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Comparison of Retreatability of Bioceramic Sealers with Epoxy Resin-Based Sealers: A Systematic Review

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KEYWORDS

Bioceramic sealers, epoxy resin-based sealers, retreatment, root canal filling material

ABSTRACT:

Aim:

Endodontic retreatment procedures using bioceramic sealers are gaining increasing credibility in tackling clinically challenging cases. The objective was to compare the retrievability of bioceramic sealers and epoxy resin-based sealers.

Methods:

The study protocol, registered in the International Prospective Register of Systematic Reviews and adhering to the Preferred Reporting Items for Systematic Reviews and Meta-analyses 2020 checklist, involved an electronic search for English-language studies from 2010 to 2023. Database used for searches were PubMed, Web of Science, Research Gate, Google Scholar, Scopus. The inclusion criteria were established based on the PICOS framework.

Studies involving artificial teeth, animal models, expert opinions, conference abstracts, book chapters, case reports, in vivo research, and narrative reviews were not considered for inclusion. The risk of bias was assessed using Quality Assessment Tool For In Vitro Studies (QUIN) Tool.

Results:

Eleven studies were categorized as low risk and eight studies as medium risk of bias. The study results were mixed with some showed that bioceramic sealers were easier or harder to remove, while others found no difference. The studies varied in the type of bioceramic sealer used, root canal anatomy, and retreatment techniques.

Conclusion:

Retreatment of canals with bioceramic sealers is usually possible with standard instruments and techniques. Additional removal methods like lasers, XP-Finisher, and ultrasonics enhance the process.

INTRODUCTION

The goal of root canal retreatment is to thoroughly disinfect the root canal space and promote periradicular healing by completely removing filling material as any remnants present can act as a mechanical barrier which can block disinfectants from reaching microbes in inaccessible areas like dentinal tubules and isthmuses.[1]

Despite high success rates, root canal treatments can fail, with a reported failure rate of 14-16%. In cases of treatment failure, alternatives include non-surgical retreatment, surgical procedures, or tooth extraction.[2]

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Endodontic retreatment involves removing remaining root filling materials, disinfecting, and subsequent refilling of the root canals. Residual material may harbor microbes, hindering the contact of irrigating solutions and intracanal dressings with the root canal walls leading to less favorable treatment outcomes.[3,4] For this purpose, it is crucial that the obturation material be completely removed to enhance the chances of treatment success.[5]

Although various materials are used to fill the root canals, gutta percha along with sealer is the most commonly used root canal filling material. Gutta percha cones cannot connect to each other and it also adheres to the dentine walls of the root canal which can hinder proper flooding of the canal.[6]

One of the fundamental properties of an ideal root canal filling material is that it can be easily removed for retreatment purposes. For proper removal, various techniques and materials have been proposed, including hand files, heat-carrying instruments, chemical solvents, ultrasonic devices, lasers, and engine-driven instruments such as Gates-Glidden drills, nickel-titanium (NiTi) rotary instruments, and reciprocating instruments.[7] Many studies have demonstrated that the use of rotary systems in retreatment is more effective and time-saving in removing gutta-percha.[8] Currently, supplementary techniques such as ultrasonic tips, XP-endo finisher rotary files, the Gentle Wave system, and photon-initiated photon acoustic streaming (PIPS) are utilized to enhance the removal of previous root filling material. However, to date, no retreatment technique facilitates complete removal of the filling material.[9]

The quality of the seal obtained with gutta-percha (GP) and conventional zinc oxide eugenol (ZOE) sealers is often less than ideal.[10,11] Despite its multiple advantages, the combination of gutta-percha (GP) and conventional sealer still has several shortcomings. These include its inability to reinforce the root structure due to poor adhesion to dentin, difficulties in controlling microleakage, and the solubility of the sealer, which can create uncertainty and affect prognosis. Monoblock approach is suggested to reduce bacterial ingress pathways and strengthen the root structure to some extent.[12,13] Therefore, several sealers have been developed as alternatives to zinc oxide eugenol (ZOE), aiming to improve the root canal seal and enhance its strength compared to conventional materials.[14]

In endodontics, Epoxy resin-based sealers are commonly employed due to their outstanding physicochemical properties and antibacterial characteristics.[15]

Recently, Bioceramic sealers have become increasingly popular which have demonstrated superior properties such as biocompatibility, bioactivity, antimicrobial efficacy, and the ability to promote mineralization of periapical tissues.[16]

The remnants of the material were assessed using various techniques including digital radiography, stereomicroscope, scanning electron microscopy, confocal microscopy, microcomputed tomography (micro-CT), and optical microscopy. The techniques utilized offer certain advantages but also come with limitations. Radiographs and digital images of vertically sectioned teeth provide two-dimensional information about a three-dimensional space, limiting accurate measurement of the total canal area. Another limitation is the subjective evaluation of the remaining material, which can vary between observers. [17]

The debate surrounding the removal of bioceramic root canal sealers during retreatment remains a significant concern among clinicians. Thus, the aim of this systematic review is to evaluate the retreatability of bioceramic-based sealers in comparison with resin-based sealers by identifying relevant published research and conducting a comparative analysis of the findings. The primary objective was to assess and compare the ease of removal of bioceramic sealer versus resin-based sealer. Additionally, the study sought to evaluate secondary factors which is the time required for retreatment.

MATERIALS AND METHODS

The preferred Reporting Items for systematic review and Meta – Analysis (PRISMA) guidelines were followed to report the current systematic review (Figure 1). The initial protocol was registered to the international prospective register of systematic reviews (PROSPERO ID:CRD42023479870).

Search strategy

The search strategy was based on research question "Which one among Bioceramic based sealers and Epoxy-Resin based sealers is easier to retrieve.?" Studies included in this systematic review were identified through electronic search of the following database: PubMed, Web of Science, Research Gate, Google Scholar, Scopus, and were searched for relevant literature using multiple combinations of keywords.

Boolean operator "AND" "OR" was used for searching article on PubMed. Terms like Bioceramic sealers AND Epoxy resin based was used. MeSH terms for both was retrieved from PubMed and was used with Boolean operator "OR". When looking in google scholar the Boolean terms were replace by "+" Retreatment + Sealers.

Eligibility criteria

PICOS(Population, Intervention, comparison, Outcome, Study design) was applied to appropriately determine the

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parameter to evaluate the retreatability of bioceramic-based sealers in comparison with Epoxy resin-based sealers.

a. Population (P): Endodontic retreatment of permanent extracted single rooted human teeth analyzed by various methods.

b. Intervention(I): Extracted single rooted permanent teeth obturated with Bioceramic based sealers.

c. Comparator(C): Extracted single rooted permanent teeth obturated with Epoxy resin based sealers.

d. Outcome (O): Retrievability of sealers

e. Study design (S): Laboratory based studies

Inclusion criteria

All the studies published from 2010-2023 that assess the retreatability of Bioceramic sealers in comparison with Resin based sealers in a single rooted teeth and single root canal with closed apex were included.

Exclusion criteria

All the studies conducted on artificial teeth or on animal, expert opinions, conference abstracts, book chapters, case reports, in-vivo studies and narrative reviews were excluded.

Study selection:

Identification and screening

All studies were extracted by electronic and Manual Search. Database search was performed by two independent reviewers and the articles were first selected by reading the title and abstracts. The duplicate search was removed. The articles were excluded based on the eligibility criteria. Full text articles were obtained and screened when the information in the title and abstract is inadequate to make a clear decision whether to include the study or exclude it and were assessed by two reviewers.

Risk of bias (quality) assessment

The quality of the selected studies was individually assessed. In accordance with the Quality Assessment Tool For In Vitro Studies (QUIN Tool), the twelve different criteria were considered. Each criterion can be adequately specified (score = 2), not adequately specified (score = 1), not specified (score = 0), or not applicable (NA). The final score for each study was determined by summing the twelve individual scores. In the end, the result obtained was used to grade every single study as high, medium, or low risk (>70% = low risk of bias, 50% to 70% = medium risk of bias, and <50% = high risk of bias) by using the following formula: Final score = (Total score × 100)/(2 × number of criteria applicable).

RESULTS

A total of 1631 articles were obtained from the electronic search, of which it was cross checked by another examiner to remove the duplicate articles. 516 articles were removed after duplicate examination. 19 articles which matched the PICO format of the review were included for final qualitative analysis.

Quality assessment

Results were presented appropriately and statistical analysis was reported adequately in all the studies. Overall, eleven studies were categorized as low risk and eight studies as medium risk of bias (Figure 2).

Types of sealers used

The reviewed studies compared ten different types of bioceramic sealers with epoxy-resin sealers (Figure 3). iRoot SP [2,18,19] were used in three articles while Endo C.P.M,[20] Well Root,[21] Ceraseal, [21] Endoseal MTA, [3] Sure-Seal Root, [8] MTA sealers [6] were used in one article each, respectively. EndoSequence BC sealer [2, 3, 18, 22] was used in four articles while BioRoot RCS [17,20,23,24,25] was used in four articles and Totalfill BC sealers [7,17,26] were used in three articles. The included articles utilized various obturation techniques such as single-cone obturation, continuous-wave compaction (CWC), thermoplasticized injectable technique, and cold lateral compaction.

Retreatment method

The included articles employed various retreatment rotary and reciprocating files, namely ProTaper Universal retreatment files, ProTaper Next, D-Race, XP-Endoshaper, Mtwo retreatment files, Reciproc, and Reciproc Blue. Additionally, some studies utilized regular rotary files such as Profile rotary files and Vortex blue files in their retreatment procedures. Some studies also incorporated supplementary techniques: one utilized passive ultrasonic irrigation, while two employed the XP-endo finisher.

Use of solvents

Four articles [5,6,8,23] used solvents such as Chloroform and Endosolv E. Athkuri *et al*. [23] employed Endosolv E exclusively during the initial stage of retreatment in the coronal third of the teeth. Oltra *et al*., [5] on the other hand, utilized chloroform throughout the root canal and found it to be effective in facilitating the removal of residual filling material.

Overview of outcome

A review of nineteen articles highlighted varying findings regarding the retrievability of bioceramic-based sealers compared to resin-based sealers. None of the studies achieved complete removal of gutta-percha and sealers from the root canals.

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The results were mixed, with five studies reporting easier retrievability of bioceramic sealers, seven studies reporting easier retrievability of epoxy resin based sealers and six studies indicating no significant difference. Kim K et al. reported no significant differences in retrievability between bioceramic sealers and AH Plus, particularly in single and double-rooted canals.

However, C-shaped canals presented challenges, with more remnants observed in canals obturated with Endoseal MTA than epoxy resin based sealers.

The differences in findings across the studies can largely be attributed to procedural heterogeneity, as variations in methodologies, techniques, and canal morphology influenced the results. Despite these differences, the studies provide valuable insights into the challenges of retrievability associated with bioceramic and resin-based sealers.

Oltra *et al.* [5] found EndoSequence BC sealer remnants primarily in the coronal third, while Kontogiannis TG *et al.*[9] reported significant AH Plus reduction using XP-endo finisher R files. Other articles noted more remnants in the apical third. [3,24,8,18,24] Uzunoglu E *et al* [2] observed similar and higher remnants in the apical and middle thirds compared to the coronal third, while Colmenar D *et al* [22] found no significant differences in material reduction between AH Plus and EndoSequence BC.

Jurić Kačunić D et al [27] found more AH Plus remnants in the apical third with Reciproc Blue than Reciproc M-Wire, while BioRoot RCS exhibited significantly more residual material with Reciproc Blue across all sections. MTA remnants were similar across all sections with both instruments. These findings reflect the influence of varying sealers and retreatment techniques.

DISCUSSION

The primary goal of non-surgical root canal retreatment is the complete removal of filling materials, debris, and microorganisms to ensure successful cleaning, reshaping, and refilling of the root canal system.[28,29,30] Incomplete removal can hinder treatment outcomes by limiting the effectiveness of irrigation solutions. [30,31] Various techniques and instruments, such as hand tools, ultrasonics, and rotary systems, are employed for retreatment. [28,29]

While epoxy resin-based sealers remain the gold standard, calcium silicate-based bioceramic sealers have emerged as promising alternatives due to their bioactivity, such as creating an alkaline environment that promotes mineralized tissue formation and antimicrobial effects.[32] These sealers also enhance bond strength through interfacial layers with tag-like structures. However, their retrievability remains a challenge.[33]

Techniques like scanning electron microscope (SEM), micro-CT, cone-beam computed tomography (CBCT), and optical microscopy are commonly used to assess residual materials on root canal surfaces.

The anatomy of the root canal plays a crucial role in determining the amount of residual root filling material. [9] Most reviewed studies used single straight canals without specifying shapes, except Oltra et al. [5] who included oval canals without verifying dimensions, and Alsubait et al. who used matched samples to reduce anatomical bias. Kim K et al. highlighted more remnants in complex C-shaped canals due to fins and webs, which hinder irrigant effectiveness.

None of the articles included in the review, except for Athkuri *et al.*[23], investigated the influence of obturation technique on the removability of the sealers. Athkuri *et al.*[23] found that warm vertical compaction and thermoplasticized injectable techniques left more remnants compared to the cold lateral compaction technique. They concluded that the type of obturation technique significantly affected the residual filling materials and the duration of retreatment procedures. However, consensus is lacking regarding the optimal obturation technique to use with bioceramic sealers.

Oltra *et al.* [5] found chloroform effective for removing filling material, while Athkuri et al.[23] used it selectively in the coronal third to soften material for easier rotary file penetration.

Nevertheless, clinicians should exercise caution when considering the use of solvents such as chloroform, given its toxicity and potential carcinogenic effects. Furthermore, solvents can create a thin layer of plasticized gutta-percha that adheres to the root canal walls and their irregularities, thereby prolonging operative times and complicating the retreatment procedure. [9]

Chloroform is widely used as a solvent in root canal retreatment procedures. However, it is known to be toxic to periradicular tissues, as well as hepatotoxic and nephrotoxic upon contact. Additionally, chloroform has the potential to alter the chemical composition of the dentin surface, which can reduce the bond strength of bonded materials. [34]

The concept of wicking action, which is crucial for removing residual filling material and sealer from fins and irregularities within root canal systems, was not addressed in any of the included articles. [34]

In clinical studies, the use of 0.5% or 1% sodium hypochlorite (NaOCl) and 2% chlorhexidine as irrigants has demonstrated retreatment success rates in teeth with persistent infections ranging from 58% to 84%. [35,36]

Specially designed retreatment files were used for the retrieval procedures such as ProTaper Universal retreatment

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files [25,2,37,8,21,24,25,22,6] R-Endo files and ultrasound ESI tips[18], Mtwo retreatment files, [20;23] and Neolix [8], NeoEndo [24], V-Blue files [19], FANTA[26]. A few of the included articles utilized regular rotary files for enlarging root canals, namely ProFile file [3,5] , Vortex blue files [5], Reciproc R40 and F6 SkyTaper[20], Reciproc M-wire [27] ProTaper Next [19], D-Race [7] which have been shown to be efficient during the retreatment of root canal.

The findings varied among the articles included in this review, with some indicating easier removal of bioceramic-based sealers, others suggesting AH Plus was easier to remove, and a few reporting no significant difference in the residual remnants left behind. The similarity in adhesion and sealing ability was cited as the reason for finding no significant difference in retrievability among the given sealers. [22]

On the other hand, Alsubait S *et al.* [25], Jurić Kačunić D *et al.* [27] suggest that the better bond strength and flow properties of AH plus sealer could make it difficult to retrieve.

AH Plus forms covalent bonds with root dentin collagen through interactions between its epoxy rings and exposed amine groups in collagen. [40]

Donyavi Z *et al.* [37] suggested that the high viscosity of MTA-containing sealers leads to poor adaptation to root canal walls, explaining fewer MTA Fillapex remnants than AH 26. Adhesion to dentin also affects retrievability, with resin-based sealers like AH 26 forming a strong monoblock and better bond strength to dentin, making them harder to remove than sealers like MTA Fillapex.

Athkuri S *et al* [23] found no significance difference in retrieval among the sealers. The highest percentage of remaining filling material was observed in groups treated with the Warm Vertical Compaction (WVC) technique. This outcome is likely due to the WVC system's capability to soften the gutta-percha, facilitating its better adaptation and compaction into the irregularities of the root canal.

This review focused exclusively on straight root canals, limiting the applicability of its findings to teeth with complex root canal anatomy. It was conducted on single-rooted teeth to minimize the influence of anatomical variations on the removal of filling materials.

Limitations

The variability among the included articles hindered the possibility of conducting a quantitative assessment for the systematic review. Differences in the sampling criteria, types of teeth or root canals studied, the endodontic sealers used, retreatment methods, and outcome measures reported across the studies prevented a meta-analysis from being conducted. However, this review provides a thorough analysis of endodontic retreatment results with various sealer types, offering insights that appear to be reported for the first time.

Conclusion

Retreatment is generally achievable with traditional methods, and supplemental techniques like lasers, XP-Finisher, and ultrasonics improve material removal. However, complete removal of remnants has not been consistently achieved. Since the reviewed studies were in vitro, they do not provide conclusive evidence on the full removal of bioceramic or resin bases sealers. Future studies with standardized protocols for assessing retrievability may yield more consistent results.

FIGURE 1: Preferred reporting items for systematic reviews and meta-analyses flow diagram

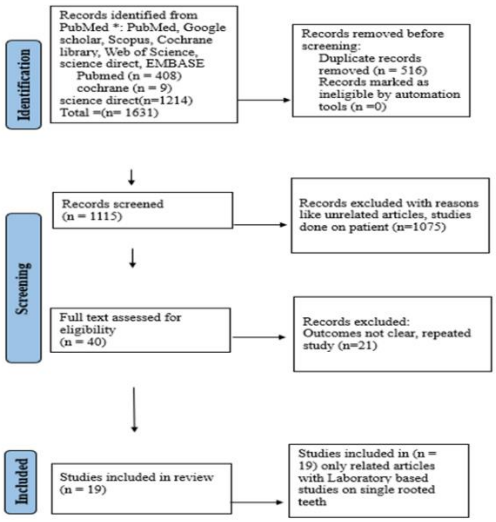
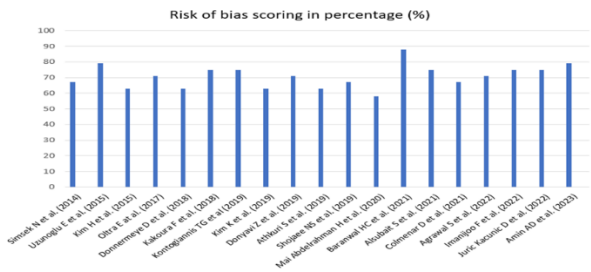


FIGURE 2: Risk of bias of included studies



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