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Review Article

Retreatment of bioceramic sealers in Endodontics – a systematic review

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ABSTRACT:

Objective: This systematic review aims to evaluate the retreatability of bioceramic sealers compared to conventional epoxy resin-based sealers in endodontic retreatment, focusing on residual material, re-establishment of patency, and the effectiveness of various removal techniques.**Materials and Methods:** A comprehensive search was conducted across multiple databases, including PubMed, Google Scholar, Web of Science, and Scopus, to identify studies addressing the retreatability of bioceramic sealers in endodontics. Studies assessing residual material, canal patency, and retreatment efficacy of bioceramic sealers, such as EndoSequence BC Sealer, TotalFill BC, and BioRoot RCS, compared with epoxy resin-based sealers like AH Plus, were included. Data on retreatment methods, including rotary instrumentation, ultrasonic activation, and solvent use, were extracted and analysed.**Results:** Bioceramic sealers demonstrated a greater degree of residual material in the apical third of root canals compared to AH Plus, posing challenges in achieving complete removal. Ultrasonic activation and advanced rotary systems, such as XP-endo Finisher R, improved material removal but did not achieve complete elimination. Patency reestablishment was notably more challenging in bioceramic-sealed canals, with bioceramic groups showing significantly lower patency rates. Solvents, effective with epoxy resin sealers, were less successful with bioceramic sealers due to their mineralised bonding to dentin. Overall, epoxy resin-based sealers were easier to remove, with shorter retreatment times and lower residuals.**Conclusion:** The strong bonding of bioceramic sealers to dentin complicates their retreatability, resulting in higher residuals and limited patency re-establishment, especially in the apical third. These findings suggest that while bioceramic sealers offer enhanced biocompatibility and sealing properties, clinicians should consider the potential retreatment challenges they pose. Future studies should explore modified formulations to improve retreatability as well as optimised retreatment techniques to address the limitations of bioceramic sealers in endodontic retreatment.

Keywords:bioceramic sealers, endodontic retreatment, residual material, canal patency, ultrasonic activation, epoxy resin-based sealers.

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INTRODUCTION

The introduction of bioceramic sealers in endodontics has transformed root canal treatment by bringing materials with good biocompatibility, bioactivity, and sealing qualities that promote healing and bone regeneration [1]. These sealers, which are primarily calcium silicate-based, have major advantages over traditional sealants like epoxy resin, zinc oxide-eugenol, and glass ionomer. Their ability to generate hydroxyapatite on the surface when in contact with tissue fluids provides a unique opportunity for physiologically integrated sealing and periapical healing [2, 3].

Bioceramic sealers have superior features such as great biocompatibility, little shrinkage, and antibacterial efficiency due to their alkaline pH and prolonged release of calcium ions [4]. Despite their promising characteristics, bioceramic sealers provide retreatment issues. The material's intrinsic adherence to root canal walls and low solubility make it difficult to remove during nonsurgical endodontic retreatment methods [5]. Retreatment is frequently required due to chronic or recurrent infections, insufficient earlier therapy, or new disease, and proper removal of root canal filling materials is a vital step in ensuring effective disinfection and healing [6, 7].

Traditional methods of root canal obturation removal, including rotational instruments, heat, or solvents, may be insufficient when dealing with bioceramic-based materials due to their adherence and bond strength. Several studies have investigated the performance of various retreatment regimens for bioceramic sealers, with an emphasis on procedural efficacy, time efficiency, and the possibility of retaining tooth structure [8]. However, these findings are frequently varied, with contradicting results, emphasising the importance of a systematic review to consolidate knowledge on bioceramic sealer retreatment [9, 10].

This systematic review seeks to critically assess and synthesise current information on the retreatment of bioceramic sealers in endodontics. This review aims to provide doctors with evidence-based information by examining procedural success, retreatment techniques, and outcomes involving bioceramic sealers in retreatment contexts.

METHODOLOGY

This systematic review was conducted following established guidelines to evaluate the effectiveness of retreatment techniques for bioceramic sealers in endodontics.

PICO Statement

The research question was formulated using the PICO framework, which helps to systematically define and address the key components of the clinical question. In this review:

- The Population (P) consists of patients who have undergone root canal treatment with bioceramic sealers and now require retreatment.
- The Intervention (I) focuses on the different methods or techniques used to remove bioceramic sealers, which may include rotary instrumentation, ultrasonic devices, heat, or solvents, among others.
- The Comparison (C) examines the effectiveness of one technique compared to another or a combination of techniques to establish the most efficient method for bioceramic sealer removal.
- The Outcome (O) includes several measures of success: procedural efficiency (time required), effectiveness in complete removal of the material, preservation of tooth structure, and overall retreatment success rate. This review aims to synthesize existing evidence on the efficacy of these techniques to provide guidance on best practices for retreating bioceramic-based obturations.

Eligibility Criteria

To ensure the inclusion of studies that directly address the PICO question, we set specific eligibility criteria. **Inclusion criteria** required studies to (1) involve human subjects who had undergone re-root canal treatments with bioceramic sealers and (2) provide comparative analyses (e.g., RCTs, cohort studies, case-control studies) that assess different techniques for removing bioceramic sealers. Only articles published in peer-reviewed journals in English were considered. Additionally, we required studies to provide quantitative data on primary outcomes, such as procedural success, retreatment efficacy, or time efficiency.

Studies were excluded if they investigated non-bioceramic sealers, were case reports, or were systematic reviews, meta-analyses, or general expert opinions. We also excluded studies on animal models or in vitro studies if they lacked a human clinical component. This selection process ensured that only clinically relevant, original research was included in our review.

Search Strategy

A comprehensive and systematic search was conducted across four major electronic databases—PubMed, Embase, Web of Science, and Scopus—covering literature from inception. We constructed a search strategy that combined keywords and Boolean operators to capture all relevant articles on bioceramic sealers and retreatment methods. The search terms included combinations of “bioceramic sealers” OR “calcium silicate sealers” AND “endodontic retreatment” OR “root canal retreatment” AND “efficacy” OR “success rate” OR “removal techniques.” Filters were applied to limit studies to human subjects, and language restrictions were set to English. Additionally, the reference lists of all included studies and relevant reviews were manually screened to identify further studies that met our criteria but may not have appeared in the initial database search.

Data Extraction

Data extraction was conducted using a standardised protocol, with two independent reviewers gathering information from each study to ensure accuracy and reliability. The reviewers extracted details on study characteristics (authors, publication year, study design, sample size, and setting) and patient demographics and clinical characteristics, such as age, health status, and specifics of the root canal treatment. For each study, the retreatment techniques used (e.g., rotary instrumentation, ultrasonic devices, or solvents) were noted, along with the outcomes assessed. Primary outcomes included procedural success, efficiency in removing bioceramic material, the time taken for the procedure, and preservation of root canal structure. Secondary outcomes, such as adverse effects, operator experience, and procedural difficulties, were also documented where available. Discrepancies in data extraction were resolved through discussion or by consulting a third reviewer if needed.

GRADE Assessment

The GRADE (Grading of Recommendations, Assessment, Development, and Evaluation) approach was used to systematically assess the quality of evidence across studies. Each study was evaluated on five key GRADE domains:

1. **Risk of bias**: Internal validity and study limitations that could affect reliability.
2. **Inconsistency**: Variability in results across studies; for instance, conflicting findings on the effectiveness of a particular retreatment technique.
3. **Indirectness**: Applicability of the study findings to the population, intervention, and outcomes defined by our PICO statement.
4. **Imprecision**: Consideration of sample sizes and confidence intervals to determine the reliability of the results.
5. **Publication bias**: Potential bias due to selective publication of studies with positive results, which could skew the review's conclusions.

By applying the GRADE assessment to each included study, we aimed to objectively rate the strength of evidence and provide more nuanced recommendations based on the quality of available data.

Risk of Bias

Risk of bias was assessed independently by the two reviewers using the Cochrane Risk of Bias Tool for randomised controlled trials (RCTs) and the Newcastle-Ottawa Scale for non-randomised studies. The Cochrane Risk of Bias Tool evaluates specific aspects such as random sequence generation, allocation concealment, blinding of participants and personnel, completeness of outcome data, and selective reporting of outcomes. For non-randomised studies, the Newcastle-Ottawa Scale examines the quality of control selection, comparability of groups, and outcome assessment.

RESULTS

Search results

The search for evidence was conducted across PubMed, Web of Science, and Scopus databases, yielded a total of418 articles. Following abstract screening, 10 articles were included for full-text evaluation and a total of 9 were included in the final qualitative analysis. The PRISMA flow chart in Figure 1 illustrates the selection process, with reasons for exclusion detailed within. After full-text screening, 9 articles were deemed eligible for qualitative analysis.

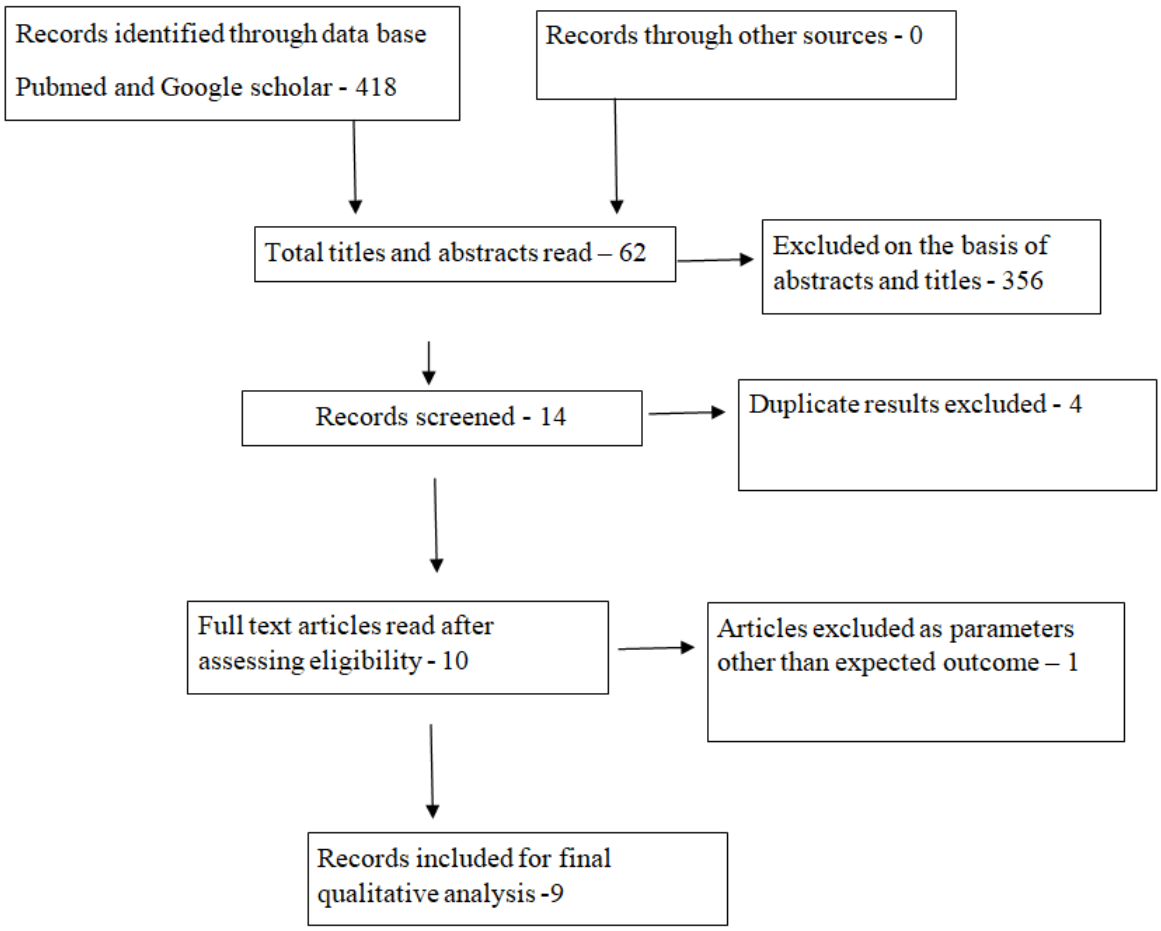

Figure 1: Flow chart diagram for article inclusion

Data Characteristics

The data characteristics table presents a summary of each study's characteristics, including sealer type, retreatment method, evaluation method, percentage of residual material, and canal patency findings as seen in Table 1.

Table 1: Data characteristics of the included studies

Study ID	Sealer Type	Retreatment Method	Evaluation Method	Residual Material (%)	Canal Patency (%)	Interpretation
Crozeta et al 2020 [11]	BC Sealer, AH Plus	Ultrasonic tip, XP-endo Finisher R	Micro-CT	BC: 16.06 ± 14.34, AH: 28.30 ± 10.54	Higher for AH Plus group	BC Sealer showed moderate residual material; ultrasonic aids improved removal, but patency remained limited for BC.
Ersev et al 2012 [12]	Hybrid Root SEAL, BC Sealer, Activ GP, AH Plus	ProTaper Universal, Manual	Radiography	Higher in apical third across sealers	Similar patency across groups	Residual material was higher in the apical third; BC Sealer displayed consistent removal challenges.
Hess et al 2011 [13]	BC Sealer, AH Plus	Rotary + Solvent	SEM	Significant in BC, less in AH Plus	20% patency regained in AH Plus	BC Sealer exhibited significant residual material; AH Plus demonstrated better patency outcomes with solvent use.
Jamleh A et al 2022 [14]	TotalFill BC, AH Plus	XP Shaper System	Micro-CT	BC: Lower residual material	Comparable patency rates	TotalFill BC showed lower residuals than other BC sealers, though patency remained difficult to maintain
Mufti et al 2021 [15]	EndoSequence BC, AH Plus	One Curve Rotary	Micro-CT	Significant residual in both groups	Similar across curvatures	Residual material was high for BC Sealer; canal curvature influenced patency challenges.
Oltra et al 2016 [16]	BC Sealer, AH Plus	ProTaper + Solvent	SEM	Higher in BC, lower in AH Plus	Patency better in AH Plus	BC Sealer was difficult to remove even with solvent, leading to lower patency rates compared to AH Plus.
Al-Dahman et al 2021 [17]	BC Sealer, GuttaFlow	ProTaper Retreatment Files	Microscopy	Less residual in GuttaFlow	Moderate for BC Sealer	GuttaFlow had better retreatability; BC Sealer retained more residuals, indicating retreatment difficulty.
Kakoura et al 2018 [18]	BioRoot RCS, AH Plus	ProTaper Universal, NeoEndo	CBCT	Similar levels of residuals	Higher retention in BioRoot RCS	BioRoot RCS displayed higher retention, with considerable residual material and patency limitations.
Baranwal et al. 2021 [19]	BioRoot RCS, AH Plus	ProTaper Universal, NeoEndo	CBCT	No significant difference across groups	80% in BioRoot RCS with PTUR	BioRoot RCS was challenging to remove with PTUR; NeoEndo showed better outcomes, yet residuals remained in the apical third

Detailed Findings and Inferences

Crozeta et al. [11] demonstrated that BC Sealers retained less residual material compared to AH Plus after retreatment using ultrasonic tips and the XP-endo Finisher R, particularly in oval-shaped root canals. This study showed that the ultrasonic tip effectively reduced residual material in both AH Plus and BC Sealer groups, though complete removal was still unattainable. The BC Sealer group exhibited lower residual percentages overall, particularly when supplementary techniques were used. Ersev et al. [12] compared Hybrid Root SEAL, EndoSequence BC Sealer, Activ GP, and AH Plus in maxillary molars using ProTaper Universal rotary retreatment and manual techniques. The study found significantly more residual material in the apical third across all sealers, with minimal variation among the types of sealers tested. Both manual and rotary systems were comparable in terms of patency achievement. The results suggest that regardless of the sealer type, retreatment procedures often left residues, with no method providing complete removal. Hess et al. [13] evaluated BC Sealer and AH Plus in mandibular molars using solvent-assisted rotary retreatment. Results indicated that BC Sealer was more challenging to remove, with 70% of BC Sealer samples unable to regain the working length or patency when obturated short of the working length. The study concluded that conventional retreatment techniques may not effectively remove bioceramic sealers, particularly in cases where obturation is incomplete or truncated. Jamleh et al. [14] examined TotalFill BC and AH Plus in single-rooted premolars using the XP Shaper system. Findings highlighted that TotalFill BC was associated with lower residual filling material than AH Plus, particularly in the apical direction. The study attributed this to TotalFill BC's lower bonding strength, which may facilitate retreatment, though some material persisted in the canals post-retreatment. Mufti & Al-Nazhan [15] investigated EndoSequence BC and AH Plus using a One Curve Rotary file on mandibular molars of varying curvatures. Micro-CT scans revealed residual materials at all canal levels, with higher accumulation in the coronal thirds for both sealers. The authors noted that despite the use of advanced rotary files, complete removal of either sealer was difficult to achieve, reinforcing the challenge of retreating bioceramic materials. Oltra et al. [16] focused on BC Sealer and AH Plus with ProTaper rotary files and chloroform as a solvent, showing that BC Sealer had a significantly higher amount of residual material compared to AH Plus. Patency re-establishment was better with AH Plus, indicating that traditional epoxy resin sealers are generally easier to remove due to their lower adherence to canal walls. Al-Dahman & Al-Omari [17] compared BC Sealer with GuttaFlowBioseal in mandibular premolars. Using ProTaper Retreatment files, they found less residual material in the GuttaFlow group, though both sealers showed moderate difficulty in complete removal. GuttaFlow demonstrated slightly better outcomes in terms of reduced residuals and working time. Baranwal et al. [18] analysed BioRoot RCS and AH Plus with ProTaper Universal and NeoEndo systems, using CBCT to assess remaining materials. Residual material was observed across all canal thirds, with BioRoot RCS showing higher residual percentages, especially in the apical region, compared to AH Plus. The study also noted that BioRoot RCS had lower patency rates, indicating that bioceramic materials generally pose a greater challenge in retreatment.

Risk of Bias

Ersev et al., Al-Dahman & Al-Omari [12, 17] used extracted human teeth with varied anatomy without randomisation or control for tooth morphology. This variability in sample characteristics may have influenced the uniformity of results, particularly regarding canal patency and residual material measurements, making it difficult to directly compare outcomes across studies with different anatomical complexities. Crozeta et al. [11] employed micro-CT, while Hess et al. [13] used SEM, and Baranwal et al. [18] relied on CBCT for their evaluations. These differences in imaging techniques could introduce variability, as each method has its own limitations and precision levels, potentially leading to inconsistent reporting across studies. Mufti & Al-Nazhan [15] did not provide exact percentages for residual material, focusing instead on general observations, while Jamleh et al. [14] provided limited details on the time taken to achieve canal patency. Overall, a moderate risk of bias was found in the included studies as seen in Table 2.

Table 2: Risk of bias across each domain among included studies.

Risk of Bias Domain	Low Risk	Moderate Risk	High Risk	Interpretation
Sample Selection Bias	Crozeta et al., Jamleh et al., Oltra et al.	Ersev et al., Al-Dahman et al., Hess et al., Mufti et al., Baranwal et al.	Kakoura et al.	Variation in tooth anatomy and lack of randomization affected sample consistency in many studies.
Evaluation and Measurement Bias	Jamleh et al., Crozeta et al.	Ersev et al., Al-Dahman et al., Hess et al., Mufti et al.,	Oltra et al.	Differences in imaging techniques (e.g., micro-CT, SEM,

		Baranwal et al., Kakoura et al.		CBCT) introduced variability in residual assessments.
Outcome Reporting Bias	Oltra et al.	Crozeta et al., Ersev et al., Al-Dahman et al., Hess et al., Mufti et al., Jamleh et al., Baranwal et al.	Kakoura et al.	Incomplete reporting of parameters (e.g., residual percentages, patency times) limited comparability.

Overall inference: Overall, these studies suggest that while newer bioceramic sealers (e.g., EndoSequence BC, TotalFill BC, BioRoot RCS) offer unique benefits, they are generally more difficult to retreat compared to conventional sealers like AH Plus. Bioceramic sealers were often associated with higher residuals and lower patency rates, particularly in the apical third, where removal is typically challenging. The findings underscore the need for innovative techniques and additional research to improve retreatability outcomes for bioceramic sealers.

DISCUSSION

This systematic review aimed to evaluate the retreatability of bioceramic sealers compared to traditional epoxy resin-based sealers in endodontics. The increasing use of bioceramic sealers is due to their biocompatibility, antimicrobial properties, and excellent sealing capabilities. However, their retreatability remains challenging due to their bonding strength and limited solubility, which complicates their removal during endodontic retreatment. Here, we discuss the findings in the context of removal techniques, effectiveness across canal areas, and the clinical implications of these retreatment challenges.

The reviewed studies used various techniques to remove bioceramic sealers, including rotary instrumentation, ultrasonic activation, and solvents, with mixed success. Studies by Crozeta et al. [11]. and Jamleh et al. [14] demonstrated that the use of ultrasonic tips and the XP-endo Finisher R effectively reduced residual material compared to conventional rotary systems, especially in oval canals. However, neither technique achieved complete removal, indicating inherent limitations in the retreatability of bioceramic sealers. Ultrasonic activation and supplementary tools like the XP-endo Finisher were noted to enhance removal efficiency, yet residuals remained in all studies, highlighting the need for further advancements in these techniques.

Solvents like chloroform showed promising results for epoxy resin-based sealers but were less effective for bioceramics. For instance, Oltra et al. [16] reported that while chloroform enhanced AH Plus removal, bioceramic samples still retained significant residues. This outcome may be due to the unique bonding mechanism of bioceramic sealers, which form hydroxyapatite upon setting, creating a mineralised interface with dentin that is resistant to solvent-based disruption.

Consistently, the reviewed studies reported higher residual material percentages in bioceramic-filled canals, especially in the apical third. This outcome was observed in studies such as those by Ersev et al. [12], where canals obturated with bioceramic sealers retained significant material even after advanced retreatment techniques. The apical third's complexity, combined with the strong adherence of bioceramic sealers, complicates complete removal, raising concerns for clinical outcomes where total disinfection is critical.

Patency re-establishment was also a challenge in bioceramic-sealed canals. Studies such as Hess et al. [13]. found that patency could not be regained in over 20% of cases with bioceramic sealers, a finding echoed by Baranwal et al. [19] in their CBCT-based study on BioRoot RCS. The difficulty in regaining patency with bioceramic sealers could be attributed to their strong chemical bond with dentin, which not only limits their removal but also hinders access to critical apical areas where persistent infection may be present.

Epoxy resin-based sealers, such as AH Plus, demonstrated easier removability and lower residual material percentages across all studies. For instance, Jamleh et al. [14] and Oltra et al. [16] found that AH Plus residues were significantly lower compared to bioceramic sealers, even without solvent use. Epoxy resin-based sealers, while effective, do not form the same mineralised bond with dentin as bioceramics, which explains the comparative ease in their removal. Furthermore, studies by Al-Dahman & Al-Omari highlighted that AH Plus removal time was shorter than that of bioceramics, suggesting that epoxy resin-based sealers may be better suited for cases with potential for retreatment.

Clinical Implications

The inability to completely remove bioceramic sealers has critical clinical implications. Residual bioceramic sealer can act as a mechanical barrier, obstructing disinfecting solutions from reaching deeper parts of the canal, such as the dentinal tubules and isthmuses, where microorganisms may reside. This incomplete removal could compromise periapical healing, as microbial remnants protected by the residual material may lead to persistent infection or reinfection, thereby reducing the success rate of retreatment.

Additionally, the challenging patency re-establishment in bioceramic-sealed canals may limit the clinician's ability to fully access the apical canal region. Mufti &

Al-Nazhan's findings on the retention of bioceramic sealer residues across different canal curvatures emphasise the variability in retreatment success, suggesting that clinicians may need to consider alternative sealers in cases where retreatment is likely.

Limitations

This review's findings are subject to limitations inherent in the included studies, such as variability in canal anatomy, differences in retreatment protocols, and inconsistency in residual material evaluation methods (e.g., micro-CT vs. SEM). The absence of a standardised method for assessing residual materials further complicates comparisons across studies. Additionally, in vitro studies may not entirely reflect in vivo clinical conditions, as factors like tissue response and operator variability play significant roles in actual retreatment outcomes.

Future research should focus on developing modified bioceramic formulations that balance effective sealing with enhanced retreatability. Investigating new solvent combinations and rotary systems specifically designed to address bioceramic removal could also advance retreatment outcomes. Longitudinal clinical studies assessing retreatment success in bioceramic versus epoxy resin-sealed canals would provide valuable insights for evidence-based material selection in endodontics.

CONCLUSION

In conclusion, while bioceramic sealers offer substantial benefits for primary root canal obturation, their retreatment challenges necessitate careful consideration in clinical practice. The strong bonding to dentin, combined with higher residual material and limited patency re-establishment, may limit their suitability in cases with potential for re-intervention. Continued advancements in retreatment techniques and material development are essential to enhance retreatability outcomes for bioceramic sealers, ultimately supporting more effective and predictable endodontic care.

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