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Comparison of Retreatability of two endodontic sealers, AH plus resin based and AH plus BC Sealer: a micro-computed tomographic comparison.

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ABSTRACT

Aim and Objectives: Aim of this study was to compare and evaluate the retreatment efficacy of two endodontic sealers, resin based and calcium silicate based: Micro Computed tomographic comparison.

Materials and Methods: Fifty-six extracted human maxillary incisors were instrumented and randomly divided into 4 groups of 14 teeth:
1. Subgroup 1A, gutta-percha, AH Plus resin based sealer retreated with chloroform.
2. Subgroup 1B, gutta-percha, AH Plus resin based sealer retreated without chloroform.
3. Subgroup 2A, gutta-percha, AH plus bioceramic sealer retreated with chloroform.
4. Subgroup 2B, gutta-percha, AH Plus bioceramic sealer retreated without chloroform.

Micro-CT scans were taken before and after obturation and retreatment was analyzed for the volume of residual material. The specimens were longitudinally sectioned and digitized images were taken with the dental operating microscope. Data was analyzed using an ANOVA and a post-hoc Tukey test. Fisher exact tests were performed to analyze the ability to regain patency.

Results: There was significantly less residual root canal filling material in the AH Plus groups retreated with chloroform as compared to the others. The AH plus BC Sealer samples retreated with chloroform had better results than those retreated without chloroform. Furthermore, patency could be re-established in only 16% of teeth in the AH plus BC Sealer without chloroform group.

Conclusion: The results of this study demonstrate that the AH plus BC Sealer

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group had significantly more residual filling material than the AH Plus resin based group regardless of whether or not both sealers were retreated with chloroform.

Key words: AH Plus; AH Plus BC sealer;Chloroform; Endodontic sealers; Micro-CT; Retreatability

Introduction

In order for nonsurgical endodontic therapy to be successful, the root canal system must be cleared of debris, bacteria, and necrotic and inflammatory tissue. Recontamination must also be avoided.[1] The results of primary root canal therapy were shown to be much improved by four conditions: root filling with no voids, root filling extending to 2 mm within the radiographic apex, excellent coronal restoration, and pre-operative lack of periapical radiolucency.[2] Endodontic failures do happen, nevertheless, and between 15 and 22 percent of cases do not recover.[3] The primary treatment of choice for post-treatment illness management is nonsurgical retreatment.

In order to disinfect the root canal system and create a favorable environment for periradicular healing, retreatment entails removing the existing obturation material.[4] Retreatment consists of the removal of existing obturation material to allow disinfection of the root canal system in order to provide an environment satisfactory for periradicular healing.[5] However, after removal is complete, the several retreatment methods and research routinely discover residual root canal filling.[6] Filling material must be removed from root canal systems because it may create a mechanical barrier that prevents intracanal dressings and irrigating solutions from reaching the root canal walls.[7] In addition, germs may be found in these regions that could cause post-treatment pathosis.[8] For this purpose, it is imperative that the obturation material be completely removed in order to improve chances of success. Gutta-percha (GP) in conjunction with sealers is the most common root canal filling material.[9] Currently, many different sealers are being used in endodontics.[10,11]More recently, bioceramic sealers like AH plus BC Sealer have been introduced and are being used in endodontic practice. BC Sealer is a premixed bioceramic endodontic sealer that is composed of zirconium oxide, calcium silicates, calcium phosphate (monobasic), calcium hydroxide, filler, and thickening agents.[12] Nevertheless, there is little research on this sealer's retreatability and it has only been used recently. The binding strength, sealing ability, root fracture resistance, setting qualities, cytotoxicity, and antibacterial effects of bioceramic sealers have all been assessed in earlier research.[13–17] Nevertheless, research on these sealers retreatability is scarce.

[18]On the contrary, AH Plus (Dentsply International Inc., York, PA, USA), an epoxy-resin-based endodontic sealer, has an extensive history of use and

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research studies [13,14,17,19] which is why it has been used for many comparative studies. [19-21] The efficacy of removing the root filling materials during retreatment has been assessed by many different methods. However, most methodologies destroy the specimens.These methodologies include horizontal or vertical splitting of the examined teeth or clearing to render the teeth transparent.[22,23] Micro-computed tomography (micro-CT) analysis is another technique. This technique has been applied before and preserves the material while offering fine-grained imaging of the root canal system.Given that these materials are often employed in endodontics and may have an impact on periapical healing, it is critical to determine whether these more recent sealers are retreatable.[24] Therefore, This study's objective was to evaluate the retreatability of AH Bioceramic Sealer using micro-CT analysis in contrast to AH Plus resin-based sealer. The null hypothesis, which was put to the test, was that AH Plus sealer and AH Plus bioceramic sealer were equally retreatable.

Materials and Method:

Selection of teeth:

A total of fifty-six human maxillary anterior teeth with straight roots that were removed were chosen. Excluded were roots with curvatures greater than twenty degrees. Included were only completely developed apices with a single apical foramen and a single root canal. Radiographs taken from the buccal and proximal regions confirmed the existence of a single canal.

Teeth were divided into 4 groups of 14 teeth each:

Group 1A: Canals obturated with GP/AH Plus resin based and retreated using chloroform.
Group 1B: Canals obturated with GP/AH Plus resin based retreated without chloroform.
Group 2A: Canals obturated with GP/AH plus BC Sealer and retreated using chloroform.
Group 2B: Canals obturated with GP/AH plus BC Sealer and retreated without chloroform.

Teeth that were larger than a size 25 in the initial apical file size were thrown out. With the help of calipers, teeth were decoronated with a diamond disk (Keystone Industries, Gibbstown, NJ, USA) to standardize the lengths to 17 mm. Following access, a size 10 Flexofile (Dentsply Maillefer, Tulsa, OK, USA) was inserted into the canal until it was visible at the apical foramen. The working length (WL) of 16 mm was calculated by deducting 1 mm from this measurement.

Instrumentation of teeth was performed by using a crown-down technique with Vortex Blue (Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) nickel titanium rotary instruments at 500 rpm to master apical file of size 45/0.04 taper. Files were used to instrument 5 canals and then replaced. Each canal was filled with irrigant during instrumentation. 3 mL of 6% NaOCl was used for irrigation after each file. A size 10 Flexofile was used to reconfirm patency. As a final rinse each canal was irrigated with 2 mL 17% EDTA, 2 mL NaOCl, followed by 2mL of sterile saline, and then dried with paper points. All irrigating solutions were delivered with a 30 G Max-i-Probe irrigating needle (Dentsply-Rinn, Elgin, IL, USA) placed 1mm short of the WL.

Micro-CT imaging, 3D rendering, and volume calculations:

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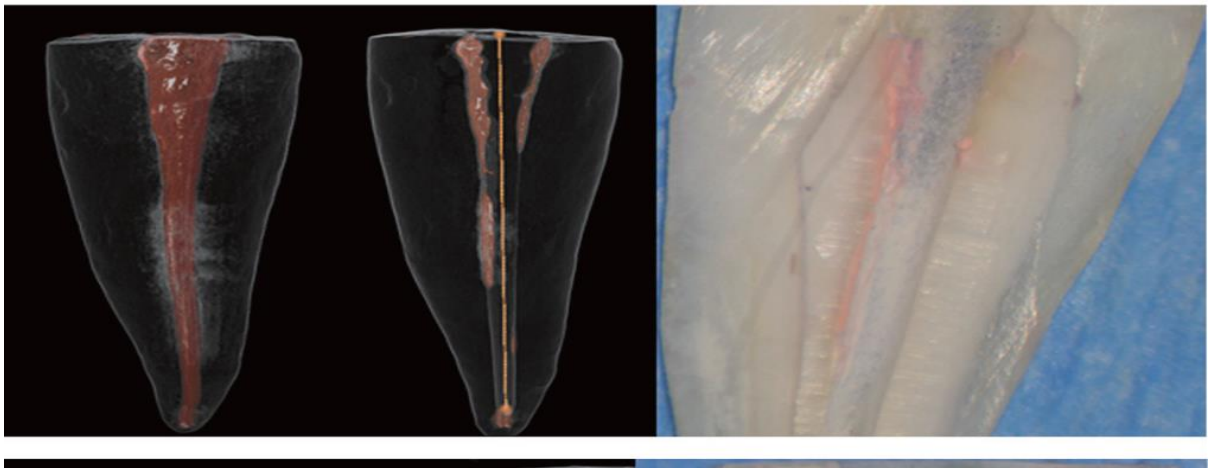
visualization of the sealer residue following retreatment.Micro-CT scans of obturated canals using (a) chloroform-treated gutta-percha and AH Plus resin-based

b) gutta-percha and AH Plus resin based retreated without chloroform



c) gutta-percha and AH Plus BC Sealer retreated with chloroform

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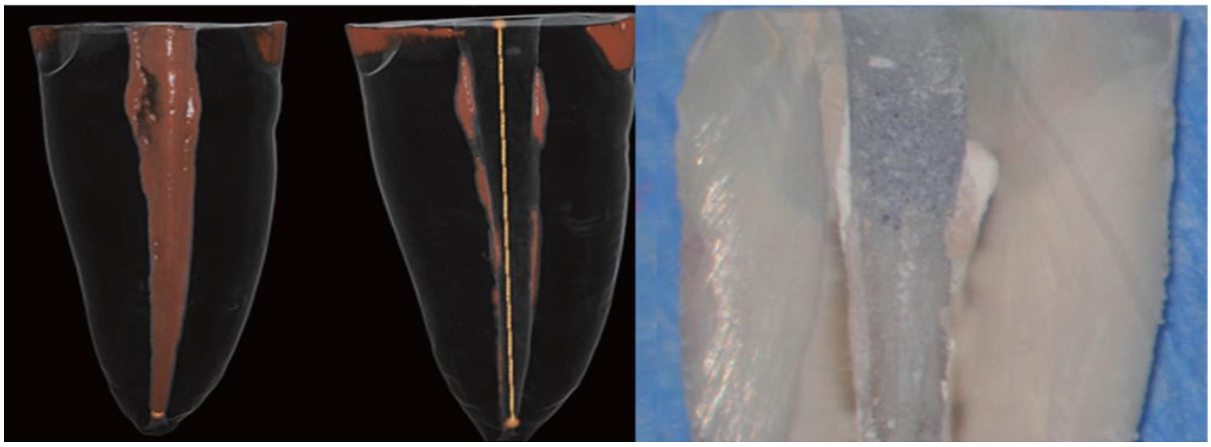

d) gutta-percha and AH plus BC Sealer retreated without chloroform retreatment

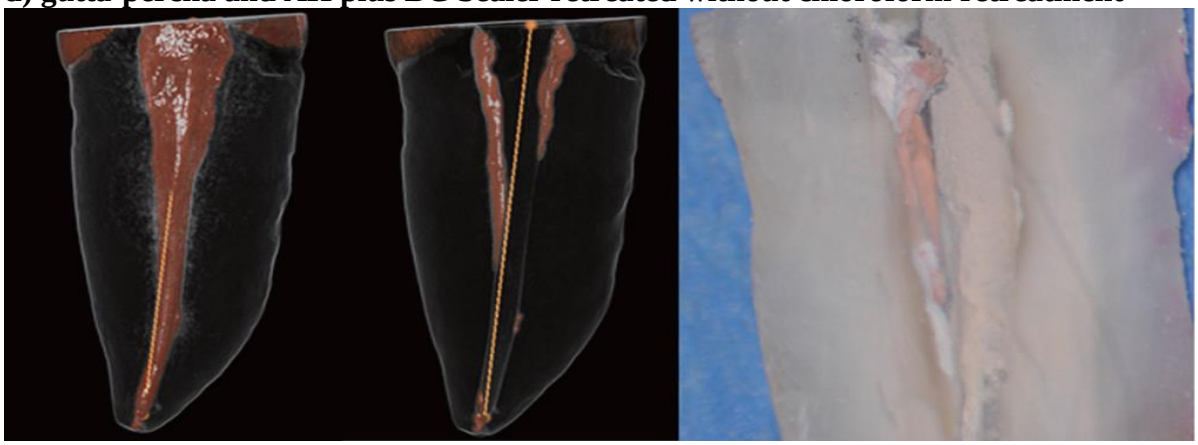

Figure 1. The left-most images are representative 3D renderings of the filled canals, while the adjacent images are the same teeth following retreatment. Black, root surface; white and orange, obturation material. The right- most images are the corresponding longitudinal sections of these teeth. Micro-CT, micro-computed tomography; AH plus BC Sealer, EndoSequence BC Sealer (Brasseler USA, Savannah, GA, USA); 3D, 3 dimensional.

Specimens were numbered and scanned with a micro- CT (Skyscan 1076, Bruker microCT, Antwerp, Belgium). Each specimen was scanned three times: once following instrumentation to enable calculation of the root canal volume, once to confirm the homogeneity of root canal obturation, and the final time to determine the volume of remaining material. The scanning parameters for each scan were kept constant: 65 kV (10 W, 154 μA), a 0.5 mm aluminum filter, a 160 millisecond exposure time and 0.70° rotation step, and isotropic voxel size of 35 μm.

The computer tool NRecon V1.6.1.0 (Bruker microCT) was used to reconstruct raw scan data into multiplanar slice data. The degree of curvature of the root canals was reassessed from pictures created using the 3D volume exploration program, Drishti V2.4 (http://sf.anu.edu.au/Vizlab/drishti), following the reconstruction of the original scan dataset. The results were compared with the initial conclusions drawn from the 2D radiographs. To make sure none had curvatures higher than 20 degrees, the curvatures were examined once more. The canal was reverse filled by flipping the rendering parameters (i.e., transfer function) and utilizing Drishti's get volume function in order to calculate the root canal volume after instrumentation. To enable calculation of total remaining sealer after retreatment, rendering settings were applied that readily detected the radiopaque sealer

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(Figure 1). The same rendering settings were applied to both the second (obturated) and third (retreated) scan datasets and the volumes of sealer determined again using the getvolume function. For visualization purposes, the 3D renderings of each tooth was manually aligned and oriented in the same multi-dimensional space and different transfer functions applied to show both the surface of the root and the sealer (Figure 1, root, black; obturation material, orange). For subdivision of the root canal into thirds (apical, middle, and coronal), the rendered datasets were virtually cut in the horizontal plane such that each third consisted of the exact number of rendered slices. The volume of sealer remaining in each third was then determined using the getvolume function of Drishti as described above.

Root canal obturation:

The teeth were randomly divided into 2 groups (Groups 1 and 2) of 28 each. All canals were obturated by the continuous wave compaction technique. In Group 1, twenty-eight canals were obturated by coating EndoSequence gutta-percha (Brasseler USA) of size 45/0.04 with AH Plus resin based sealer (Dentsply Maillefer) following the manufacturer's protocol. In Group 2, 28 canals were obturated with EndoSequence gutta-percha points and AH plus BC Sealer again following the manufacturer's protocol. The access preparations were sealed with Cavit (3M ESPE, St. Paul, MN, USA). The same volumes of sealer were used for both groups of teeth. The specimens were scanned a second time with the micro-CT using the same scanning parameters to confirm the homogeneity of root canal obturation. All samples were stored at 37°C in 100% humidity for 30 days to allow the sealers to set completely. A single operator performed all the procedures.

Retreatment with or without chloroform:

Each group was divided into two subgroups: Groups 1A and 2A were retreated using chloroform; Groups 1B and 2B were retreated without chloroform. Briefly, for Groups 1A and 2A, Cavit was removed and a total of 0.2 mL of chloroform was used for each tooth. Two drops of chloroform were introduced in the access preparations. ProFile ISO Rotary Files (Dentsply Maillefer) of size 45/0.04 taper at 300 rpm were used until WL was reached or resistance was met. If the WL was reached, crown-down instrumentation was performed using Vortex Blue size 45/0.04 at 500 rpm to WL to remove the remaining obturation material. If the WL was not reached, small hand files (C+ Files, and Flexofile sizes 6, 8, and 10) were used to reach WL. When Working length was reached, the canal was instrumented to length with Vortex Blue size 50/0.04.The remaining volume of chloroform was introduced in the canals and any remaining gutta-percha was removed with paper points. As a final rinse, each canal was irrigated with 5 mL of 6% NaOCl, 5 mL of 17% EDTA, followed by 2 mL of sterile saline, and then dried with paper points. Files were used to instrument 5 canals and then replaced. Retreatment was carried out for Groups 1B and 2B using the same rotary files as described in the techniques section, but without chloroform. A third micro-CT scan was carried out using the same parameters as the first two scans following the retreatment of all samples.

Statistical analysis:

SigmaPlot 11.0 (Systat Software Inc., San Jose, CA, USA) was used for the statistical testing. The required sample size was calculated to be 14 samples per group. This gave at least 95%

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power to detect a maximum difference between group means. Data from the experiments were analyzed using an analysis of variance (ANOVA) to determine differences among the groups, with further pairwise multiple comparisons with a post hoc Tukey test. Fisher exact tests were performed to analyze the ability to regain patency. Differences with $p < 0.05$ were considered.

Results:

Residual root canal filling material;

The percentages of residual filling material was calculated based on an equation stated in a previous study.8 Analysis of the rendered micro-CT images showed significantly less residual root filling material in Group 1A when compared to Groups 1B, 2A, and 2B when the entire length of the root canal was analyzed.

The AH plus BC Sealer group retreated with chloroform ; Group 2A showed significantly less sealer than the AH plus BC Sealer; Group 2B (Figure 2). These results were verified and related closely with the longitudinal sections of the teeth (Figure 1). Group 1B showed less residual material compared to Group 2B, however, these results were not statistically significant. All teeth were scanned using micro-CT but only representative images have been shown in Figure 1.

Comparison of apical, middle, and coronal one-thirds for residual root canal filling material;

Following micro-CT analysis, the teeth were examined further to check for any remaining filling material in the apical, middle, and coronal thirds of the canal. In comparison to the one-thirds of Groups 1B, 2A, and 2B, there was noticeably less leftover root canal filling material in every area of Group 1A (Figure 3).Additionally, compared to teeth that received chloroform treatment (Group 2A), the AH plus BC Sealer group that had no chloroform treatment (Group 2B) displayed noticeably more sealer in the coronal 1/3 of the root restoring patency and working length.

Re-establishing working length and patency;

It has been demonstrated that establishing patency and WL in retreatment instances greatly increases the rates of periapical healing.Hence these two factors were considered in this study when evaluating all the groups. Patency and WL were re-established in all the teeth (100%) in the AH Plus resin based groups (Groups 1A and 1B). WL and patency were re-established in 93% of teeth in Group 2A. In contrast, although WL was re-established in 93% of Group 2B teeth, patency could only be re-established in 12% of the cases, which was significantly different from the other groups ($p < 0.0001$,Table 1).

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Table 1: Ability to regain patency and re-establish working length during retreatment for the different groups

	Group 1A(%)	Group 1B(%)	Group 2A(%)	Group 2B(%)
Patency regained	100	100	93	12*
WL re-established	100	100	93	93

Mean volume percentages (%) of the remaining filling material are shown in the table. For patency regained, a statistically significant difference was found between Group 2B and each of the remaining groups (*$p < 0.001$). Patency could be regained in only 12% of cases that were obturated with AH plus BC Sealer and retreated without chloroform. For WLs there were no significant differences between the groups. WL, working length.

Discussion:

After treatment, chronic periapical illness is the cause of root canal failures.[24] Necrotic tissue, bacterial biofilms, coronal leakage, recurrent caries, and tooth fractures are some of the factors that can cause failure to heal.[25, 26] To ensure proper periapical healing, these causative variables need to be eliminated. Therefore, it is essential to thoroughly clean the root canal system, which would include removing the whole root canal filling that is already in place. Additionally, it has been demonstrated that retreatment cases with established patency and WL greatly increase periapical healing rates.[24] This isn't always feasible, though, for a number of reasons, including the structure of the root canal.[27]

The market has seen the introduction of numerous novel sealers, however it is still unclear if some of them are retreatable. Therefore, in contrast to the more widely used AH Plus resin-based sealer, this study assessed the retreatability of the relatively new AH plus BC Sealer. The AH Plus resin-based sealer was chosen for this comparison investigation because prior research has demonstrated that it is 99% soluble in chloroform.[28, 29] Our findings show that, regardless of whether they were retreated with chloroform or not, AH plus BC Sealer left noticeably more residual filling material in the root canal than AH plus resin based; however, the differences were even more pronounced when chloroform treatment was used.

However, the AH plus BC Sealer group left less residue after being treated with chloroform than the group that did not receive chloroform. The tendency for BC Sealer to stick to the dentin may be the cause of this noticeable variation between the sealers.[20] This observation may also be explained by the tag-like structures of calcium and phosphate materials, which indicate intratubular precipitation and may be in charge of the material's ability to seal and form a dentine bond.[30, 31] According to some earlier research, AH Plus and BC Sealer had similar amounts of filler left over.[18,32] . However, as the methodologies and retreatment methods employed in these investigations differed, it is impossible to draw definitive conclusions. In this work, we used quantitative, non-destructive, high resolution micro-CT-based imaging to determine the EndoSequence BC Sealer's percentage of residual filling material in comparison to AH Plus, either with or without chloroform.

This methodology, which has been successfully used in other studies, allows stepwise assessment by repeated scans of the same root specimen.[11,33]. Analysis of the apical, middle, and coronal one-thirds of the canals of retreated teeth indicated that AH Plus resin based with

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the use chloroform had significantly less residual filling material compared to all one-thirds from all the other groups. The longitudinal sections of the teeth corroborated the findings from the micro-CT scans(Figure 1). An interesting observation was the coronal 1/3 of both the Groups 1B and 2B, which demonstrated more filling material remaining. This could be attributed to tooth anatomy and the fact that no chloroform was used in these groups and maybe a solvent is necessary to clean the coronal 1/3 of the canal more efficiently. Most sections showed only residual sealer, however, there were a few specimens in all the groups that did show some residual gutta percha with sealer (Figure 1). This is an important finding as it correlates to some earlier studies that mention that no technique or solvent was effective in completely cleaning the root canal system during retreatment Procedures.[18,34] Concerns regarding the toxicity of chloroform should also be taken into account. [35] Because of toxicity concerns, the U.S. Food and Drug Administration (FDA) outlawed the use of chloroform in medications and cosmetics in 1976.Nevertheless, prior research has shown that chloroform is safe for use in endodontics, and there is currently no information available regarding its toxicity in this field.[36–38] Additionally, it has been demonstrated that during retreatment processes, chloroform effectively softens gutta percha and exhibits modest antibacterial activity against E. faecalis.[39, 40]

Hence, based on previous research chloroform was used in this study.

Our study focused on single rooted teeth based on previous studies and the fact that we wanted to demonstrate differences in less complex anatomy.[33] It is a possibility that more complex anatomy like mesial roots of mandibular molars could demonstrate even more significant differences between the two sealer groups. Another important aspect that was taken into consideration was the volume of sealer and the quantity of chloroform used in the study. The quantity of chloroform was standardized between Groups 1A and 2A, and the same volume of sealer was used for all the groups. Both these aspects of this study are important as these could have been potential variables when analyzing the results of the study. Hess et al. evaluated the retreatability of AH plus BC Sealer and AH Plus resin based related to patency and loss of WL using the scanning electron microscope.[41] This study reported that Ah plus BC Sealer was impenetrable to small hand files when it remained in the apical foramen. Our findings in this investigation were comparable. We showed that whereas WL and patency could be restored in all AH Plus resin-based samples, they were not able to be restored in all of the Ah plus BC Sealer groups' teeth. Chloroform was used to restore WL and patency in 93% of BC Sealer samples. In contrast to the other groups, WL was re-established in 93% of cases without the use of chloroform, with patency in just 12% of the BC Sealer samples.(Table 1).This is an important factor to consider especially during retreatments as this could affect periapical healing.[24]

Koch and Brave published a series of three review articles that included retreatment techniques for the removal of gutta-percha and Ah plus BC Sealer.[42]

In the reviews, They suggested using rotary files, hand files, ultrasonics, and solvents (like chloroform) as part of retreatment approaches, which is why rotary files were employed in this investigation. According to a recent study, using solvents during retreatments shortened the time needed for retreat teeth and decreased the quantity of debris extruded apically.[43] Furthermore, chloroform has been shown to have a superior ability over other solvents in dissolving canal sealing materials.[44] Chloroform did prove to be effective when used with AH plus BC Sealer as it increased the likelihood of regaining patency in these samples (Table 1).

To increase the retreatability of bioceramic sealers, we think it might be essential to create a solvent with a better effect on them.

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Conclusion:

This in vitro study's findings demonstrate that traditional retreatment methods can't always completely remove all of the filling material from the canal; nevertheless, the AH Plus resin group that underwent chloroform treatment left substantially less material behind than the AH plus BC Sealer group, whether or not chloroform was applied. Furthermore, although it was not possible in every instance, the application of chloroform raised the possibility of restoring patency in a small number of the AH Plus BC Sealer samples. We think that practitioners should be aware of this information, particularly when retreating teeth that had previously been sealed with AH plus BC Sealer.

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

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