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THE ABILITY OF THREE DIFFERENT PROTOCOLS IN REMOVING BIOCERAMIC- AND RESIN-BASED SEALER FROM SIMULATED INTERNAL ROOT RESORPTION CAVITIES: AN IN VITRO SUTDY

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ABSTRACT

Aim: this study aims to to compare two sealers removability (bioceramic based and resin based) using three approaches (XP-endo shaper, XP-endo finisher, and Passive Ultrasonic Irrigation) in internal root resorption simulated teeth.

Methodology: 132 extracted mandibular premolars were prepared and split, artificial cavities were placed on both teeth segments 5 mm from root apex then teeth segments were brought back together and fixed in epoxy resin model. Models were randomly assigned to six groups (n=22) according to the root canal filling and retreatment protocol. Group 1: (filled with GP + BC sealer and retreated using XP-endo Finisher). Group 2: (filled with GP + Resin sealer and retreated using XP-endo Finisher). Group 3: (filled with GP + BC sealer and retreated using XP-endo Shaper). Group 4: (filled with GP + Resin sealer and retreated using XP-endo Shaper). Group 5: (filled with GP + BC sealer and retreated using PUI). Group 6: (filled with GP + Resin sealer and retreated using PUI). Samples were incubated for 4 weeks then teeth were extracted from epoxy model and split again to evaluate sealer removability under digital light microscope.

Results: No significant difference were found between the six groups when it comes to sealer removability Van der Sluis score ($p = 0.013$). Group 5 showed the highest Van der Sluis score followed by groups 1, 2, 4 and 6 without significant difference between them. Group 3 showed a significantly lower Van der Sluis score than group 5. There was no significant difference between group 3 and groups 1, 2, 4 and 6 in the Van der Sluis score.

Conclusion: No treatment protocol was able to eliminate all sealer remnant effectively. Resin based sealer showed no significant difference when compared to Bioceramic based sealer when it comes to sealer removability, the exception was that XP-endo shaper showed significantly better results when compared to passive ultrasonic activation which has failed to remove Bioceramic remnants compared to XP-endo shaper.

KEYWORDS: Bioceramic, Resin, Passive Ultrasonic Irrigation, XP-endo Shaper, XP-endo Finisher, Retreatment, Sealer removability.

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INTRODUCTION

Atypical Root Canal Anatomy

The main objective of the endodontic treatment is to fully disinfect and three dimensionally seal the root canal to prevent reinfection and to preserve the health of the periapical tissue. Thus, several types of sealers have been recommended to achieve this goal **Kazachkov (2015)**.

During initial root canal treatment, a considerable volume of debris are packed into the atypical root canal anatomy areas such as isthmuses or any other irregularities inside root canal system that often harbor debris and microorganisms after chemo-mechanical debridement **Endal et al. (2011)**. These variations in the root canal system are the rule rather than the exception and many complex multispecies bacterial biofilms were found in such atypical root morphology of teeth with failed root canal treatment. These bacteria were detected surviving and caused failure **Carr et al. (2009)**.

Root Canal Sealer Role:

Root canal filling consist of gutta-percha core and a sealer, this sealer is mainly used to ensure a hermetic seal, adequately form a fluid-tight filling and adhere to root canal irregularities.

Multiple sealers are available at the present, probably the most famous and most studied in the last two decades is the Resin-based sealer, with various favorable properties such as: low solubility, strongly bond to gutta-percha and dentinal walls and a good flowability that serves one of the ultimate purposes of root canal sealer. **Azizi et al. (2024)**

Recently the Bioceramic-based sealer gained popularity due to its superior properties: bioactive, highly bactericidal and high flowability that it could even penetrate dentinal tubules. Its flowability and dimensional stability even presented the novel single cone obturation technique. **Alves Silva et al. (2020)**

Sealer Removability

Despite the high success rate of primary endodontic treatment unfortunately failure could occur and the conservative solution would be to properly redo the root canal treatment or as it called non-surgical root canal retreatment. Root canal retreatment were found to have excellent results and very comparable to the initial or primary treatment in terms of tooth survival rate. Hence, it is proven to be the best choice in case of treatment failure, with multiple prognostic factors, one of them is regaining apical patency and eliminating the previous root canal filling **Gulabivala & Ng (2023)**.

Sealer removability is a subject of current studies, regaining patency and sealer removability both were proven to increase success to reach a predicted treatment outcome. So many attempts and methods are suggested that include chemical solvents, mechanical or integrating recent technologies **Al akam et al. (2024)**.

In this in-vitro study we tried to test the benefits of the innovative MAX-wire alloy in both XP-endo Shaper and XP-endo Finisher files and compare it to the well-known Passive Ultrasonic Irrigation in sealer removability of both Resin- and Bioceramic-based sealers

MATERIALS AND METHODS

This in vitro experiment was conducted on extracted human lower premolar teeth. This study was reviewed and approved by Cairo University Institutional Review Board (IRB) prior to study initiation under reference 6-1-22.

Sample size was calculated using the (G power software). As regarding the primary outcome (sealer removability) we found that 22 teeth per group will be appropriate sample size for the study with total sample size 132 teeth (6 groups) the power is 80% and α error probability =0.05

z tests - Proportions: Difference between two independent proportions. The magnitude of the

effect to be detected was estimated as proportion of the variable of interest and obtained from the scientific literature.

Inclusion criteria were permanent lower premolar human teeth with complete mature apices, no previous root canal treatment and teeth with a straight canal. Exclusion criteria were cracked, carious or calcified root canal teeth. Each sample were examined under dental operating microscope and confirmed to fit in the inclusion criteria after radiographic images.

Access and mechanical preparation

The average root length was 18 mm. Teeth were sectioned using a low-speed sectioning disc and then confirmed with a digital caliper. Proper access cavity was done. Tooth pulp was extirpated then #15 K-file was used to determine the working length, which is 1 mm shorter from the apical foramen. root canal was mechanically prepared to the size #35/.04 using BT Race(FKG Dentaire, La Chaux-de-Fonds, Switzerland).

Internal resorption simulation

Following **Topçuoğlu et al. (2015)** methodology, samples were set in silicon(Zetaplus; Zhermack, Rovigo, Italy) in an "Eppendorf" tube to facilitate precise reassembly later (Figure 1). Samples then were removed, and two longitudinal grooves were prepared (buccal and lingual) along the roots, and then root was split using a chisel and mallet. On both segments, standard cavities (0.8 mm depth, 1.6 mm diameter) were prepared 5 mm from the apex, using a very small amount of superglue (3M, St. Paul, MN) only one root outer surface to glue root halves together and avoid canal blockage later and then allowed to set in the silicone models. Each Eppendorf tube was coded with a number for allocation later.

Reassembling the roots

Following **Bramante et al. (1987)** idea, a 2-piece metal "aluminum" were used to model a resin-block, where transparent epoxy resin was poured in, and then root was fixed in. After resin polymerization, muffle was opened, and the resin block was ready. (Figure 2)

Obturation and incubation

Following to the allocation, each sample was obturated accordingly with either "resin-based" or "bioceramic-based" sealer as follows: 66 teeth were obturated with warm vertical compaction technique with resin-based "AH plus® resin-based sealer(Dentsply International, Addlestone, UK)" 66 teeth were obturated with warm vertical compaction technique with Bioceramic based sealer "TotalFill® BC Sealer(FKG Dentaire, La Chaux-de-Fonds, Switzerland)"

Composite filling was placed coronally to insure adequate coronal seal and then the blocks were stored 37º C and 100% humidity for 4 weeks to allow the complete setting of the sealer.

After 4 weeks:

Group 1: [XP-endo Finisher(FKG Dentaire, La Chaux-de-Fonds, Switzerland) + TotalFill BC Sealer]

Patency was secured using #15 K-file8 along with D-Race retreatment files. After NaOCl (5mL/5.25%) irrigation XP-F was used at (800rpm/1N.cm^{-1}) for 60 seconds using gentle vertical movements (60 strokes), then flushed with distilled water and dried, then flushed again with EDTA (5mL/17%) and instrumented with XP-F again for 60 seconds and dried with paper point.

Group 2: [XP-endo Finisher + AH plus resin-based sealer]

Patency was secured using #15 K-file8 along with D-Race retreatment files. After NaOCl (5mL/5.25%) irrigation XP-F was used at (800rpm/1N.cm^{-1}) for 60 seconds using gentle vertical movements (60 strokes), then flushed with distilled water and dried,

then flushed again with EDTA (5mL/17%) and instrumented with XP-F again for 60 seconds and dried with paper point.

Group 3: [XP-endo Shaper (FKG Dentaire, La Chaux-de-Fonds, Switzerland) + TotalFill BC Sealer] Patency was secured using #15 K-file along with D-Race retreatment files. Then XP-S was used following the manufacture instructions: after NaOCl (5mL/5.25%) irrigation XP-S file was used at (800rpm/1N.cm^{-1}) in vertical movements for a total of 15 strokes, the root canal was then flushed with distilled water and dried, then flushed again with EDTA (5mL/17%) and instrumented with XP-S again for 15 strokes.

Group 4: [XP-endo Shaper + AH plus resin-based sealer]

Patency was secured using #15 K-file along with D-Race retreatment files. Then XP-S was used following the manufacture instructions: after NaOCl (5mL/5.25%) irrigation XP-S file was used at (800rpm/1N.cm^{-1}) in vertical movements for a total of 15 strokes, the root canal was then flushed with distilled water and dried, then flushed again with EDTA (5mL/17%) and instrumented with XP-S again for 15 strokes.

Group 5: (PUI + TotalFill BC Sealer]

Patency was secured using #15 K-file along with D-Race retreatment files. Then the canal was flushed with 5mL of 5.25% NaOCl and then Ultrasonically activated using an ultrasonic activation tip "#20 .02" for 30 seconds then the irrigating solution was replaced to remove the debris. This cycle was repeated 4 times, then flushed again with distilled water, dried, then flushed with 5mL of 17% EDTA for another 1 minute.

Group 6: [PUI + AH plus resin-based sealer]

Patency was secured using #15 K-file along with D-Race retreatment files. Then the canal was flushed with 5mL of 5.25% NaOCl and then Ultrasonically activated using an ultrasonic activation tip "#20 .02" for 30 seconds then the irrigating solution was replaced to remove the debris. This cycle was repeated 4 times, then flushed again with distilled water, dried, then flushed with 5mL of 17% EDTA for another 1 minute.

Evaluation of the sealer removability

Specimens were stored at 100% humidity for 1 week in order to imitate oral environment.

Then the bulk of the epoxy resin was removed using double cut carbide rotary burs with the help of universal paint thinner to facilitate the process until we reach the tooth surface allowing us to split each specimen.

Digital images of each half have been taken from Inverted Laboratory Microscope equipped with a digital camera (Leica Microsystems©, Wetzlar, Germany) (Figure 3) and assessed using the scoring system established by **Van Der Sluis et al. (2007)** (Table 1).

Data were presented as mean, standard deviation (SD), median, minimum and maximum values. Van der Sluis score was compared among the 6 groups using Kruskal Wallis test followed by Dunn's post hoc test with Bonferroni correction for pairwise comparisons. The level of significance was set at p=0.05.

Statistical analysis was performed using SPSS software Version 25.0. Armonk, NY: IBM Corp.

TABLE (1) Van Der Sluis score

0	Debris-free cavity.
1	Less than 50% of the cavity is filled.
2	More than 50% of the cavity is filled.
3	Completely filled cavity.

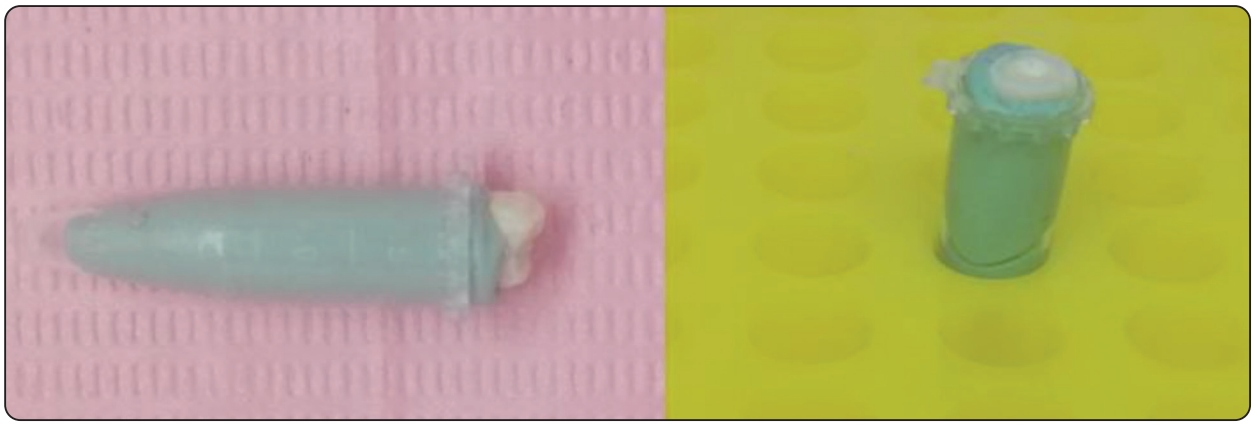

Fig. (1) Eppendorf model

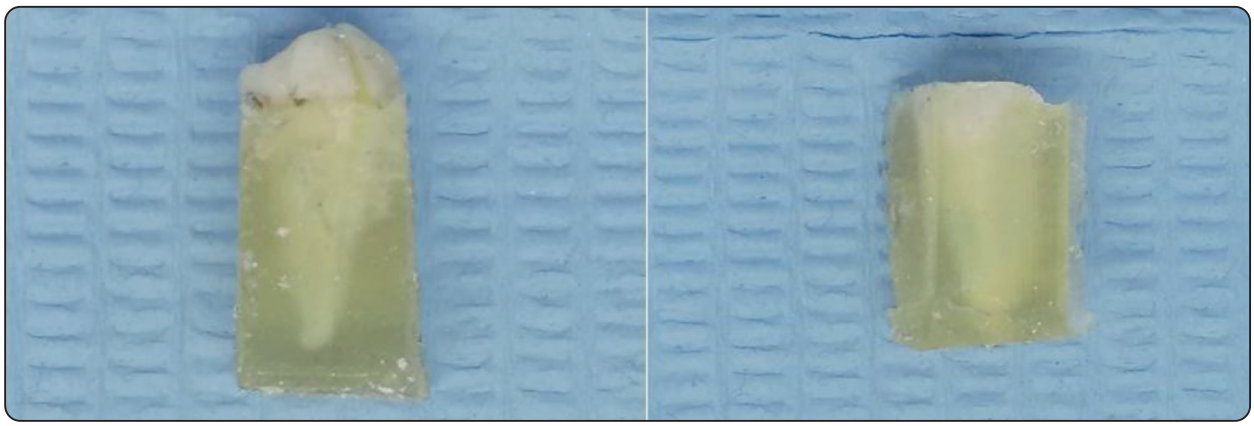

Fig. (2) Epoxy resin model

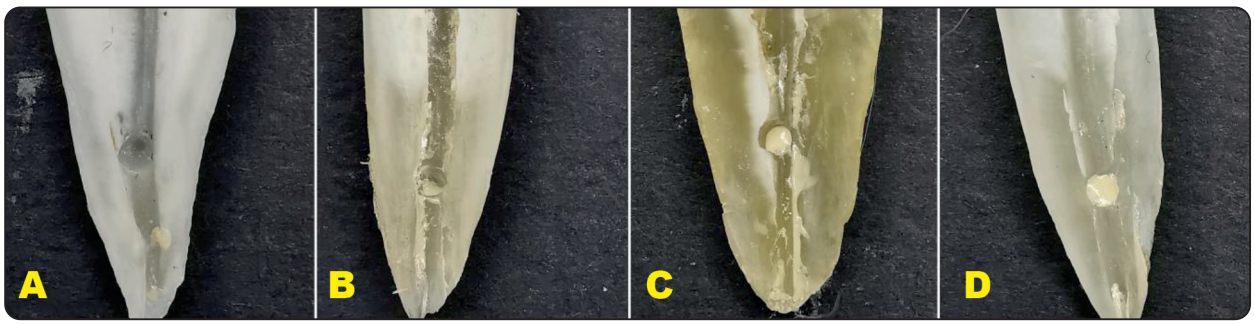

Fig. (3) Microscopic images evaluation (A) score 0. (B) score 1. (C) sore 2. (D) score 3.

RESULTS

There was a statistical significant difference between the 6 groups in the sealer removability Van der Sluis score ($p = 0.013$). Group 5 showed the highest Van der Sluis score followed by 1, 2, 4 and 6 without significant difference between them. Group 3 showed a significantly lower Van der Sluis score than group 5. No statistical significant difference between group 3 and any of groups 1, 2, 4 and 6 in the Van der Sluis score (Table 2) (Figure 4)

TABLE (2) number of specimen according to each score

Group \ Score	0	1	2	3
1 (XP-F + BC)	×	1	11	10
2 (XP-F + Resin)	×	2	12	8
3 (XP-S + BC)	×	6	14	2
4 (XP-S + Resin)	×	4	9	9
5 (PUI + BC)	×	×	11	11
6 (PUI + Resin)	4	5	5	8

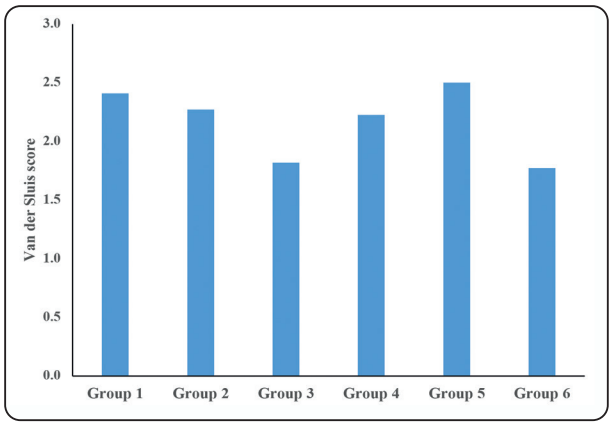

Fig. (4) Bar chart representing the mean sealer removability Van der Sluis score in the 6 groups.

DISCUSSION

This study aimed to compare three treatment protocols in removing two types of sealer, the resin-based and biceramic-based, from simulated intra-canal cavities that somehow mimic some clinical scenarios.

This research design was carried out in a laboratory setting as it offers many advantages. The close look to evaluate sealer remnants in such cases are relatively impossible to obtain clinically in a clinical study.

This study includes single-rooted mandibular premolars as they are bulky enough to survive the relatively harsh methodology

Simulated internal root canal resorption was done following **Topçuoğlu et al. (2015)** methodology which was found to be a simple but yet effective method in tracing irrigation protocol efficacy.

One extra step than **Topçuoğlu et al. (2015)** and other researchers who had followed his methodology. The extra step was the retreatment procedures, removing gutta-percha with rotary NiTi files and hand files could project extra forces to the studied tooth, so we had to combine it with **Bramante et al. (1987)** method "2-piece metal muffle" the epoxy block containing the tooth was used to attain maximum strength for specimen.

5 mL of 5.25% NaOCl was used to irrigate between every two successful files in each group as it is the gold standard endodontic irrigant owing to its capacity to disintegrate necrotic pulp tissue, neutralize bacterial byproducts and most importantly to actively flush organic and inorganic materials **Abu Zeid et al. (2021)**

17% EDTA is the most popular chelating agent used as a final irrigant because it has a powerful capacity in removing smear layer **Abu Zeid et al. (2021)**

Bioceramic sealer and resin sealer were both used in this study to generalize this attempt in evaluating

sealer removability, both kinds are considered the gold standard in root canal obturation, and both are studied together in comparative studies nowadays **Shim et al. (2021)Mahajan et al. (2023)**

Passive Ultrasonic Activation was chosen to be one of the treatment approaches as it is considered to be one of the best procedures when it comes to irrigant activation in both primary endodontic treatment and non-surgical root canal retreatment. Moreover, it has showed good efficacy in removing root canal sealer in recent studies **Tandon et al. (2022)E. Hassan et al. (2022)**

XP-Shaper and XP-Finisher are both made from the innovative alloy Max-wire (martensite-austenite electropolish flex). This alloy can transform from the Martensite phase (room temperature) to Austenite phase (body temperature). So, when introduced into canal, the alloy transforms into the Austenite phase, forming a spoon-shape of 1.5 mm in depth in the very last 10 mm. The Austenite phase allows the instrument to reach inaccessible areas, activating the irrigating solution without changing the canal shape **Alves et al. (2016)**

The scoring established by **Van Der Sluis et al. (2007)** was used after the visual assessment of the quantity of root sealer in the cavity under the optical microscope, owing to its clarity and simplicity to obtain a categorical unit and acquire measurable data as evident in literature **Arslan et al. (2014); Balvedi et al. (2010); Taşdemir et al. (2011)**

In this study, neither the intervention nor control groups were able to repeatedly or predictably eliminate the root canal sealer, whether it was bioceramic-based or resin-based, this fining came in agreement with the previous researcher's works **H. Y. Hassan et al. (2023); R. Hassan & El Zahar (2022); İriboz et al. (2019); Machado et al. (2019)**

There was no incidence of complete elimination of root canal sealer from the cavities except for group 6, the control group, which was the PUI in resin-based sealer obturation. This incident occurred 4 times out of 22 samples. Such finding did not affect statistically the overall results, where there was no significant difference between study groups, only group 5 showed the higher score with significant difference when compared to group 3.

Regarding Bioceramic based sealer "groups 1,3 and 5", passive ultrasonic activation showed the higher amount of sealer residuals with a significant difference when compared to the XP-endo shaper, and both XP-endo shaper and finisher did not show significant difference between them. This comes in agreement with **H. Y. Hassan et al. (2023)** findings, which claim that both XP-endo shaper and finisher had a significantly better results in term of cleaning efficacy, also in agreement with **R. Hassan & El Zahar (2022)** work where both XP-S and XP-F had significantly better results when tested under scanning electronic microscope. The ineffectiveness of PUI may be due to bioceramic strong bond to root canal dentin that the acoustic waves created by the ultrasonic device just failed to break, on the other hand the special metallurgy of the XP files and the transformation from M-phase to A-phase when subjected to higher temperature (body temperature) allows the instrument to contact and debride the inaccessible areas within the root canal which appears to have better mechanical cleaning efficacy. The XP-S showed higher percentage of cleaner cavities than the XP-F group, with no significant difference between the two groups in agreement with **Silva et al. (2018)**, the XP-F has a different core diameter and tip angulation compared to XP-S but this changes to the file did not differ in the overall results as both files can follow the root canal morphology owning its special metallurgic property.

On the Resin based sealer "groups :2,4 and 6" there was no significant difference between them, but Passive ultrasonic activation had the 4 incidence of cavity sealer free out of the whole groups, which

comes in an agreement with **Cavenago et al. (2014)** with the recommendation of coupling the PUI with xylene for a better results. On the other hand, **Machado et al. (2019)** stated that using XP-Finisher as a supplementary step significantly improved sealer removal.

Surprisingly and unlike the bioceramic groups, PUI had the higher percentage of clean cavities with no significant difference with XP-S and XP-F groups, this finding could arise as a consequence of Resin-based sealer properties. Lower flowability, relatively weaker bond strength and polymerization shrinkage could all be the reason that the resin sealer fails to withstand the acoustic waves of the ultrasonic **Grischke et al. (2014); Kim et al. (2010)**.

CONCLUSION

Giving this in-vitro study limitations, we can conclude:

- No treatment protocol was able to eliminate all sealer remnant effectively.
- Resin based sealer showed no significant difference when compared to Bioceramic based sealer when it comes to sealer removability, except for passive ultrasonic activation which has failed to remove Bioceramic remnants when compared to XP-endo shaper.

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Author contribution(s) Authors contributed to the manuscript.

Ethical approval Institutional Review Board (IRB) of Cairo University has reviewed and approved this research under reference 26-9-21 before the commencement of the study. Informed consent Not applicable.

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Conflict of interest We'd like to declare that there is no conflict of interests.

Data and materials availability All data are available upon request from the corresponding author.

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