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Removal of AH Plus Bioceramic Sealer from Artificial Internal Resorption Cavities Using Different Irrigation Activation Systems

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ABSTRACT

Objectives: The objective of this investigation was to assess the efficacy of XP-Endo Finisher (XPF), XP-Endo Finisher R (XPF-R), passive ultrasonic irrigation (PUI), and conventional needle irrigation (CNI) systems in the removal of AH Plus Bioceramic Sealer from artificial internal root resorption (IRR) cavities.
Materials and Methods*:* A total of 52 mandibular premolars with single oval canals were chosen. Following instrumentation, each tooth was longitudinally sectioned, and an artificial resorption cavity was established at a distance of 8 mm from the apex, with a diameter of 1.6 mm and a depth of 0.8 mm. The root halves were subsequently reassembled after the cavities were filled with sealer (AH Plus Bioceramic sealer). The activation techniques were applied to randomly assign the specimens to four groups (n = 13). The residual sealer was evaluated using a four-point scoring system at 20X magnification.
Results: The sealer was not completely removed from the artificial resorption cavities by any of the methods. A statistically significant difference was observed among the groups based on data analysis (p < 0.001). PUI, XPF-R, and XPF demonstrated significantly greater efficacy in sealer removal than CNI (p < 0.05), with no statistically significant differences between XPF, XPF-R, and PUI. The XPF-R system exhibited a higher percentage of 'Score 0' outcomes than XPF and PUI, despite no significant statistical differences.
Conclusions: XPF, XPF-R and PUI removed more sealer from artificial IRR cavities compared with CNI. These findings indicated that especially XPF-R is an effective additional activation system in IRR cavities filled with bioceramic sealers.

Keywords: AH Plus Bioceramic, internal resorption, irrigation activation, XP Finisher R.

Farklı İrrigasyon Aktivasyon Sistemleri Kullanılarak Yapay İnternal RezorpsiyonKavitelerinden AH Plus Biyoseramik Kanal Patının Uzaklaştırılması

Araştırma Makalesi

Süreç

Geliş: 02/04/2025
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ÖZ

Amaç: Bu araştırmanın amacı, XP-Endo Finisher (XPF), XP-Endo Finisher R (XPF-R), pasif ultrasonik irrigasyon (PUI) ve konvansiyonel iğne irrigasyon (KİI) sistemlerinin AH Plus Biyoseramik kanal patının yapay internal kök rezorpsiyonu (İKR) kavitelerinden uzaklaştırılmasındaki etkinliğini değerlendirmektir.
Gereç ve Yöntemler: Tek oval kanallara sahip toplam 52 mandibular premolar diş seçildi. Enstrümantasyondan sonra, her bir diş boylamasına kesildi ve apeksten 8 mm uzaklıkta 0.8 mm derinlikte ve 1.6 mm çapında yapay bir rezorpsiyon kavitesi oluşturuldu. Bu boşluklar kanal patı (AH Plus Bioceramic sealer) ile dolduruldu ve kökler daha sonra yeniden birleştirildi. Örnekler aktivasyon yöntemlerine göre rastgele dört gruba (n = 13) ayrıldı. Kalan kanal patı, 4 dereceli bir skorlama sistemi kullanılarak 20X büyütme altında değerlendirildi.
Bulgular: Yöntemlerin hiçbiri yapay rezorpsiyon kavitelerinden kanal patını tamamen uzaklaştırmadı. Veri analizi sonucunda gruplar arasında istatistiksel olarak anlamlı fark gözlendi (p < 0,001). XPF, XPF-R ve PUI, KİI ile karşılaştırıldığında kanal patının uzaklaştırılmasında önemli ölçüde daha fazla etkinlik gösterdi (p < 0,05), XPF, XPF-R ve PUI arasında istatistiksel olarak anlamlı bir fark yoktu. İstatistiksel farklılıklar gözlenmemesine rağmen, XPF-R sistemi XPF ve PUI'ye kıyasla daha yüksek oranda 'Skor 0' sonucu göstermiştir.
Sonuçlar: XPF, XPF-R ve PUI, KİI ile karşılaştırıldığında yapay İKR kavitelerinden daha fazla kanal patı uzaklaştırdı. Bu bulgular, özellikle XPF-R'nin biyoseramik kanal patı ile doldurulmuş İKR kavitelerinde etkili bir ek aktivasyon sistemi olduğunu gösterdi.

Anahtar Kelimeler: AH Plus Bioceramic, internal rezorpsiyon, irrigasyon aktivasyonu, XP Finisher R.

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Introduction

The irregular concave structure of internal resorptive defects makes proper chemomechanic debridement and void-free obturation difficult, which can lead to treatment failure.[1,2] When primary root canal treatment fails, the preferred management strategy is usually orthograde non-surgical endodontic retreatment.[3] Moreover, surgical procedures or tooth extractions—especially invasive ones involving manipulation of bone tissue, such as periapical surgery—are considered risk factors for medication-related osteonecrosis of the jaws (MRONJ) in patients using antiresorptive drugs or those with systemic conditions,[4,5] therefore, non-surgical retreatment may become a necessary and preferable treatment option. However, achieving a successful outcome after non-surgical root canal retreatment can be a significant challenge for clinicians. To ensure effective treatment, it is crucial to remove previously contaminated filling material. This step allows the instruments and irrigants to adequately reach and act upon the entire working length (WL) of the canal, promoting thorough cleaning and disinfection.[6]

Hydraulic calcium silicate-based sealers (HCSBS) have emerged as a promising option for filling IRR defects, due to their excellent sealing ability, healing promotion, and superior flow properties.[7] Recent premixed AH Plus Bioceramic sealer (Dentsply Sirona, North Carolina, USA) which provides good cytocompatibility and bioactive potential and is a hydrophilic sealer that has already demonstrated considerable clinical success.[8-10]

Current evidence indicates that the complete removal of root canal filling materials using the available instruments and conventional needle irrigation (CNI) techniques is not achievable.[11,12] Therefore, the use of additional procedures was recommended because of effectiveness in removing residual material. Most commonly used techniques following endodontic retreatment are passive ultrasonic irrigation (PUI), sonic activation, laser-assisted irrigation, negative apical pressure and mechanically assisted activation through canal brushes or The XP-endo Finisher and XP-endo Finisher R (FKG Dentaire, La Chaux-de-Fonds, Switzerland) instruments.[13]

PUI uses ultrasonic vibrations (25–30 kHz) to cause a wire or small file to oscillate within a root canal filled with irrigating solution.[14] This process generates energy through cavitation and acoustic streaming, which improves the activation of the irrigant and helps to remove debris, smear layer, and left over filling material from the root canal system.[15,16]

The XP-endo Finisher (XPF) file features innovative technology utilizing the MaxWire alloy, which is enabling shape adaptation to complex canal morphologies at body temperature.[17,18] The XP-endo Finisher -R (XPF-R), a newer version of the XPF, features a larger core diameter (ISO 30 vs. ISO 25), enhancing its efficiency in removing root filling materials, particularly in oval canals, while preserving the canal's original anatomy. Retreatment with XPF and XPF-R as a supplementary step generally held superior results.[19]

Despite advancements in irrigation activation technologies, the efficacy of XP-endo Finisher R in removing AH Plus Bioceramic (AHP-Bio) sealer from artificial internal resorption cavities remains unclear. This research aimed to assess the ability of XPF, XPF-R, PUI, and CNI activation systems in removal of calcium silicate-based root canal sealer from artificially created internal resorption cavities. The null hypothesis (H_0) of the study indicates that there will be no significant difference between the groups ($p \geq 0.05$).

Materials and Methods

Sample Calculation and Selection

Based on data from a previous study,[20] the minimum necessary sample size was calculated using G*Power 3.1.9.7 software. The analysis determined that a total of five teeth were needed with a Type I error (α) set at 0.05, a statistical power ($1 - \beta$) of 0.95, and an effect size of 2.7284. To increase the study's statistical power, fifty-two mandibular premolars with fully developed, single-canalled roots were ultimately selected, with thirteen samples allocated to each group.

All procedures involving human participants were carried out in compliance with the institutional ethical guidelines and the principles of the Declaration of Helsinki. The study protocol received approval from the university ethical committee board (Decision No: 2024/927). The teeth were preserved in a saline solution containing 0.1% thymol at +4°C until experimentation. To ensure they met the inclusion criteria, preoperative mesiodistal and buccolingual radiographs were taken to confirm the presence of a single canal with curvature less than 5°.[21]

Sample Preparation Steps

The crowns were reduced under continuous water cooling using a high-speed diamond bur until a standardized length of 18 mm was achieved. The WL was established as 1 mm from the apical foramen using a size #10 K-file. The canals were enlarged up to size R40 Blue (VDW, Munich, Germany) using the reciprocating file system by an experienced endodontist. During the enlargement process, irrigation was carried out using NaOCl (2 mL of 2.5%, Cerkamed, Poland) applied with a 30-G side-vented needle (Cerkamed, Poland). Root canals were flushed in a sequence beginning with NaOCl (5 mL of 2.5%, Cerkamed, Poland), then EDTA (5 mL of 17%, Cerkamed, Poland), and finally distilled water (DW) (5 ml) for final irrigation protocol. Each tooth sample was inserted into an Eppendorf tube containing polyvinyl silicone-based impression material (Zhermack) to form a simulated alveolar socket. Once the impression material had set, the roots were carefully extracted. The teeth were sectioned longitudinally using a metal separator while maintaining water cooling to avoid thermal damage and to obtain mesial and distal sections. Finally, the two halves were gently separated using a fine chisel and hammer, taking care to avoid damaging the canal wall.

Formation of Internal Resorption Cavities

Internal resorption cavities were created under a dental operating microscope (Carl Zeiss Meditec AG) at a distance of 8 mm from the apex using a diamond round bur. The cavities were prepared to a depth of 0.8 mm and a diameter of 1.6 mm. The localization of the resorptive cavities was ensured to match and label the same region in both root segments using a digital caliper. The smear layer of the IRR cavities was removed by sequential irrigation with 2.5% NaOCl, 17% EDTA, and DW, using a micro-brush, with each solution applied in a volume of 1 mL.

Placement of AHP-Bio Sealer and Retreatment Procedure

The artificial resorption cavities were filled with AH-Plus Bio. The samples were reinserted into the Eppendorf tubes and the canal orifices were sealed with teflon tape and temporary filling material. The specimens were stored at 37°C in 100% humidity for four weeks.

Each tooth was reconstructed, including the apical region, using a gingival barrier and then replaced into the silicone material in the Eppendorf tubes before retreatment and activation protocols. The canals were initially instrumented with a R50 Blue file (VDW), followed by the XP-endo Rise Shaper (XP-RS) (FKG Dentaire, Switzerland) file to simulate the retreatment procedure. The canals were flushed with NaOCl (2 ml of 2.5%) between the use of each file. The samples were then randomized into four groups according to the experimental groups [*CNI; PUI; XPF and XPF-R*] using the online tool (https://www.randomizer.org).

Experimental Groups

The CNI group served as the control without any supplementary activation, while the other three groups were categorized according to the type of supplementary irrigant activation applied (Figure 1).

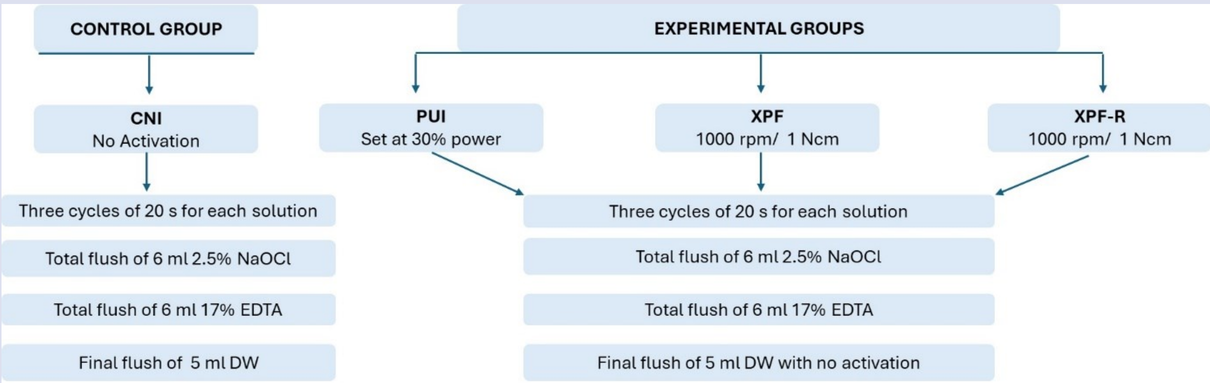

Figure 1. Illustrating the methodology of the study.

CNI

Root canals were freshly flushed with 6 mL of 2.5% NaOCl with a flow rate of 2 mL in 20 seconds, followed by 6 mL of 17% EDTA with a flow rate of 2 mL in 20 seconds, and finally 5 mL of DW. A side-vent irrigation needle (Cerkamed, 30-G) was positioned 1 mm short of WL. The needle was gently moved in an up-and-down motion of 7-8 mm within the canal.

PUI

Two millilitres of 2.5% NaOCl was delivered into the canal using a 30-G needle, followed by insertion of the ultrasonic tip (E93, Woodpecker), positioned 1 mm short of WL. A smooth ultrasonic tip (21.5 mm long, 0.2 mm diameter) connected to an ultrasonic device (UDS-E LED, Woodpecker, Japan) was activated at 30% power in the endodontic mode. The irrigant was activated in three cycles of 20 seconds with gentle vertical in-and-out movements (7-8 mm amplitude). The same activation protocol was repeated for 17% EDTA, and the procedure was completed with a final rinse of 5 mL DW without activation.

XPF and XPF-R:

The XPF (25/.00) and XPF-R (30/.00) instruments were connected to an endomotor (X-Smart Plus, Dentsply) and operated at 1000 rpm with a torque setting of 1 N·cm. Gentle in-and-out motions of 7–8 mm were performed up to 1 mm short of the WL. The irrigation protocol was consistent with that used in the other groups. Supplementary activation techniques were performed at 37°C within a temperature-controlled cabinet equipped with a heater and monitored by a thermometer to maintain precise conditions.

Visualization and Scoring of Sealer in Resorption Cavities

Following this step, the samples were taken out of the Eppendorf tubes, split again using a microchisel, and placed in an oven at 37°C for 24 hours to evaporate moisture. The simulated IRR cavities were visualized under a stereomicroscope (Zeiss, Discovery.V8) at 20X magnification. Two calibrated endodontists evaluated blindly each digital image using the scoring system described by Van der Sluis et al. (Table 1).[22] After a 10-day interval, the examiners re-assessed the digital images.

Statistical Analysis

The intergroup comparison of scores in each group was analysed using Kruskal–Wallis. Dwass-Steel-Critchlow-Fligner test was performed for pairwise comparison of groups. The Cohen–Kappa test was used to assess intra/inter-observer reliability in scoring the images. Statistical analyses were conducted using Jamovi software (version 2.5.28.0), with the significance level set at $p < 0.05$.

Results

Intra-observer reliability for scoring the artificial internal resorption cavities was "almost perfect" [23] with a Cronbach's alpha value of 0.907 and 0.902 for two observers, respectively, whereas the inter-observer reliability resulted in a Cronbach's alpha value of 0.905 and 0.901 for initial and second evaluation.

Figure 2 represents the four-grade scoring system for assessment of removal of AHP- Bio sealer from artificial

IRR cavities. Figure 3 presents the distribution of the scores for the removal of the sealer. CNI group could not completely remove the sealer (Score 0) from the artificial IRR cavities. A score of 3, namely a cavity completely filled sealer, was given in 69.23% of the canals irrigated with CNI. A score of 0, namely a completely empty cavity, was given in 15.4%, 38.46% and 53.85% of the canals activated with PUI, XPF and XPF-R, respectively (Figure 3). The Kruskal–Wallis test revealed that significant difference was detected among groups ($p < 0.001$). The PUI, XPF, and XPF-R techniques were significantly more effective than CNI ($p < 0.05$); however, no significant differences were found among them (Table 2). Median (min-max) values of scores and pairwise comparison p-values of activation groups are shown in Table 2.

Table 1. The scoring scale used to evaluate the presence of sealer in the resorption cavities

Score 0: No sealer was observed in the resorption cavity.
Score 1: Sealer was present in less than half of the resorption cavity.
Score 2: Sealer was present in more than half of the resorption cavity.
Score 3: Sealer completely filled the resorption cavity.

Scoring Scale

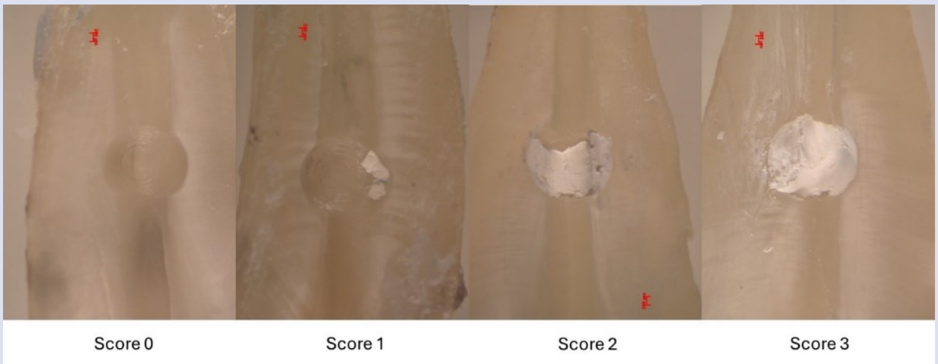

Figure 2. Representative stereomicroscopic images of score scale.

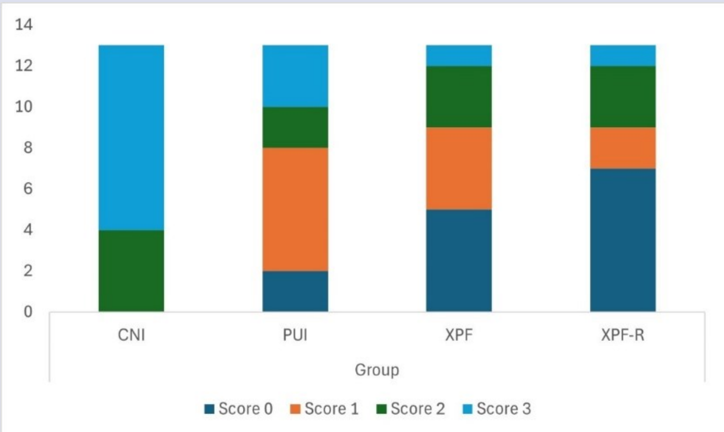

Figure 3. The distribution residual sealer scores of experimental groups.

Table 2. Median (min-max) values of scores and DSCF pairwise comparisons of groups

Median (min-max)		p values			
Groups		CNI	PUI	XPF	XPF-R
CNI	3 (2-3)	---	**0.014**	**<.001**	**<.001**
PUI	1 (0-3)	**0.014**	---	0.673	0.407
XPF	1 (0-3)	**<.001**	0.673	---	0.961
XPF-R	0 (0-3)	**<.001**	0.407	0.961	---

Bold letters indicate significant differences. DSCF: Dwass-Steel-Critchlow-Fligner pairwise comparisons test.

Discussion

The complete removal of root canal filling materials from the irregularities of the root canal presents significant challenges, and the literature indicates that no instrument or technique can entirely eliminate these materials during non-surgical root canal retreatment.[24] Supplemental activation of irrigation solutions during retreatment has been found to improve the efficiency of root-filling material (RFM) removal by approximately 1.15 to 2.1 times.[25] This research was structured to compare the effectiveness of supplemental activation techniques (PUI, XPF, XPF-R, and CNI) in the removal of AH Plus Bioceramic sealer from IRR cavities. The present research demonstrated that no statistically significant differences were found between the PUI, XPF, and XPF-R techniques. However, these techniques were found to be significantly more effective than CNI. Therefore, the null hypothesis of our study was partially rejected.

Ultrasonic activation with a smooth ultrasonic tip is an effective supplementary technique that significantly reduces the amount of RFM.[26] In the study conducted by Duzgun et al.[27] which evaluated various irrigation activation methods for removing calcium silicate-based sealer from artificially created cavities, passive ultrasonic irrigation (PUI) emerged as the most effective technique. Despite its effectiveness, no sealer-free samples were observed. This difference in findings may be attributed to methodological variations in irrigation activation protocols, such as differences in activation time, irrigant volume, or power settings.

The XPF file is a non-cutting rotary file made of MaxWire alloy, which adapts to the root canal system's anatomy by changing its shape based on temperature differences.[28] Adopting a spoon-like shape when transitioning to an austenitic phase facilitates the delivery of irrigation solutions to irregular areas without compromising dentin integrity. The ability of XPF to achieve the removal of the sealer in oval canals from artificial groove was reported by Sümbüllü et al.[29] which was similar to the results observed in the present study.

The XPF-R instrument, specifically designed for retreatment procedures, features a larger core diameter (ISO 30) and enhanced stiffness. Its unique MaxWire alloy composition ensures exceptional flexibility, enabling effective performance in complex root canal anatomies. [19] This study demonstrated that the XPF-R group achieved a significantly higher percentage of a ‘score of 0’ compared to CNI. This result is attributed to XPF-R's ability to reach, adapt to, and effectively remove sealer from artificial resorption cavities. The findings of this study is consistent with the findings by Da Silva et al.[30] suggesting that the use of XPF-R following the initial retreatment protocol enhances the removal of bioceramic sealer from oval-shaped root canals.

A score of 0, namely a cavity completely empty was observed in 15.4% of the samples agitated with PUI, 38.46% with XPF, and 53.85% with XPF-R, indicating varying levels of effectiveness across the activation methods with no significant differences between groups. This difference may be attributed to the fact of agitation principle. Ultrasonic activation of irrigant solutions relies primarily on cavitation effects and the propagation of acoustic waves, which generate fluid movement and enhance RFM removal.[16] In contrast, XP-endo instruments combine this hydraulic effect with mechanical action, achieved through their unique design and material properties, allowing direct interaction with the canal walls. This dual approach enables XP-endo instruments to provide both effective irrigation and mechanical debridement.[17]

The XPF-R group demonstrated a higher percentage of cleaned resorption cavities compared to the XPF group, although the difference was not statistically significant. This finding aligns with study by Silva et al.[19] which reported comparable effectiveness of XPF-R and XPF files in removing residual filling materials from root canals. The XPF-R file features a larger core diameter, and a distinct tip angulation compared to the XPF file, making it potentially more aggressive, both instruments effectively adapt to canal morphology due to their mixed-phase (M-phase/A-phase) working mechanism. However, none of the instruments were able to completely eliminate all the residual filling material. Supplementary irrigation activation techniques after the use of a retreatment file significantly have been provided better efficacy of the sealer removal.[31] In our study, XP-RS files were used before applying supplemental techniques. The design of the XP-RS file enables maximum contact with the canal walls, resulting in a higher percentage of touched walls.[32] The use of XP-RS may have enhanced the effectiveness of the sealer removal by PUI, XPF, and XPF-R techniques.

When IRR perforates the root structure and creates a contact between the root canal and the periodontal area, achieving proper cleaning and sealing becomes challenging, and the orthograde approach may be insufficient.[33] However, in our study, a limited resorption model was used, with cavities prepared to a depth of 0.8 mm and a diameter of 1.6 mm, allowing these goals to be considered achievable through an orthograde approach.

The storage duration of 1 to 4 weeks was in the majority of research conducted on the removal of root canal sealers.[34,35] A recent study observed that bioactive sealers peeled off from the root canal walls during retreatment of specimens that had been stored for 4 months following obturation.[36] Considering this information, a 4-week storage period was selected in the present study to simulate an early stage of sealer setting and interaction with dentinal walls, without allowing excessive maturation or aging.

In the current study, both irrigation solution (NaOCl and EDTA) was activated in three cycles of 20 seconds, with irrigant renewal after each cycle, totaling 2 minutes for all activation systems. This protocol created a cumulative effect, effectively removing additional materials. Previous findings also suggest that this activation method improves the elimination of residual filling material after re-instrumentation, making it a beneficial approach in retreatment procedures.[37]

Several limitations of this study need to be noted for a better understanding of the findings. In this study, root canal with artificial IRR cavity was not fully obturated with gutta- percha and sealer. The findings should be interpreted accordingly, since the clinical conditions are not fully reflected. Additionally, a cost-effective, feasible method that provides qualitative and quantitative assessment, the stereomicroscope, was used to score sealer removal. However, in the present study stereomicroscope was used for qualitative assessment. Further studies could quantitatively evaluate the effect of different activation techniques on sealer removal from artificial IRR cavities obturated with different obturation techniques.

Conclusions

The PUI, XPF, and XPF-R activation systems have been identified as efficient alternatives for removal of the sealer in IRR cavities. Supplementary strategies for removing filling materials have been scientifically validated and offer notable benefits in non-surgical retreatment therapy, despite their inability to completely eliminate all remnants of filling materials.

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Conflicts of Interest Statement

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

References

1. Tek V, Türker SA. A micro-computed tomography evaluation of voids using calcium silicate-based materials in teeth with simulated internal root resorption. Restor Dent Endod 2020;45:e5.
2. Küçükkaya Eren S, Aksel H, Askerbeyli Örs S, Serper A, Koçak Y, Ocak M, Çelik HH. Obturation quality of calcium silicate-based cements placed with different techniques in teeth with perforating internal root resorption: a micro-computed tomographic study. Clin Oral Investig 2019;23:805-811.
3. Lyngdoh D, Alam S, Iftekhar H, Mishra SK. Evaluation of canal patency and cleanliness following retreatment of bioceramic sealer-obturated root canals using three different irrigant activation protocols. Aust Endod J 2024;50:475-485.
4. Ruggiero SL, Dodson TB, Aghaloo T, Carlson ER, Ward BB, Kademani D. American Association of Oral and Maxillofacial Surgeons' position paper on medication-related osteonecrosis of the jaws—2022 update. J Oral Maxillofac Surg 2022;40:920-943.
5. Aminoshariae A, Donaldson M, Horan M, Mackey SA, Kulild JC, Baur D. Emerging antiresorptive medications and their potential implications for dental surgeries. J Am Dent Assoc 2022;153: 649-658.
6. Gulabivala K, Ng YL. Factors that affect the outcomes of root canal treatment and retreatment—A reframing of the principles. Int Endod J 2023; 56:82-115.
7. Drukteinis S, Camilleri J. Bioceramic materials in clinical endodontics. Springer 2021.
8. Sanz JL, López-García S, Rodríguez-Lozano FJ, Melo M, Lozano A, Llena C, Forner L. Cytocompatibility and bioactive potential of AH Plus Bioceramic Sealer: An in vitro study. Int Endod J 2022;55:1066-1080.
9. Sanz JL, López-García S, García-Bernal D, Rodríguez-Lozano FJ, Forner L, Lozano A, Murcia L. Comparative bioactivity and immunomodulatory potential of the new Bioroot Flow and AH Plus Bioceramic sealer: An in vitro study on hPDLSCs. Clin Oral Investig 2024;28:195.
10. Hamdy TM, Galal MM, Ismail AG, Saber S. Physicochemical properties of AH plus bioceramic sealer, Bio-C Sealer, and ADseal root canal sealer. Head Face Med 2024;20:2.
11. Jiang S, Zou T, Li D, Chang JW, Huang X, Zhang C. Effectiveness of sonic, ultrasonic, and photon-induced photoacoustic streaming activation of NaOCl on filling material removal following retreatment in oval canal anatomy. Photomed Laser Surg 2016;34:3-10.
12. Fischer BV, Goulart TS, Vitali FC, de Souza DL, Teixeira CDS, Garcia LDFR. Supplementary methods for filling material removal: A systematic review and meta-analysis of Micro-CT imaging studies. J Dent 2024:105445.
13. da Rosa AF, Fischer BV, Dias-Junior LCL, Serique AVC, Bortoluzzi EA, Teixeira CDS, da Fonseca Roberti Garcia L. Effectiveness of different supplementary protocols for remaining filling material removal in endodontic reintervention: an integrative review. Odontology 2024;112:51-73.
14. van der Sluis LW, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. Int Endod J 2007;40:415-426.
15. Căpută PE, Retsas A, Kuijk L, Chávez de Paz LE, Boutsioukis C. Ultrasonic irrigant activation during root canal treatment: a systematic review. J Endod 2019 45:31-44.e13.
16. Cavenago BC, Ordinola-Zapata R, Duarte MA, del Carpio-Perochena AE, Villas-Bôas MH, Marciano MA, Bramante CM, Moraes IG. Efficacy of xylene and passive ultrasonic irrigation on remaining root filling material during retreatment of anatomically complex teeth. Int Endod J 2014;47:1078-1083.
17. De-Deus G, Belladonna FG, Zuolo AS, Cavalcante DM, Carvalhal JCA, Simões-Carvalho M, Souza EM, Lopes RT, Silva EJNL. XP-endo Finisher R instrument optimizes the removal of root filling remnants in oval-shaped canals. Int Endod J 2019;52:899-907.
18. Sağlam BC, Hazar E, Koçak S, Koçak MM. Efficacy of XP-Endo Finisher and passive ultrasonic irrigation on modified triple antibiotic paste removal. Cumhuriyet Dent J 2019;22:108-113.
19. Silva EJNL, Belladonna FG, Zuolo AS, Rodrigues E, Ehrhardt IC, Souza EM, De-Deus G. Effectiveness of XP-endo Finisher and XP-endo Finisher R in removing root filling remnants: a micro-CT study. Int Endod J 2018;51:86-91.
20. Sinsareekul C, Hiran-Us S. Comparison of the efficacy of three different supplementary cleaning protocols in root-filled teeth with a bioceramic sealer after retreatment—a micro-computed tomographic study. Clin Oral Investig 2022;26:1-7.
21. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971;32:271-275.
22. van der Sluis LW, Wu MK, Wesselink PR. The evaluation of removal of calcium hydroxide paste from an artificial standardized groove in the apical root canal using different irrigation methodologies. Int Endod J 2007;40:52-57.
23. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159-174.
24. Crozeta BM, Silva-Sousa YT, Leoni GB, Mazzi-Chaves JF, Fantinato T, Baratto-Filho F, Sousa-Neto MD. Micro–computed tomography study of filling material removal from oval-shaped canals by using rotary, reciprocating, and adaptive motion systems. J Endod 2016;42:793-797.

25. Arul B, Varghese A, Mishra A, Elango S, Padmanaban S, Natanasabapathy V. Retrievability of bioceramic-based sealers in comparison with epoxy resin-based sealer assessed using microcomputed tomography: A systematic review of laboratory-based studies. J Conserv Dent 2021;24:421-434.
26. Bernardes RA, Duarte MAH, Vivan RR, Alcalde MP, Vasconcelos BC, Bramante CM. Comparison of three retreatment techniques with ultrasonic activation in flattened canals using micro-computed tomography and scanning electron microscopy. Int Endod J 2016;49:890-897.
27. Düzgün S, Topçuoğlu HS, Kahraman Ö, Eminsoy AT. Efficacy of different irrigation agitation systems in the removal of root canal sealers from artificial standardized grooves. Aust Endod J 2023;49:339-344.
28. Uzunoglu-Özyürek E, Küçückkaya Eren S, Karahan S. Contribution of XP-Endo files to the root canal filling removal: A systematic review and meta-analysis of in vitro studies. Aust Endod J 2021;47:703-714.
29. Sümbüllü M, Ali A, Büker M, Arslan H. The efficiency of different irrigation activation techniques in the removal of calcium silicate-based endodontic sealer from artificially created groove. Aust Endod J 2023;49:238-244.
30. Da Silva V, Loroño G, Valencia de Pablo O, Estevez R, Conde AJ, Rossi-Fedele G, Cisneros R. The supplementary use of XP-endo Finisher R after Reciproc enhances the removal of a bioceramic sealer in oval root canals. Aust Endod J 2023;49:156-161.
31. Crozeta BM, Lopes FC, Menezes Silva R, Silva-Sousa YTC, Moretti LF, Sousa-Neto MD. Retreatability of BC Sealer and AH Plus root canal sealers using new supplementary instrumentation protocol during non-surgical endodontic retreatment. Clin Oral Investig 2021;25:891-899.
32. De-Deus G, Belladonna FG, Zuolo AS, Cavalcante DM, Simões Carvalho M, Marinho A, Souza EM, Lopes RT, Silva EJNL. 3-dimensional ability assessment in removing root filling material from pair-matched oval-shaped canals using thermal-treated instruments. J Endod 2019;45:1135-1141.
33. Asgary S, Eghbal MJ, Mehrdad L, Kheirieh S, Nosrat, A. Surgical management of a failed internal root resorption treatment: a histological and clinical report. Restor Dent Endod 2014;39:137-142.
34. Ersahan, S. & Aydin, C. Solubility and apical sealing characteristics of a new calcium silicate-based root canal sealer in comparison to calcium hydroxide-, methacrylate resin-and epoxy resin-based sealers. Acta Odontologica Scandinavica 2013;71:857-862.
35. Weller RN, Tay KC, Garrett LV, Mai S, Primus CM, Gutmann JL, Pashley DH, Tay FR. Microscopic appearance and apical seal of root canals filled with gutta-percha and ProRoot Endo Sealer after immersion in a phosphate-containing fluid. Int Endod J 2008;41:977-986.
36. Pedullà E, Abiad RS, Conte G, Khan K, Lazaridis K, Rapisarda E, Neelakantan P. 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;52:1377-1387.
37. van der Sluis LW, Vogels MP, Verhaagen B, Macedo R, Wesselink PR. Study on the influence of refreshment/activation cycles and irrigants on mechanical cleaning efficiency during ultrasonic activation of the irrigant. J Endod 2010;36:737-740.