harder. More studies with larger sample size are recommended. since sealers are composed of materials with different radioopacities, evaluating sealers using CBCT radiographs may produce artifacts, which interfere eith the study results. Thus, we suggest using methods to control and reduce the artifacts as much as it is possible in the future studies.

CONFLICT OF INTEREST STATEMENT

None declared.

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