Evaluation of the Retreatability of BC Sealer, BC Sealer Hiflow, and AH Plus: A Micro-Computed Tomography Study

Priscilla Gouveia, DDS, MSc,[*] Ana Grasiela Limoeiro, DDS, MSc, PhD,[†] Caroline Beatriz Farias Silva, DDS, MSc,[*] Marília Fagury Videira Marceliano-Alves, DDS, MSc, PhD,[‡§||] Carlos Eduardo Fontana, DDS, MSc, PhD,[¶] Daniel Guimarães Pedro Rocha, DDS, MSc, PhD,[#] Carlos Eduardo da Silveira Bueno, DDS, MSc, PhD,[*] and Alexandre Sigrist De Martin, DDS, MSc, PhD[*]

SIGNIFICANCE

Passive ultrasonic irrigation improves the removal of AH Plus and Bio C Sealer but not BC Sealer Hiflow, emphasizing the need for careful consideration when choosing sealers for endodontic procedures.

From the *Faculdade São Leopoldo Mandic, Instituto de Pesquisa São Leopoldo Mandic, Campinas, São Paulo, Brazil; †Faculdade de Odontologia de Bauru, Departamento de Dentística, Endodontia e Materiais Dentários, Universidade de São Paulo, Bauru, São Paulo, Brazil; ‡Departamento de Endodontia e Pesquisa Odontológica, Universidade Iguaçu, Nova Iguaçu, Rio de Janeiro, Brazil; §Department of Dental Research Cell, Dr. D. Y. Patil Dental College and Hospital, Dr. D. Y. Patil Vidyapeeth, Pune, India; ||Maurício de Nassau University Centre (UNINASSAU), Rio de Janeiro, Rio de Janeiro, Brazil; ¶Pontifical Catholic University of Campinas, Programa de Pós-graduação em Ciências da Saúde, Campinas, São Paulo, Brazil; and #Departamento de Endodontia, Pontifical Catholic University of Campinas, Campinas, São Paulo, Brazil

Address requests for reprints to Dr Ana Grasiela da Silva Limoeiro, Faculdade de Odontologioa de Bauru, Departamento de Endodontia, Dentística e Materiais Dentários, Universidade de São Paulo, Alameda Doutor Octávio Pinheiro Brisolla, 9-75, Bauru, São Paulo, Brazil.
E-mail address: grasielalimoeiro@gmail.com

0099-2399/$ - see front matter

https://doi.org/10.1016/j.joen.2025.02.009

ABSTRACT

Introduction: In this study, the ability to remove obturation material in canals filled with Bio C Sealer, BC Sealer Hiflow, and AH Plus was compared using micro-computed tomography. **Materials and methods:** In phase 1, 45 premolars were prepared with Reciproc Blue 25 files and divided into 3 experimental groups according to sealer and obturation techniques ($n = 15$): Group HI - BC Sealer Hiflow and continuous wave technique; Group AH - AH Plus and continuous wave technique; Group BC - Bio C Sealer and single cone technique. The teeth were stored for 30 days and scanned by micro-computed tomography to evaluate the volume of the obturation material. In phase 2, the teeth were unblocked with the Reciproc R40 file and the Flatsonic ultrasonic insert and scanned again. In phase 3, all samples were subjected to passive ultrasonic irrigation and a final scan was performed. The volume of obturation material was compared across all phases and groups. The volume of obturation material was calculated for the entire canal using an ANOVA analysis with a significance level of 5%. **Results:** The BC group showed a significant difference compared to the AH group ($P = .005$) and HI group ($P < .001$). There was no significant difference between the AH and HI groups. Within the groups, only the comparison of phase 2–3 in the HI group showed no significant difference ($P = .005$). No group achieved complete removal of the obturation material. **Conclusion:** Bio C Sealer had the least residual obturation material and passive ultrasonic irrigation improved material removal in AH Plus and Bio C Sealer sealers, but not in the BC Sealer Hiflow sealer. *(J Endod 2025;51:748–754.)*

KEY WORDS

Calcium silicate; ultrasound; X-ray microtomography

Endodontic retreatment is the treatment option in cases where primary root canal treatment has failed. This procedure is generally performed in cases of inadequate cleaning, shaping and obturation, iatrogenic events or reinfection of the root canal system due to loss of coronal sealing after completion of endodontic treatment[1]. In these cases, retreatment aims to disinfect the root canal space and reduce the microbial population by completely removing all obturation materials and the dentin surface[2].

The incomplete removal of obturation materials may affect the treatment outcome, as the presence of these materials in the root canal may prevent irrigants from coming into contact with persistent microorganisms[3].

Various techniques have been proposed for nonsurgical retreatment and have shown good results. Most of the root canal filling can be safely removed during root canal retreatment[4]. However, studies have shown that complete cleaning is not achieved in oval canals characterized by a buccolingual diameter equal to or greater than twice the mesiodistal diameter, regardless of the technique or instrument used for retreatment[5–7].

To improve the removal of obturation materials in oval canals, a stainless-steel ultrasonic insert with a length of 18 mm, an equilateral triangular flat shape (2 mm high), and an inactive tip, called Flatsonic Gold, has been proposed as an aid in retreatment[8]. The use of ultrasound in retreatment cases was initially reported with the additional use of passive ultrasonic irrigation (PUI) with fine and flexible inserts, such as the Irrisonic insert, as the activation of an irrigant induces acoustic currents and/or cavitation, which are phenomena that can promote better cleaning and removal of debris[9,10].

The type of obturation material has a direct effect on removal. The use of bioceramic and epoxy resin-based sealers presents an additional challenge in the removal of material from the root canal system[3].

Calcium silicate-based materials may contain alumina and zirconia particles, bioactive glass, calcium silicates, hydroxyapatite, and resorbable calcium phosphates in their formulation. These materials are biocompatible, nontoxic, chemically stable in the biological environment, and unlike conventional sealers, which are negatively affected by moisture, bioceramics are hydrophilic, nonresorbable, and do not shrink[11].

Epoxy resin-based sealers, such as AH Plus, are recommended for the warm vertical obturation technique to reduce the interface between sealer and gutta-percha and the associated shrinkage. Conversely, bioceramic sealers have been recommended for use with the single cone technique, as the slight expansion of the material cancels out the shrinkage of the gutta-percha[12]. With these obturations, the percentage of sealer in the root canal is higher than with other techniques, and the penetration of the material into the dentinal tubules can clog them, making endodontic retreatment a challenge and impairing the repair of the dentinal wall[13].

To overcome quality limitations at high temperatures, the premixed bioceramic cement EndoSequence BC Sealer Hiflow (Brasseler, Savannah, Georgia, USA) was recently introduced. According to the manufacturer, it has a lower viscosity when heated and is more radiopaque than its predecessor BC Sealer, which optimizes its use for thermoplastic obturation techniques. However, there is little data on the penetration of Hiflow into the dentinal tubules with different obturation techniques. The removability of this sealer is also still unknown[14].

Those calcium silicate-based and resin-based sealers were chosen due to their superior properties that enhance endodontic treatment outcomes. Epoxy resin-based sealers, such as AH Plus, offers excellent properties for endodontic obturations, including superior adhesion to dentin and gutta-percha, which minimizes the risk of microleakage. Its epoxy resin-based formulation provides outstanding dimensional stability and biocompatibility, contributing to prolonged durability and reduced treatment failures. Additionally, its radiopacity facilitates precise post-treatment assessment, ensuring thorough evaluation of obturation quality[12,13]. Calcium silicate sealers are highly biocompatible and promote bioactivity by inducing hydroxyapatite formation, which supports natural healing and bone regeneration[11]. Their hydrophilic nature allows them to set effectively in moist conditions, reducing microleakage. Resin-based sealers offer exceptional adhesion to dentin and gutta-percha, providing a strong seal and reducing leakage. Additionally, their radiopacity helps in post-treatment evaluations, and the flexible setting time provides clinical convenience, making them preferred choices in contemporary endodontic practice[11,15].

Therefore, the aim of the present study was to compare the retreatability of canals filled with the bioceramic sealers BC Sealer Hiflow, Bio C Sealer, and AH Plus using micro-computed tomography (micro-CT). The null hypothesis was that there is no difference between these sealers in terms of the amount of residual obturation material.

MATERIALS AND METHODS

Selection of Samples

This study was approved by the local ethics committee (No. 6.225.268). Forty-five first and second mandibular premolars with straight roots and single foramina were used, divided into 3 groups ($n = 15$). The sample size was determined using G*Power 3.1.9.4 software (Düsseldorf University, Düsseldorf, Germany) with an alpha error probability of 0.05, an effect size of 0.6 and a power of 0.9.

Periapical radiographs in the mesiodistal and buccolingual directions were taken for sample selection based on the following inclusion criteria: single-rooted teeth with fully developed roots and foramina, apical curvature of less than 5°[16], no previous endodontic treatment, no internal/external apical resorption, carious radicular lesions, dilacerations and visible root cracks under an operating microscope with 8× magnification (Alliance, São Carlos, Brazil). Teeth with root resorption, caries, restorations or fissures and previous endodontic treatment were excluded.

The 45 teeth were stored in 0.1% thymol solution (A Fórmula, Salvador, Brazil) for 30 days and their root surfaces were scraped with a periodontal curette No. 14 (Hu-Friedy, Chicago, USA) to remove remnants of the periodontal ligament, followed by prophylaxis with Robinson brush 10 (Microdont, São Paulo, Brazil), a pumice stone (Asfer, São Caetano do Sul, Brazil) and water. After this step, the teeth were washed and stored in saline solution until the experiment.

The access cavity was prepared with a spherical diamond bur 1014 (Microdont, São Paulo, Brazil) at high speed and under irrigation. The apical patency of the root canal was confirmed with a K #10 file (Dentsply, São Paulo, Brazil). The working length (WL) was determined visually under an operating microscope with 8x magnification, subtracting 1 mm from the outer limit of the apical foramen. The cervical-apical dimension of the root was measured with a digital caliper (King Tools, São Paulo, Brazil) and transferred to a millimeter ruler (Angelus, Lindóia, Brazil), obtaining a length of 17 mm for all specimens.

Phase 1: Endodontic Treatment and Obturation

The root canals were instrumented with the Reciproc Blue 25 system (Dentsply, Maillefer). The instrument was inserted into the canal opening, flooded with irrigation fluid and moved inwards and outwards 3 times. Every 3 cycles, the instrument was removed, and the coils were cleaned with gauze soaked in sodium hypochlorite (NaOCl) 2.5%. The canal was then recapitulated with a manual K #10 file (Dentsply, São Paulo, Brazil). This procedure was repeated until the WL was achieved.

The canals were irrigated with NaOCl 2.5% using a 5-mL syringe and a 30-G blunt needle with a lateral vent 2 mm from the foramen. After instrumentation, final irrigation with PUI was performed with an Irrissonic ultrasonic insert (Helse Ultrasonic, Santa Rosa de Viterbo, Brazil) activated by the Newton Booster ultrasonic device (Satelec Acteon, Merignac Cedex, France) at 35 kHz. The device operated at 30% power and used 3 mL of EDTA 17%, agitated for 3 cycles of 20 seconds to remove the smear layer, followed by 3 cycles of NaOCl 2.5%. The canals were dried with an aspiration tip for 5 seconds and 2 size 25 paper points (Dentsply, Maillefer).

After drying, the teeth were randomly distributed (www.random.org) according to the obturation sealers used ($n = 15$).

Group AH

AH Plus Jet sealer with a mixing tip attached to the sealer syringe was used, and the syringe plunger was activated, automatically mixing the 2 pastes in equal amounts in each canal. In the continuous wave technique, the main cone was cut off at the canal opening and a heated plugger was inserted into the obturation paste 4 mm from the WL. The cone was cut along this length and the obturation material was compacted vertically with a Schilder endodontic plugger. The middle and coronal thirds were filled with thermoplastic gutta-percha using an obturation system thermoinjector (Waks Dental Products, Campo Belo, Brazil).

Group BC

Bio C Sealer, ready-to-use, filled the canal with the product's own application attachments. The main cone was coated with a thin layer of sealer and slowly inserted into the WL. It was then cut at the canal opening with a 200°C heated plugger (Waks Dental Products, Campo Belo, Brazil) and vertically condensed with a Schilder endodontic plugger (Odous de Deus, Belo Horizonte, Brazil).

Group HI

The ready-to-use Hiflow sealer was placed in the root canal from the apex to the canal opening using the product's own application attachments, and the same continuous wave technique was used as for the AH group.

All sealers were prepared according to the manufacturer's instructions. The access cavities were temporarily sealed with glass ionomer sealer and radiographed to confirm the quality of obturation. The samples were stored at 100% humidity and 37°C for 30 days.

Preretreatment Micro-CT Analysis

The tooth specimens were scanned using a SkyScan 1173 micro-CT scanner (Bruker-microCT, Kontich, Belgium) with a 70 kV X-ray source at 114 mA. Scanning parameters included a rotation step of 0.8°, 360° rotation around the vertical axis, 12-mm pixel size, and 1-mm thick aluminum filter. Tooth images were reconstructed using NRecon v.1.6.9.15 software (Bruker-microCT, Kontich, Belgium), and the filling material volume was quantified using the plug-in 3-dimensional analysis tool from CTAn 1.16.4.1 software (Bruker-microCT, Kontich, Belgium). Analyses were performed for the root canal length.

Phase 2: Endodontic Retreatment

The provisional coronal seal was removed with a spherical bur 1014 (Kg Sorensen, Maringá, Brazil). The obturation material was first removed using an R25 instrument (VDW GmbH, Munich, Germany), which was inserted into the canal until resistance of the obturation material was felt. The instrument was set in a reciprocating motion using a VDW Silver electric motor (VDW GmbH, Munich, Germany). The instrument was moved apically with an amplitude of about 3 mm under slight apical pressure by in and out pecking movements.

After 3 cycles of in and out movements, the instrument was removed from the canal and cleaned with alcohol-soaked gauze. This protocol was repeated until the instrument had reached the WL. Irrigation was performed with 2.5 mL NaOCl 2.5% using a disposable syringe and a NaviTip 30-G needle (Ultradent, South Jordan, UT, USA) positioned 2 mm anterior to the foramen. The permeability of the apical foramen was checked with a K #15 file, and the obturation material removal was considered complete when no residual material was seen on the instrument flutes, and the canal walls were considered smooth. The root canals were reprocessed with an R40 instrument (VDW GmbH, Munich, Germany) following the same treatment protocol.

Supplementary material removal was performed with the Flatsonic Gold ultrasonic insert (Helse Ultrasonic) activated with the Newton Booster ultrasonic unit (Satelec Acteon) at 35 kHz and 30% power. The insert was inserted 1 mm short of the WL, activated for 20 s in 2 cycles, and gently oscillated toward the canal walls using a surgical microscope with 8x magnification until no debris was visible. The procedure was performed under irrigation with 1 mL of NaOCl 2.5% in each cycle. The specimens were then subjected to a second scan.

Postretreatment Micro-CT Scanning

The specimens were scanned again in the micro-CT and the images reconstructed. The volume of filling material remaining in full length was measured, using the same parameters described above.

Phase 3: PUI

PUI was performed using the Irrissonic ultrasonic insert (Helse Ultrasonic), agitating 3 mL of EDTA 17% in 3 cycles of 20 seconds. The same procedure was repeated with NaOCl 2.5% solution. The retreatment and supplementary procedures were performed under an operating microscope. The instruments and inserts were used for three samples and then discarded.

Micro-CT Analyses after the Supplementary Procedure

The specimens were scanned again in the micro-CT, and the images reconstructed. The volume of filling material remaining in full length and the apical canal segment was measured, using the same parameters described above. The CTAn 1.16.4.1 software (Bruker Micro-CT) was used to measure the volume and to create representative images of the sample canals, which were color-coded using the CTVol v.2.2.3.0 software (Bruker-microCT, Kontich, Belgium).

Data Analysis

Nonparametric methods were used to analyze the data. The interaction effect between stage and group was tested with ANOVA and implemented in the nparLD package. The relative treatment effect was used to estimate the difference between groups. Multiple comparisons were performed using the nparcomp package. A significance level of 5% was assumed for all analyzes.

RESULTS

The average volume of obturation material in each group and in each phase is shown in Table 1. The average value of the obturation material in each group can be seen in the obturation phase (phase 1). Although this volume progressively decreases in the retreatment (phase 2) and ultrasonic activation by PUI (phase 3) phases, obturation material was always present in all phases of all groups (Fig. 1).

The results showed significant effects of phase, F (1.482267, ∞) = 431.879428; $P < .001$, and of the interaction between phase and group, F (2.666606,

TABLE 1 - Comparison Between the Experimental Groups for the Volume of Remaining Filling Material

Phase	Group	Average	RTE (IC95%)	N
1	AH	209,893	0.833 (0.833; 0.833)	15
	BC	169,929	0.832 (0.828; 0.835)	15
	HI	168,739	0.829 (0.820; 0.837)	15
2	AH	32,675	0.364 (0.349; 0.379)	15
	BC	30,534	0.466 (0.441; 0.490)	15
	HI	35,513	0.355 (0.342; 0.367)	15
3	AH	24,748	0.303 (0.289; 0.318)	15
	BC	07,951	0.202 (0.178; 0.229)	15
	HI	32,189	0.316 (0.303 0.330)	15

RTE, relative treatment effect; IC, Intervalo de Confiança.

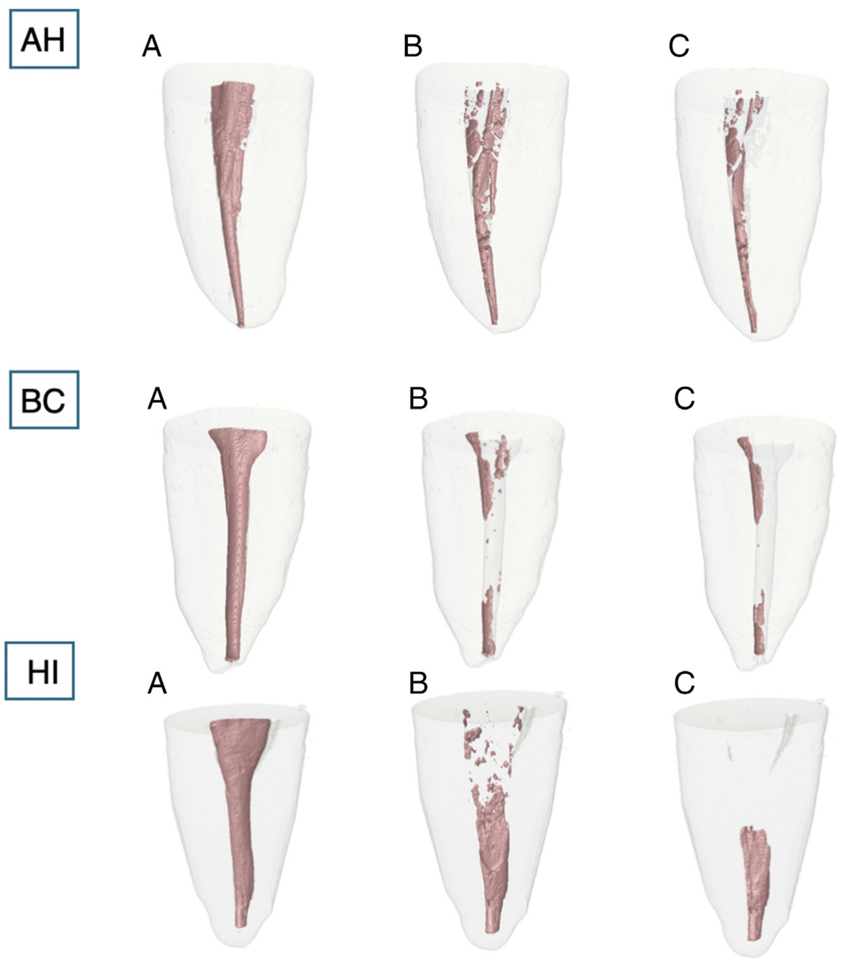

FIGURE 1 – Views of representative micro- CT reconstructions of the root canals showing the remaining filling material. Phase 1 - (*A*), phase 2 - (*B*), and phase 3 – (*C*). micro-CT, micro-computed tomography.

$\infty) = 9.759294$; $P < .001$. The main effect of group was not statistically significant ($P = .122$).

In the post-hoc tests by experimental group, the HI and AH groups showed significant statistical differences when comparing phases 2–1 and 3–1 ($P < .001$). The AH group showed a significant difference when comparing phases 3–2 ($P = .005$), but the HI group showed no significant change between 3 and 2. The BC group showed a significant difference when comparing all phases ($P < .001$). Residual obturation material was observed in all specimens after retreatment and after the application of PUI. PUI resulted in a significant decrease in the percentage of residual obturation material in the AH and BC groups ($P < .005$ and $P = .001$, respectively) (Table 2).

In the posthoc tests by phase, the HI and AH groups showed no statistically significant difference. In the BC group, there was a significant difference when comparing the BC-AH ($P = .005$) and HI-BC ($P < .001$) groups, but not between HI-AH (Table 3).

Canals obturated with Bio C Sealer showed significantly less residual obturation material after post-treatment with reciprocating files and after the additional use of PUI than canals obturated with AH Plus and BC Sealer Hiflow.

TABLE 2 - Posthoc Tests by Experimental Group

Group	Phase	Effect size (IC 95%)	*P*
HI	2–1	−1.278 (−1.361; −1.195)	<.001
	3–1	−1.380 (−1.477; −1.282)	<.001
	3–2	−0.102 (0.205; 0.002)	.055
AH	2–1	−1.274 (−1.324; −1.225)	<.001
	3–1	−1.435 (−1.489; −1.381)	<.001
	3–2	−0.161 (−0.264; −0.057)	.005
BC	2–1	−1.020 (−1.100; −0.939)	<.001
	3–1	−1.746 (−1.881; −1.610)	<.001
	3–2	−0.726 (−0.936; −0.516)	<.001

CI, confidence interval.

DISCUSSION

In this study, the removal of various obturation materials was investigated using Reciproc and an ultrasonic insert. The lowest amount of residual obturation material was found in the BC group, so the null hypothesis was rejected. Residual obturation material was present in all samples in all phases. The AH and HI groups did not differ in any of the compared phases.

Root canal retreatment requires removal of the obturation material, restoration of permeability, debridement, and disinfection of the root canal systems. In this study, the Reciproc system was used in the radicular unblocking phase of the retreatment technique, as this instrument had shown good performance in the results of previous studies[17-19].

The selection of Reciproc Blue 25 for preparation and Reciproc R40 for retreatment, in the present study, is supported by its flexibility and enhanced resistance to cyclic fatigue, good for the initial canal instrumentation as it can prepare the root canal without significant risk of fracture[17]. For retreatment, Reciproc R40 is preferred due to its superior cutting efficiency and ability to remove obturation materials effectively. Its reciprocating motion reduces the risk of instrument fatigue, providing better control during the removal process, which is crucial in retreatment scenarios[18]. The R40's design facilitates the penetration of obturation materials, making it easier to remove them while minimizing the risk of canal damage[19]. Additionally, studies have shown that the Reciproc system, including both Reciproc Blue 25 and R40, performs well in bioceramic removal and resin-based sealers during retreatment procedures[17,20]. This effectiveness system in both preparation and treatment enhances clinical outcomes by optimizing the cleaning and shaping process while ensuring efficient material removal[8].

The Flatsonic Gold insert was used to supplement the removal of the obturation

TABLE 3 - Posthoc Tests by Phase

Group	Phase	Effect size (IC 95%)	P
1	BC-AH	−0.406 (−1.161; 0.349)	.362
	HI-AH	−0.409 (−1.104; 0.285)	.300
	HI-BC	−0.004 (−0.573; 0.566)	.999
2	BC-AH	0.021 (−0.666; 0.708)	.996
	HI-AH	0.094 (−0.438; 0.626)	.888
	HI-BC	0.073 (−0.468; 0.614)	.933
3	BC-AH	−0.742 (−1.256; −0.228)	.005
	HI-AH	0.251 (−1.219; 0.721)	.368
	HI-BC	0.993 (0.540; 1.446)	<.001

CI, confidence interval.

material[21], as the use of this ultrasonic instrument after the reciprocating instruments significantly reduced the residual volume of obturation material[19]. In this study, the phase comparison showed a significant difference between phases 1–3 in all groups studied, and although the obturation material was not completely removed from the samples, there was a significant reduction in volume.

Ultrasonic activation is more effective than syringe and needle irrigation for debridement of noninstrumented oval dilatations, isthmuses and lateral canals[22] and also maximizes the removal of obturation material[9]; therefore, a PUI was performed in phase 3 of this study.

In this study, micro-CT was used to evaluate the initial volume of obturation material as well as the remaining material[23]. Computed microtomography (micro-CT) is a highly reliable tool in endodontic investigations, offering precise quantification of remaining root canal filling materials. Its non-destructive nature allows for detailed 3D visualization of canal anatomy and obturation material distribution, enhancing the accuracy of retreatment assessments[11,24,25]. Recent studies have demonstrated its effectiveness in evaluating the efficacy of different sealers and techniques, providing critical insights into material removal and canal cleanliness[7,26]. This advanced imaging technology continues to be indispensable in optimizing endodontic treatment strategies and improving clinical outcomes.

The results found among the BC-AH, BC-HI, and HI-AH groups can be explained by the obturation technique used in each group. In addition to the obturation material, the obturation technique is another critical factor for the feasibility of retreatment[27]. Although the single cone technique provides a larger sealer volume than the cone technique due to the low compression of the material condensation, it is not considered capable of adequately filling a complex root canal anatomy. The continuous wave technique, on the other hand, enables better three-dimensional obturation of the root canal anatomy, as the heating and condensation of the gutta-percha results in better adaptation to the canal walls, which leads to less sealer but a monobloc obturation of the root canal[28].

Athkuri et al[20] investigated the retrievability of obturation material from root canals obturated with cold lateral condensation, warm vertical condensation, and injectable thermoplastic techniques together with AH Plus and BioRoot RCS sealer. The ampullae obturated with the thermoplastic technique had a higher percentage of root canal filling residue after removal than the lateral condensation or warm vertical condensation techniques, like this study, which contributes to the understanding of the effects of the obturation technique on the retrievability of a material.

Previous studies[23,29] have compared the retrievability of bioceramic obturation sealers with AH Plus and found better results for hydraulic sealers. The rationale for these results in these studies was based on the bonding capacity of the sealers to dentin, which cannot be observed in the present study, as the HI-AH groups showed no difference in the residual volume of the obturation material. Yang et al[14] reported in their study that BC Sealer Hiflow had less residual obturation material compared to AH Plus, even when the continuous wave technique was used for initial obturation, which contradicts the present study. The differences could be due to the method of analysis used in these studies.

When analyzing the phases within the groups, only the 2–3 phase comparison in the HI group showed no difference. It can therefore be assumed that in this group, unlike the AH and BC groups, the PUI did not affect the reduction in the volume of the remaining obturation material. The failure of PUI to enhance material removal in the BC Sealer Hiflow group could be attributed to several factors. The particle packing density of BC Sealer Hiflow might create a more compact structure, resisting the disruptive effects of ultrasonic agitation[13]. Additionally, its lower viscosity when heated can lead to deeper sealer penetration into dentinal tubules, making it more challenging to dislodge during PUI[28]. Furthermore, the chemical composition and bonding properties of BC Sealer Hiflow might provide greater resistance to ultrasonic forces, as seen in studies where similar sealers exhibited strong adhesion to canal walls, impeding removal[14,29].

There are conflicting results in the literature regarding the effectiveness of PUI in removing residual material in filled canals. Some studies reported limited removal of root canal fillings[8,30], while others showed significant improvement[9,31]. Garrib et al[13] reported that irrigant activation methods can only improve the irrigant used but are not sufficient to efficiently remove all sealers from the root canal and recommended a chemical-mechanical method with 5% formic acid for sealer removal.

Proper sealer removal is essential in retreatment procedures to establish healthy periapical tissue. Considering the logic of endodontic treatment and its complexity, including the potential need for retreatment, it is necessary to consider not only the efficiency of the obturation technique but also the efficiency of sealer removal. Long-term laboratory and clinical studies with calcium silicate-based sealers are strongly recommended. The present results show that Bio C Sealer had the best residual material removal, which is crucial for cases requiring potential retreatment, particularly in complex root canal anatomies[14]. Despite this advantage, AH Plus remains a strong contender due to its superior adhesion and dimensional stability, making it ideal for achieving a robust seal in straightforward cases[12]. BC Sealer Hiflow, with its lower viscosity and enhanced radiopacity, are particularly suited for thermoplastic obturation techniques, offering flexibility in clinical applications[28]. Clinicians should weigh these attributes against the complexity of the canal system and the likelihood of retreatment to optimize treatment outcomes.

Complete removal of the obturation material was not achieved with any of the tested sealers, although a significant reduction was noted[1]. Bio C Sealer demonstrated superior retrievability compared to AH Plus and BC Sealer Hiflow, making it advantageous for cases where retreatment might be necessary[14]. Its ease of removal is a key strength, although it may not offer the same level of initial sealing as AH Plus. AH Plus, known for its excellent adhesion and dimensional stability, provides a robust seal, which is beneficial in straightforward cases but can complicate retreatment due to its strong bond with dentin[12]. BC Sealer Hiflow, while offering lower viscosity and improved radiopacity, did not benefit from PUI in terms of material removal, which may limit its use in scenarios requiring enhanced retrievability[13]. Each sealer presents unique strengths and weaknesses, influencing their application in various clinical scenarios.

The efficiency of root canal filling removal during endodontic retreatment can be influenced by several factors and the type of sealer used plays a decisive role, as some sealers, for example calcium silicate-based ones, due to their strong bonding to the dentin and are therefore more difficult to remove[13]. The obturation technique also affects the efficiency of removal, ones with a denser filling can be more difficult remove[20]. In addition, the complexity of the root canal anatomy, such as the presence of isthmuses and lateral canals, can hinder the complete removal of material, because the sealer can flow into the recesses making its removal almost impossible using existing modern techniques[8]. Finally, the choice of instruments and supplementary techniques, such as passive ultrasonic irrigation, can significantly improve or limit the removal process.

The findings of this study can have significant implications for clinical decisions regarding the selection of obturation materials, especially in complex root canal anatomies. The results showed that Bio C Sealer had the least residual obturation material after retreatment, indicating its superior retreatbility compared to AH Plus and BC Sealer Hiflow, similar findings were also found in previous studies for Bio C Sealer[32,33]. This suggests that in complex root canal anatomies, where complete removal of obturation material might be challenging, using a sealer like Bio C Sealer could improve retreatment outcomes.

CONCLUSION

Complete removal of the obturation material could not be achieved with any of the sealers used, although a significant reduction was observed. The root canal retreatment ability of BC Sealer was better than AH Plus and BC Sealer Hiflow. PUI improved material removal with AH Plus and Bio C Sealer, but not with BC Sealer Hiflow.

ACKNOWLEDGMENTS

The authors deny any conflicts of interest related to this study.

REFERENCES

1. Rossi-Fedele G, Ahmed HMA. Assessment of root canal filling removal effectiveness using micro-computed tomography: a systematic review. J Endod 2017;43:520–6.
2. Hassan R, Elzahar S, El Zahar S. Cleaning efficiency of XP finisher, XP finisher r and passive ultrasonic irrigation following retreatment of teeth obturated with TotalFill HiFlow Bioceramic Sealer. Eur Endod J 2022;7:143–9.
3. Crozeta BM, Chaves de Souza L, Correa Silva-Sousa YT, et al. Evaluation of passive ultrasonic irrigation and GentleWave system as adjuvants in endodontic retreatment. J Endod 2020;46:1279–85.
4. Crozeta BM, Silva-Sousa YTC, Leoni GB, et al. Micro-computed tomography study of filling material removal from oval-shaped canals by using rotary, reciprocating, and adaptive motion systems. J Endod 2016;42:793–7.
5. Volponi A, Pelegrine RA, Kato AS, et al. Micro-computed tomographic assessment of supplementary cleaning techniques for removing bioceramic sealer and gutta-percha in oval canals. J Endod 2020;46:1901–6.
6. Pedullà E, Abiad RS, Conte G, et al. Retreatability of two hydraulic calcium silicate-based root canal sealers using rotary instrumentation with supplementary irrigant agitation protocols: a laboratory-based micro-computed tomographic analysis. Int Endod J 2019;52:1377–87.
7. Santos-Junior AO, Tavares KIMC, Pinto JC, et al. Flatsonic ultrasonic tip optimizes the removal of remaining filling material in flattened root canals: a micro-computed tomographic analysis. J Endod 2024;50:612–8.
8. Cavenago BC, Ordinola-Zapata R, Duarte MAHH, et al. Efficacy of xylene and passive ultrasonic irrigation on remaining root filling material during retreatment of anatomically complex teeth. Int Endod J 2014;47:1078–83.
9. Bernardes RA, Duarte MAHH, Vivan RR, et al. Comparison of three retreatment techniques with ultrasonic activation in flattened canals using micro-computed tomography and scanning electron microscopy. Int Endod J 2016;49:890–7.
10. Rodrigues CT, Duarte MAH, Guimarães BM, et al. Comparison of two methods of irrigant agitation in the removal of residual filling material in retreatment. Braz Oral Res 2017;31:e113.
11. Alberdi Koki J, Martin G, Risso L, Kaplan A. “Effect of heat generated by endodontic obturation techniques on bond strength of bioceramic sealers to dentine”. J Endod 2023;49:1565–9.
12. Reynolds JZ, Augsburger RA, Svoboda KKH, Jalali P. Comparing dentinal tubule penetration of conventional and ‘HiFlow’ bioceramic sealers with resin-based sealer: an *in vitro* study. Aust Endod J 2020;46:387–93.

13. Garrib M, Camilleri J. Retreatment efficacy of hydraulic calcium silicate sealers used in single cone obturation. J Dent 2020;98:103370.

14. Yang R, Tian J, Huang X, et al. A comparative study of dentinal tubule penetration and the retreatability of EndoSequence BC sealer HiFlow, iRoot SP, and AH plus with different obturation techniques. Clin Oral Investig 2021;25:4163–73.

15. Janini ACP, Moraes BF, Pelepenko LE, et al. Physicochemical properties and biological interaction of calcium silicate-based sealers - *in vivo* model. Clin Oral Investig 2025;29:86.

16. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971;32:271–5.

17. Romeiro K, de Almeida A, Cassimiro M, et al. Reciproc and Reciproc blue in the removal of bioceramic and resin-based sealers in retreatment procedures. Clin Oral Investig 2020;24:405–16.

18. De-Deus G, Belladonna FG, Zuolo AS, et al. 3-dimensional ability assessment in removing root filling material from pair-matched oval-shaped canals using thermal-treated instruments. J Endod 2019;45:1135–41.

19. Crozeta BM, Lopes FC, Menezes Silva R, et al. Retreatability of BC sealer and AH Plus root canal sealers using new supplementary instrumentation protocol during non-surgical endodontic retreatment. Clin Oral Investig 2021;25:891–9.

20. Athkuri S, Mandava J, Chalasani U, et al. Effect of different obturating techniques and sealers on the removal of filling materials during endodontic retreatment. J Conserv Dent 2019;22:578–82.

21. Rivera-Peña ME, Duarte MAH, Alcalde MP, et al. Ultrasonic tips as an auxiliary method for the instrumentation of oval-shaped root canals. Braz Oral Res 2019;33:e011.

22. Boutsioukis C, Lambrianidis T, Verhaagen B, et al. The effect of needle-insertion depth on the irrigant flow in the root canal: evaluation using an unsteady computational fluid dynamics model. J Endod 2010;36:1664–8.

23. Alsubait S, Alhathlol N, Alqedairi A, Alfawaz H. A micro-computed tomographic evaluation of retreatability of BioRoot RCS in comparison with AH plus. Aust Endod J 2021;47:222–7.

24. Tavares SJO, Gomes CC, Marceliano-Alves MF, et al. Supplementing filling material removal with XP-Endo finisher R or R1-Clearsonic ultrasonic insert during retreatment of oval canals from contralateral teeth. Aust Endod J 2021;47:188–94.

25. Monteiro TM, Cortes-Cid VO, Marceliano-Alves MFV, et al. Intracanal removal and apical extrusion of filling material after retreatment using rotary or reciprocating instruments: a new approach using human cadavers. Int Endod J 2024;57:100–7.

26. Braga VM, Limoeiro AG, Marceliano-Alves MF, et al. Efficacy of WaveOne Gold and ProDesign RT systems in removing filling material: a micro-CT analysis. Acta Odontol Latinoam 2024;37:34–9.

27. Al Akam H, Kim H-C, Jeong JW. Retreatment Strategies for cases containing calcium silicate-based root canal sealers: a comprehensive review. Dent J 2024;12:41.

28. Casino Alegre A, Aranda Verdú S, Zarzosa López JI, et al. Intratubular penetration capacity of HiFlow bioceramic sealer used with warm obturation techniques and single cone: a confocal laser scanning microscopic study. Heliyon 2022;8:e10388.

29. Donnermeyer D, Bunne C, Schäfer E, Dammaschke T. Retreatability of three calcium silicate-containing sealers and one epoxy resin-based root canal sealer with four different root canal instruments. Clin Oral Investig 2018;22:811–7.

30. Fruchi Lde C, Ordinola-Zapata R, Cavenago BC, et al. Efficacy of reciprocating instruments for removing filling material in curved canals obturated with a single-cone technique: a micro-computed tomographic analysis. J Endod 2014;40:1000–4.

31. Grischke J, Müller-Heine A, Hülsmann M. The effect of four different irrigation systems in the removal of a root canal sealer. Clin Oral Investig 2014;18:1845–51.

32. Pinto JC, Torres FFE, Santos-Junior AO, et al. Influence of sealer and supplementary approach on filling material removal during endodontic retreatment. Braz Oral Res 2024;38:e022.

33. Bincelli Seckler IN, Pelegrine RA, Stringheta CP, et al. Comparative evaluation of supplementary cleaning techniques for removal of Bio-C sealer and AH-Plus from oval root canals: A Micro-CT analysis. Iran Endod J 2024;19:199–207.