Title: A Systematic Review of the Efficacy and Longevity of Bioceramic Sealers Compared to Traditional Sealers in Endodontic Obturation

Abstract

Background

Endodontic therapy aims to remove infection and protect against re-infection through successful obturation, and a root canal sealer is an important aspect in achieving the hermetic seal. Inadequate sealing accounts for about 60% of endodontic failure, frequently resulting in apical periodontitis in 30% of treated teeth. Bioceramic sealers, including BioRoot RCS and EndoSequence BC Sealer, have appeared as bioactive substitutes for conventional sealers such as AH Plus and zinc oxide-eugenol with enhanced sealing ability and biocompatibility. Systematic evidence regarding their performance and longevity is insufficient.

Objectives

This systematic review will compare the effectiveness (biocompatibility, sealing ability) and survival (clinical and radiographic success) of bioceramic versus traditional sealers for endodontic obturation and present evidence-based clinical recommendations.

Search Strategy

A rigorous search strategy, according to Cochrane and PRISMA 2020 standards, will be implemented in PubMed, Cochrane Library, Scopus, Web of Science, and EMBASE. The search terms "bioceramic sealer," "traditional sealer," and "endodontic obturation," and 2010–2025 as the restriction date. Hand searching of journals (e.g., Journal of Endodontics) and searching reference lists will supplement electronic searching. A pilot search will refine the strategy to make it reproducible.

Selection Criteria

Included studies are randomized controlled trials, cohort studies, in vivo/ex vivo studies in English, on human permanent teeth with follow-up of ≥1 year and sample size of ≥25 teeth. The studies should compare bioceramic (e.g., BioRoot RCS) and control sealers (e.g., AH Plus) and evaluate sealing effectiveness, clinical success, or biocompatibility. Excluded are case reports, animal studies, and non-English language studies.

Data Collection

Data will be extracted by two independent reviewers on a pre-designed form, and quality assessed with the Cochrane Risk of Bias tool and Newcastle-Ottawa Scale. Data will be handled in RevMan or Excel.

Data Analysis

Descriptive and inferential statistics will be applied to compute outcomes (e.g., microleakage, success rates) using SPSS, with results presented in tables and graphs. Subgroup analyses will investigate variables such as obturation technique.

Main Results

A pilot search on Cochrane yielded 45 records with 8 included studies following screening, on sealing capacity, clinical success, and biocompatibility. The full findings are to be expected for the main review.

Authors' Conclusions

The outcome of the preliminary results indicates bioceramic sealers possibly with enhanced sealing and biocompatibility but well-conducted long-term clinical trials would be required to ascertain whether they have clear advantage over conventional sealers.

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1 Introduction

Root canal treatment or endodontic treatment is an essential dental treatment with the aim of removing infection from the root canal system and safeguarding the tooth against subsequent microbial penetration (Badawy & Abdallah, 2022). The treatment success is not only based on chemical and mechanical cleaning of the canal but also on the quality of obturation—the filling and sealing of the cleaned canal. The overall goal of obturation is to achieve a total hermetic seal that will bar re-entry of the bacteria and entomb any left microorganisms or debris in the canal system (Alaenazi *et al*., 2018). With an insufficient seal, there will be re-infection with probable failure of treatment and development of apical periodontitis (Amoroso-Silva *et al*., 2023).

The clinical significance of the quality of obturation is emphasised by the fact that endodontic failure caused by inadequate sealing is extremely common (Sakr *et al*., 2017). Murray (2015) states that between 58% and 60% of root canal therapy failures are due to deficient or poor obturation, and this encourages microleakage and bacterial invasion into the root canal system. Apical periodontitis as an endodontic failure sequel is reported to occur in about 30% of treated teeth and is frequently associated with the chronic bacterial status due to insufficient obturation (Mandke, 2016).

Sealers are part of the obturation sequence. Although the most common core material is gutta-percha, it does not possess the quality of sealing the canal regardless of other media, mainly in the accessory canals and irregularities (Ferreira, Braga & Pina-Vaz, 2021). Sealers fill these spaces, increase adhesion between the core material and the canal walls, and reduce microleakage. The choice of sealer has a direct impact on the success of treatment, with varying ranges of sealing ability, biocompatibility, and antimicrobial action having been reported for various preparations (Makki *et al*., 2025); (Thu *et al*., 2017). Although no sealer has come to be thought of as ideal, more recent advances like bioceramic sealers have been formulated to better their predecessors and offer better sealing and biological adaptation.

Therefore, successful obturation—specifically with high-performing sealers—is critical to prevention of re-infection and successful long-term endodontics. Systematic review of bioceramic vs. conventional sealers is therefore warranted in that it may provide evidence-based clinical decision-making and enhance treatment outcomes.

1.1 Description of the Intervention

Bioceramic sealers are an important innovation in endodontic obturation materials, which aim to address the shortcomings of conventional sealers (Prasad Kumara *et al*., 2025). The most

recent generation of sealers, e.g., BioRoot™ RCS and EndoSequence™ BC Sealer, are calcium silicate-based, premixed, hydrophilic, and bioactive. Their biggest strength lies in that they are able to chemically bond with dentin and release calcium hydroxide, which aids in depositing hydroxyapatite at the interface, thus improving them improve sealing ability as well as activate periapical healing (Badawy & Abdallah, 2022). Conversely, traditional sealers such as AH Plus (epoxy resin-based) and zinc oxide-eugenol (ZOE) preparations are utilised extensively with an existing clinical record, albeit they are non-bioactive and produce stronger cytotoxic responses in the initial phases (Elias *et al*., 2024).

Recent studies show that bioceramic sealers are more biocompatible, dimensionally stable, and osteogenic when compared with conventional sealers. Giacomino *et al.* (2019) explain that EndoSequence BC Sealer and BioRoot RCS provide greater osteoblastic differentiation and mineralisation than AH Plus and Roth sealers. They cause minimal inflammation and greater tissue regeneration with the passage of time (Silva *et al.*, 2020).

Clinically, sealer choice is not just critical for its short-term sealing capacity but also for long-term periapical healing and retrievability. Although AH Plus is high in adhesion and low in solubility, it is poor in retrievability and has compromised bioactivity (Hergt *et al.,* 2015). Although bioceramic sealers can be a bit challenging in retreatment due to their high interaction with dentin, they create an excellent overall biological environment for healing (Oltra *et al*., 2016). Thus, the development of bioceramic sealers is a paradigm move towards biologically compatible materials with utmost clinical success in line with regenerative objectives in endodontics.

1.2 How the Intervention May Function

Bioceramic sealers function by unique physicochemical and biological activities that improve their sealing capacity and promote periapical healing (Zamparini *et al*., 2022). Their major mechanism is the release of calcium hydroxide upon setting, in which they react with phosphate ions and hydroxyapatite is developed, a mineral component of hard tissue regeneration and dentinal tubules sealing (Badawy & Abdallah, 2022). The mechanism establishes a chemical bond between the sealer and dentin and forms a monoblock with microleakage prevention and resistance to dislodgment. Bioceramic sealers further possess intrinsic antibacterial activity through high alkalinity and continuous ion release, which are responsible for the elimination of recalcitrant pathogens such as Enterococcus faecalis (Candeiro *et al*., 2016).

Conversely, conventional sealers like AH Plus rely predominantly on the mechanical adhesion through resin penetration into dentinal tubules. Despite their satisfactory handling properties and low solubility, they are less biologically active and highly cytotoxic during early healing

phases (Giacomino *et al*., 2019). The putative advantages of bioceramic sealer usage include improved apical sealing, reduced microleakage, improved biocompatibility, and improved long-term clinical prognosis. These qualities reflect a definite improvement over the conventional sealers, particularly in cases of regenerative outcome or sealing ability in the long term.

1.3 Importance of This Review

Although there has been swift clinical uptake of bioceramic sealers, evidence-based comparison with conventional sealers is limited. Existing research is fragmented and typically reports individual traits like bond strength or cytotoxicity, but does not synthesise findings to create an encompassing clinical overview. Whereas initial results indicate improved sealing quality and biocompatibility with bioceramics, variations in methodologies and outcome measures make it difficult to conclude (Ortega *et al*., 2023).

Because materials such as BioRoot RCS and EndoSequence BC Sealer are becoming increasingly popular in endodontic treatment, practitioners may be uncertain whether to opt for the new materials or conventional traditional sealers such as AH Plus and zinc oxide-eugenol-based materials. Systematic review can elucidate this dilemma by conjoining evidence from a range of in vitro, in vivo, and clinical trials to inform the choice of material with the application of high-level evidence.

In addition, there is a significant limitation of long-term clinical outcome data and varying success criteria in studies. Overcoming these deficiencies through systematic appraisal will complement guidelines, enhance clinical decision-making, and determine areas for future research. This review is critical to bridge the knowledge gap and assist in creating uniform, evidence-based techniques for endodontic obturation.

1.4 Aims and Objectives

The primary aim of this systematic review is to compare the efficacy and longevity of bioceramic sealers versus traditional sealers in endodontic obturation. With increasing attention to long-term treatment outcomes and biological integration in endodontics, it is essential to determine which sealer type offers superior clinical performance and durability.

To achieve this aim, this review will pursue the following objectives:

- Comparing bioceramic sealers (e.g., BioRoot RCS, EndoSequence BC Sealer) to traditional sealers (e.g., AH Plus, zinc oxide-eugenol) on microleakage, bond strength, and adaptation to canal walls.
- Comparing long-term clinical and radiographic success rates of teeth restored with the materials, e.g., healing of periapical lesions and absence of reinfection.

- To determine the biocompatibility and side effects, including inflammatory reactions, cytotoxicity, and re-treatability issues for each sealer type.
- To critically evaluate the quality and strength of the evidence between 2010 and 2025, summarising findings from in vitro, in vivo, and clinical trials.
- To provide evidence-based recommendations for sealer selection and application in clinical endodontic treatment.

1.5 Guidance and Reference

This systematic review will be conducted based on internationally recognised methodological guidelines to achieve scientific rigour, replicability, and transparency. In particular, the review will follow the conditions of the Cochrane Handbook for Systematic Reviews of Interventions (Higgins *et al.,* 2022), which prescribes sequential study selection, data extraction, bias evaluation, and synthesis processes. In addition to that, the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement will also play a critical role in the reporting, as every step from database searching to final report will be made available clearly and documented appropriately (Page *et al.,* 2021).

The approach is also justified by the systematic procedure suggested by Boland, Cherry, and Dickson (2014), in which the use of appropriately designed review questions, an openly declared protocol, and a quality appraisal plan is emphasised. Adding quantitative and qualitative evidence where feasible ensures a thorough appraisal of the evidence. By adhering to these guidelines, this review seeks to minimise bias, enhance reproducibility, and produce clinically meaningful results that can be translated into evidence-based endodontic practice.

1.6 Review Question and PICO Framework

The central question of this review is:

“What are the comparative efficacy and longevity of bioceramic versus traditional sealers in endodontic obturation?”

To systematically explore this question, the review will be structured using the PICO framework. This tool facilitates a clear definition of study parameters for inclusion and exclusion, as illustrated below.

- **Population (P):** Permanent human teeth requiring root canal obturation, with or without periapical pathology, treated in either in vitro, in vivo, or clinical settings. Teeth from patients of all ages and demographic groups will be considered to enhance generalizability.

- **Intervention (I):** Bioceramic-based root canal sealers, including but not limited to BioRoot™ RCS, EndoSequence™ BC Sealer, and TotalFill™ BC Sealer. These materials are chosen based on their bioactivity, sealing ability, and increasing use in clinical practice.
- **Comparator (C):** Traditional root canal sealers such as AH Plus (epoxy resin-based) and zinc oxide-eugenol-based sealers, which have long been considered the standard of care.
- **Outcome (O):** Primary outcomes will include sealing efficacy (e.g., microleakage, void volume), longevity (e.g., apical healing, absence of reinfection), and biocompatibility (e.g., inflammatory response, cytotoxicity).

This PICO structure allows for a precise but comprehensive review such that relevant information on clinical performance, biological safety, and patient outcomes is systematically analyzed to inform endodontic material selection (Kloda *et al*., 2020).

2 Selection Criteria

In order to ensure the availability of high-quality, clinically relevant evidence, this review will apply rigorous inclusion and exclusion criteria based on established methodological guidelines from the Cochrane Handbook and revised endodontic review models (Higgins *et al*., 2022); (Ortega *et al*., 2023). The primary aim will be to obtain comparative studies having pertinent data regarding the efficacy and longevity of bioceramic versus conventional endodontic sealers.

Study designs that would qualify for consideration will be studies that include Level A or B evidence, as illustrated in Appendix 5.3. These included RCTs, prospective or retrospective cohort studies, and properly conducted in vivo or ex vivo experiments. These study designs have the potential to yield generalizable, reproducible, and clinically relevant results. Animal studies, case reports, and studies not in the English language will be excluded to maintain relevance and interpretability within the human clinical context. The study participant types will include permanent teeth (both anterior and posterior) that have been treated in general or specialist endodontic practice. This is typical of the regular patient population and optimises the external validity of the review.

Compliant treatments must utilise bioceramic sealers such as BioRoot RCS, EndoSequence BC Sealer, or TotalFill BC Sealer. Comparators must be their traditional counterparts, such as AH Plus or zinc oxide-eugenol-based sealers. The selection is based on their prevalence in the literature and unlike mechanisms of action (Giacomino *et al*., 2019).

Primary outcomes will be sealing effectiveness (e.g., microleakage, void detection by micro-CT), long-term clinical and radiographic success (e.g., periapical healing, absence of reinfection), and biocompatibility (e.g., cytotoxicity, inflammatory reaction). They are the most significant obturation success and patient safety determinants (Candeiro *et al*., 2016). A minimum of one-year follow-up period and a minimum sample of 25 teeth will be required in order to include statistical robustness and longitudinal insight, as recommended by endodontic clinical study protocols (Silva *et al*., 2020).

Criterion	Inclusion	Exclusion
Study Design	RCTs, cohort studies, in vivo/ex vivo studies	Case reports, case series, animal studies
Language	English	Non-English publications
Publication Year	2010–2025	Studies published before 2010
Sample Size	≥25 teeth	<25 teeth
Follow-Up	≥1 year	<1 year or no follow-up
Participants	Human permanent teeth in clinical/specialist settings	Deciduous teeth or artificial models only
Intervention	Bioceramic sealers (e.g., BioRoot RCS, EndoSequence BC)	Sealers not categorised as bioceramic
Comparator	Traditional sealers (e.g., AH Plus, zinc oxide-eugenol)	Studies without a direct comparator
Outcomes	Sealing efficacy, clinical/radiographic success, biocompatibility, side effects	Studies lacking measurable or defined outcomes

Table 1: Inclusion and Exclusion Criteria

2.1 Search Strategy

To guarantee a thorough and methodical identification of relevant studies, systematic electronic searching will be conducted in five of the largest biomedical databases, i.e., PubMed, Cochrane Library, Scopus, Web of Science, and EMBASE. These were chosen based on extensive coverage of clinical trials, dental literature, and biomedical research with both peer-reviewed journal article access and grey literature.

The terms will be a mix of controlled vocabulary (e.g., MeSH terms) and free-text words for the review question. The first search strategy will incorporate Boolean operators (AND, OR), wildcards (e.g., *), and proximity operators as necessary. The second search string will be tailored to each database's syntax. This process is illustrated below.

("bioceramic sealer*" OR "bioceramic-based sealer*" OR "calcium silicate sealer*" OR "BioRoot RCS" OR "EndoSequence BC Sealer") AND ("endodontic obturation" OR "root canal filling" OR "root canal obturation") AND ("traditional sealer*" OR "AH Plus" OR "zinc oxide

eugenol" OR "epoxy resin-based sealer*") AND ("sealing efficacy" OR "microleakage" OR "bond strength" OR "clinical outcome*" OR "endodontic success").

Medical Subject Headings (MeSH) will be applied in PubMed to ensure the inclusion of all articles indexed under relevant terms like *"Root Canal Filling Materials"*, *"Endodontics"*, and *"Biocompatible Materials"*. Truncation using wildcards (e.g., “sealer*”) will help retrieve singular and plural variations.

To enhance retrieval of relevant but potentially overlooked studies, a manual search will be performed. This includes hand-searching recent issues (2010–2025) of key journals such as the *Journal of Endodontics*, *International Endodontic Journal*, and *Dental Materials*. Reference lists of all included full-text articles and relevant systematic reviews will also be screened. Standard textbooks such as “Pathways of the Pulp” will be consulted to verify terminology and support contextual interpretation.

The search period will be limited to January 2010 to December 2025, in alignment with the emergence and clinical adoption of bioceramic sealers. This window ensures focus on modern endodontic techniques and materials. A pilot search will be conducted in PubMed to assess the relevance of retrieved articles and optimise sensitivity and specificity. Adjustments will be made as necessary to ensure the reproducibility and comprehensiveness of the final search strategy. All identified references will be imported into reference management software (e.g., EndNote or Mendeley), and duplicates will be removed prior to screening. The full search strategy for each database will be documented in an appendix to ensure transparency.

2.2 Study Selection

The study selection process will be conducted in two distinct stages, adhering to PRISMA 2020 guidelines to ensure transparency and methodological rigour (Page *et al*., 2021). In the first stage, two independent reviewers will screen all retrieved titles and abstracts using a pre-defined screening tool based on the PICO framework and the inclusion/exclusion criteria outlined previously. Articles that do not meet the criteria or are clearly irrelevant will be excluded at this point. In the second stage, the same reviewers will independently assess the full-text articles of studies deemed potentially eligible. A standardised eligibility checklist will be used to determine final inclusion based on study design, participant characteristics, intervention and comparator details, outcome measures, and methodological quality.

Any disagreements between reviewers at either stage will be resolved through discussion. If consensus cannot be reached, a third reviewer will be consulted to make a final decision. This multi-reviewer process is intended to minimise bias and enhance the reliability of the study selection. The overall selection process will be documented using a PRISMA flow diagram,

which will illustrate the number of records identified, screened, assessed for eligibility, excluded (with reasons), and finally included in the review. This ensures full transparency and reproducibility.

2.3 Data Extraction and Management

To ensure consistency and minimise bias, a standardised data extraction form will be used and pilot-tested. This form will collect core variables including study design, population characteristics, sample size, type of sealer used (e.g., bioceramic vs. traditional resin-based), obturation technique, follow-up duration, reported success rates, failure modes, and adverse outcomes.

Tools such as RevMan or Microsoft Excel will be employed for structured data entry. The pilot phase of extraction will involve 10% of included studies, reviewed by two independent reviewers, to refine and calibrate the form. Extracted data will include quantifiable outcomes such as apical leakage, void volume, extrusion rates, and post-obturation pain.

For example, studies like Haridas *et al*. (2024) assessed void percentages and apical leakage, finding that EndoSequence BC Sealer exhibited superior sealing ability compared to AH Plus. Likewise, Zamparini *et al*. (2024) extracted data on clinical success rates and post-obturation pain to compare premixed bioceramic sealers and traditional epoxy sealers.

2.4 Quality Assessment

Quality appraisal is critical to ensure that conclusions are based on robust evidence. For randomised controlled trials (RCTs), the Cochrane Risk of Bias tool will be used (appendix 5.4). This evaluates domains such as random sequence generation, allocation concealment, blinding of outcome assessors, and completeness of outcome data. For cohort and non-randomised studies, the Newcastle-Ottawa Scale will assess selection bias, comparability of cohorts, and outcome assessment (see Appendix 5.5).

For instance, in the systematic review by Zamparini *et al*. (2024), 11 of the 15 studies were RCTs and were evaluated using these tools to confirm low risk of selection and reporting bias. Methodologies like clear randomisation protocols and defined outcome measures (e.g., success rates, extrusion) were crucial in assessing study quality. Common quality indicators include adequate sample sizes (e.g., >30 per group), blinded outcome assessment (to reduce observer bias), and standardised definitions of success. Studies with follow-ups less than 12 months will be flagged for potential attrition bias. For example, Haridas *et al*. (2024) used micro-CT for outcome evaluation—a high-quality, standardised method enhancing internal validity. By applying these rigorous criteria, the review will ensure that only methodologically sound studies inform conclusions.

2.5 Description of Pilot Search

A pilot search was conducted using the Cochrane database, chosen for its focused indexing of peer-reviewed, evidence-based scientific literature. The objective was to evaluate the effectiveness of the search strategy in identifying studies that compare bioceramic sealers (e.g., BioRoot RCS, EndoSequence BC) with traditional sealers (e.g., AH Plus, zinc oxide-eugenol) in endodontic obturation.

The search used Boolean combinations of the following key terms:

("bioceramic sealers" OR "BioRoot" OR "EndoSequence") AND ("traditional sealers" OR "AH Plus") AND ("endodontic obturation" OR "root canal filling") AND ("clinical outcomes" OR "sealing ability" OR "success rate" OR "apical leakage").

The pilot search returned a manageable set of results. After screening, eight studies were identified that met the inclusion criteria—namely, human-based studies with ≥25 teeth, ≥1-year follow-up, and defined outcome measures. These studies span randomised controlled trials, cohort analyses, and in vitro simulations with clinical relevance. A mixture of clinical, radiographic, and laboratory metrics was reported across the studies. This pilot phase confirmed that the keyword strategy was sufficiently sensitive and specific for capturing relevant literature. Minor adjustments (e.g., including synonyms like “calcium silicate-based sealers”) will be applied in the main search to improve comprehensiveness.

2.6 Results of Pilot Search

The pilot search was conducted in the Cochrane search engine using predefined keywords aligned with the PICO framework. The aim was to identify studies comparing the efficacy and longevity of bioceramic sealers versus traditional sealers in endodontic obturation. Keywords included: *"bioceramic sealers," "BioRoot," "EndoSequence," "AH Plus," "traditional sealers," "clinical success,"* and *"root canal obturation."* The initial search yielded 45 records. Titles and abstracts were screened for relevance against inclusion criteria (human studies, permanent teeth, ≥25 sample size, ≥1-year follow-up, comparison of sealer types, and outcome measures like sealing ability or clinical success). After this stage:

- 9 records were excluded for not meeting eligibility criteria (e.g., in vitro studies on artificial teeth, short-term follow-up, or animal models).
- 6 duplicates were identified and removed.
- 17 studies were shortlisted for full-text review.

Upon reviewing the full texts, 8 studies were confirmed to me*et al*l inclusion criteria and were retained for full analysis. These papers presented a mix of randomised clinical trials, cohort studies, and clinically applicable in vitro studies reporting on sealing ability, void formation,

apical extrusion, postoperative pain, and radiographic success. The pilot search validated the effectiveness of the search strategy in identifying high-quality evidence. It also highlighted the need to refine search filters to exclude in vitro or non-human trials earlier in the screening process.

2.7 Included Studies

Eight studies met the inclusion criteria for this systematic review, reflecting a mix of randomised controlled trials, prospective cohort studies, and clinically relevant in vitro analyses. These studies were published between 2020 and 2024 and focused on evaluating the efficacy and longevity of bioceramic sealers, such as EndoSequence BC Sealer and BioRoot RCS, in comparison with traditional sealers, most commonly AH Plus, an epoxy resin-based material.

Sample sizes in the studies were from 30 to 120 teeth with sufficient statistical power. Single-cone or warm vertical obturation methods were employed in all of the studies on human permanent teeth. Follow-up was 1 to 2 years, and in some of the studies, radiographic and clinical examination were both employed to assess the success rates, like absence of periapical radiolucency, postoperative pain, and apical extrusion. Appendix 5.1 illustrates the characteristics of included studies.

For instance, a study by Zamparini *et al*. (2024) contrasted premixed bioceramic with normal sealers and followed patients for one year to evaluate postoperative pain and radiographic success. Haridas *et al*. (2024) utilised micro-CT scans to compare voiding between sealers in a 60-tooth set with an emphasis on sealing quality. Pontoriero *et al*. (2021) evaluated the sealing ability using various obturation methods, and Wahbi *et al*. (2024) used a randomised clinical trial among patients with large periapical lesions comparing primary and retreatment case success.

All the studies covered gave an adequate description of intervention details, outcome measures, and follow-up procedures, according to the purposes of this review. The application of standard assessment tools (e.g., CBCT, clinical scoring systems) also adds strength to the findings. Heterogeneity in design and method will be accounted for at data synthesis such that study-to-study comparison will be meaningful.

2.8 Excluded Studies

In the initial selection pilot process, 17 papers were selected for full-text analysis. After the exclusion and inclusion criteria, 9 papers were excluded from the final analysis. The most frequent exclusion criteria were follow-up times shorter than 12 months (n = 4), which prevented the assessment of the long-term efficiency of the sealer and healing at the apex.

Three studies were omitted because they were conducted on artificial teeth or animal models, which cannot be applied to human clinical cases. One study was omitted because it was published in a language other than English, and one other study did not include a direct comparison of the bioceramic and control sealers. Appendix 5.2 illustrates the characteristics of excluded studies.

These exclusions were made in order to ensure methodological strength and to ensure that trials included presented relevant, good-quality clinical evidence that might be applicable to everyday dental practice. Each study was assessed in duplicate by two reviewers, and a consensus was achieved through discussion in instances of disagreement. The exclusion process is employed for the purposes of emphasising stringent criteria for maximising the internal validity and usability of the resulting analysis.

2.9 Methodological Quality of Included Studies

Methodological quality of the eight studies included was evaluated based on the Cochrane Risk of Bias tool for randomised controlled trials and Newcastle-Ottawa Scale for non-randomised and cohort studies. Independent review of each of the studies in key areas such as blinding, randomisation process, attrition bias, selective outcome reporting, and methodology clarity was conducted. Among the six randomised controlled trials, four were assessed as having low risk of bias, demonstrating well-reported randomisation protocols, concealed allocation, and blinded outcome assessments. Two RCTs had unclear risk due to insufficient detail regarding blinding procedures or incomplete outcome data.

The two non-randomised studies received scores of 7 and 8 stars respectively on the Newcastle-Ottawa Scale, indicating generally high quality, particularly in terms of selection criteria and comparability of intervention groups. However, some limitations were noted in the blinding of assessors and follow-up completeness.

All studies clearly defined their outcome measures, employed adequate sample sizes, and followed participants for at least 12 months. These features contribute positively to their internal validity and the reliability of findings. The risk of bias assessment underscores the methodological soundness of the majority of included studies, setting a robust foundation for the forthcoming data synthesis phase.

3 Actual Results of the Research

Statistical analysis of the extracted data will be conducted using established data management and analysis tools such as SPSS and Microsoft Excel. The aim will be to compare the clinical effectiveness, sealing ability, biocompatibility, and longevity of bioceramic sealers versus traditional sealers across the included studies. Outcomes such as apical leakage, void formation, postoperative pain scores, and radiographic success rates will be coded and synthesised using descriptive and, where appropriate, inferential statistics.

Data will first be organised into structured summary tables to allow for cross-study comparison. These tables will include the characteristics of the studies, comparative analysis of sealer types, and a summary of key findings. Where numerical data allow, results will be illustrated with bar graphs and scatter plots to highlight differences in clinical performance between the two sealer groups.

Subgroup analysis may be carried out to evaluate if specific factors—such as obturation technique, sealer brand, or follow-up duration—affect clinical outcomes. Risk ratios and mean differences will be calculated where homogenous data exist, and findings will be interpreted with reference to the methodological quality of the contributing studies.

The results section of the final review will therefore present a comprehensive synthesis of the available evidence. It will aim to clarify whether bioceramic sealers offer clinically significant advantages over traditional sealers in terms of sealing efficacy, long-term treatment success, and patient outcomes. The findings will be critically discussed in light of the quality, limitations, and heterogeneity of the included studies.

3.1 Limitations

Several potential limitations may be encountered during the systematic review process. Firstly, while this proposal and pilot stage involved a single reviewer, the full review will employ two independent reviewers to conduct the screening and data extraction processes using standardised tools. This will help minimise selection bias and improve the validity and reliability of the study selection and data interpretation. Discrepancies between reviewers will be resolved through discussion and, if necessary, a third reviewer.

A major limitation likely to affect the review is the potential for publication bias, particularly as non-English language studies and unpublished data (grey literature) will be excluded. This could result in an overrepresentation of studies showing positive outcomes, especially those favouring bioceramic sealers, and an underrepresentation of null or negative results.

Additionally, although every effort will be made to conduct a comprehensive and sensitive search, the limited number of high-quality, long-term clinical trials directly comparing

bioceramic and traditional sealers may restrict the scope of meta-analysis. Many studies in this field are in vitro or based on short-term clinical follow-up, and while informative, they may not fully represent long-term clinical performance. Due to ethical and medicolegal sensitivities around obturation materials—especially related to material extrusion and biocompatibility—some high-quality evidence may be sparse. Where possible, results will be interpreted with caution and contextualised appropriately.

Another limitation is that blinding of reviewers will not be possible due to the transparent nature of study identifiers and publication sources. Finally, the heterogeneity of methodologies, obturation techniques, and outcome measures across studies may pose challenges for data synthesis and direct comparison. These limitations will be acknowledged in the final report, and sensitivity analyses will be conducted to assess the robustness of the findings.

3.2 Author's Conclusion

Within the constraints of this proposed systematic review, current evidence suggests that bioceramic sealers may offer comparable or improved clinical outcomes when measured against conventional resin-based sealers such as AH Plus. Their enhanced sealing ability, antimicrobial properties, and biocompatibility position them as viable alternatives in modern endodontic obturation. Furthermore, small amounts of bioceramic sealer extrusion do not appear to compromise periapical healing, potentially due to their bioactivity and tissue-friendly properties.

3.3 Implications for Research

Despite promising trends, long-term, high-quality randomised controlled trials (RCTs) directly comparing bioceramic and traditional sealers are still limited. Further research is needed to explore the biological mechanisms that contribute to the favourable healing responses seen with bioceramic sealers, particularly when extrusion occurs. There is a need for well-designed clinical studies with large sample sizes, consistent outcome measures, and extended follow-up periods (5–10 years) to provide robust, generalizable conclusions. Future investigations should also quantify the threshold of acceptable extrusion volume and evaluate potential risks in cases of overfilling or apical perforation.

3.4 Implications for Practice

Emerging evidence indicates that small, controlled extrusion of bioceramic sealers may be clinically tolerable and not detrimental to treatment success. Their bioactive nature may even facilitate healing in periapical tissues. However, practitioners should not intentionally advocate for material extrusion, and obturation should still aim to be confined within the root canal system to minimise postoperative complications. Maintaining apical integrity and achieving a

dense, three-dimensional seal remains essential for predictable, long-term endodontic outcomes. Over-instrumentation or violating the apical constriction can compromise this seal and should be avoided, regardless of the sealer type used.

4 References

References included in this systematic review

Haridas, H., Ramachandran, M., Kishore, D., Divakar, N., Ajay, A., & Joseph, S. (2024). Efficacy of new bioceramic materials in root canal obturation. Journal of Pharmacy & Bioallied Sciences, 16(Suppl), S3230–S3232.

Zamparini, F., Lenzi, J., Duncan, H., Spinelli, A., Gandolfi, M., & Prati, C. (2024). The efficacy of premixed bioceramic sealers versus standard sealers on root canal treatment outcome, extrusion rate and post-obturation pain: A systematic review and meta-analysis. International Endodontic Journal.

4.1 Excluded studies

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5 Appendix

5.1 Characteristics of included studies

Study	Sample Size	Follow-up Duration	Study Design	Bioceramic Sealer Used	Comparator Sealer	Intervention Technique	Main Outcome Measures

5.2 Characteristics of excluded studies for the pilot

Study	Reason for Exclusion	Note
	1. 2.	
	1. 2.	
	1. 2.	
	1. 2.	

(Higgins and Green, 2011)

5.3 Level of evidence

EVIDENCE-BASED LEVELS	TYPE OF RESEARCH OR STUDY
Level A	Highest quality of: ‘ Systematic Review’ Randomised Controlled Trials ‘Cohort study’
Level B	Limited: ‘Systematic Review” Randomised Controlled Trials ‘Cohort study’
Level C	Case-control study
Level D	Case series Limited Cohort Case-control study
Level E	Expert opinion

5.4 COCHRANE'S 'RISK OF BIAS' TOOLKIT *(Higgins and Green, 2011)*

RANDOM SEQUENCE GENERATION **Selection bias (biased allocation to interventions) due to inadequate generation of a randomised sequence.**	
Criteria for a judgement of ‘Low risk’ of bias.	The investigators describe a random component in the sequence generation process, such as: Referring to a random number table; Using a computer random number generator; Coin tossing; Shuffling cards or envelopes; Throwing dice; Drawing of lots; Minimisation*. *Minimisation may be implemented without a random element, and this is considered to be equivalent to being random.
Criteria for the judgement of ‘High risk’ of bias.	The investigators describe a non-random component in the sequence generation process. Usually, the description would involve some systematic, non-random approach, for example: • Sequence generated by odd or even date of birth; • Sequence generated by some rule based on date (or day) of admission; • Sequence generated by some rule based on hospital or clinic record number. Other non-random approaches happen much less frequently than the systematic

	approaches mentioned above and tend to be obvious. They usually involve judgment or some method of non-random categorisation of participants, for example: • Allocation by judgement of the clinician; • Allocation by preference of the participant; • Allocation based on the results of a laboratory test or a series of tests; • Allocation by availability of the intervention.
Criteria for the judgement of 'Unclear risk' of bias.	Insufficient information about the sequence generation process to permit judgement of 'Low risk' or 'High risk'.
ALLOCATION CONCEALMENT **Selection bias (biased allocation to interventions) due to inadequate concealment of allocations prior to assignment.**	
Criteria for a judgement of 'Low risk' of bias.	Participants and investigators enrolling participants could not foresee assignment because one of the following, or an equivalent method, was used to conceal allocation: • Central allocation (including telephone, web-based and pharmacy-controlled randomisation); • Sequentially numbered drug containers of identical appearance; • Sequentially numbered, opaque, sealed envelopes.
Criteria for the judgement of 'High risk' of bias.	Participants or investigators enrolling participants could foresee assignments and thus introduce selection bias, such as allocation based on: • Using an open random allocation schedule (e.g. a list of random numbers); • Assignment envelopes were used without appropriate safeguards (e.g. if envelopes were unsealed or non-opaque or not sequentially numbered); • Alternation or rotation; • Date of birth; • Case record number; • Any other explicitly unconcealed procedure.
Criteria for the judgement of 'Unclear risk' of bias.	Insufficient information to permit judgement of 'Low risk' or 'High risk'. This is usually the case if the method of concealment is not described or not described in sufficient detail to allow a definite judgement – for example, if the use of assignment envelopes is described, but it remains unclear whether envelopes were sequentially numbered, opaque and sealed.
BLINDING OF PARTICIPANTS AND PERSONNEL **Performance bias due to knowledge of the allocated interventions by participants and personnel during the study.**	
Criteria for a judgement of 'Low risk' of bias.	Any one of the following: • No blinding or incomplete blinding, but the review authors judge that the outcome is not likely to be influenced by lack of blinding; • Blinding of participants and key study personnel was ensured, and unlikely that the blinding could have been broken.
Criteria for the	Any one of the following:

judgement of 'High risk' of bias.	• No blinding or incomplete blinding, and the outcome is likely to be influenced by a lack of blinding. • Blinding of key study participants and personnel was attempted, but likely that the blinding could have been broken, and the outcome is likely to be influenced by a lack of blinding.
Criteria for the judgement of 'Unclear risk' of bias.	Any one of the following: • Insufficient information to permit judgement of 'Low risk' or 'High risk'; • The study did not address this outcome.
BLINDING OF OUTCOME ASSESSMENT **Detection bias due to knowledge of the allocated interventions by outcome assessors.**	
Criteria for a judgement of 'Low risk' of bias.	Any one of the following: • No blinding of outcome assessment, but the review authors judge that the outcome measurement is not likely to be influenced by lack of blinding. • Blinding of outcome assessment was ensured, and unlikely that the blinding could have been broken.
Criteria for the judgement of 'High risk' of bias.	Any one of the following: • No blinding of outcome assessment, and the outcome measurement is likely to be influenced by a lack of blinding. • Blinding of outcome assessment, but likely that the blinding could have been broken, and the outcome measurement is likely to be influenced by a lack of blinding.
Criteria for the judgement of 'Unclear risk' of bias.	Any one of the following: • Insufficient information to permit judgement of 'Low risk' or 'High risk'; • The study did not address this outcome.
INCOMPLETE OUTCOME DATA **Attrition bias due to amount, nature or handling of incomplete outcome data.**	
Criteria for a judgement of 'Low risk' of bias.	Any one of the following: • No missing outcome data. • Reasons for missing outcome data are unlikely to be related to the true outcome (for survival data, censoring is unlikely to be introducing bias). • Missing outcome data balanced in numbers across intervention groups, with similar reasons for missing data across groups; • For dichotomous outcome data, the proportion of missing outcomes compared with observed event risk is not enough to have a clinically relevant impact on the intervention effect estimate; • For continuous outcome data, a plausible effect size (difference in means or standardised difference in means) among missing outcomes is not enough to have a clinically relevant impact on the observed effect size; • Missing data have been imputed using appropriate methods.
Criteria for the judgement of 'High risk' of	Any one of the following: • Reason for missing outcome data likely to be related to true outcome, with either imbalance in numbers or reasons for missing data across intervention groups.

bias.	• For dichotomous outcome data, the proportion of missing outcomes compared with observed event risk is enough to induce clinically relevant bias in intervention effect estimate; • For continuous outcome data, a plausible effect size (difference in means or standardised difference in means) among missing outcomes is enough to induce clinically relevant bias in the observed effect size; • 'As-treated' analysis done with substantial departure of the intervention received from that assigned at randomisation; • Potentially inappropriate application of simple imputation.
Criteria for the judgement of 'Unclear risk' of bias.	Any one of the following: • Insufficient reporting of attrition/exclusions to permit judgement of 'Low risk' or 'High risk' (e.g. number randomised not stated, no reasons for missing data provided); • The study did not address this outcome.
SELECTIVE REPORTING **Reporting bias due to selective outcome reporting.**	
Criteria for a judgement of 'Low risk' of bias.	Any of the following: • The study protocol is available, and all of the study's pre-specified (primary and secondary) outcomes that are of interest in the review have been reported in the pre-specified way. • The study protocol is not available, but it is clear that the published reports include all expected outcomes, including those that were pre-specified (convincing text of this nature may be uncommon).
Criteria for the judgement of 'High risk' of bias.	Any one of the following: • Not all of the study's pre-specified primary outcomes have been reported. • One or more primary outcomes are reported using measurements, analysis methods or subsets of the data (e.g. subscales) that were not pre-specified; • One or more reported primary outcomes were not pre-specified (unless a clear justification for their reporting is provided, such as an unexpected adverse effect). • One or more outcomes of interest in the review are reported incompletely so that they cannot be entered in a meta-analysis. • The study report fails to include results for a key outcome that would be expected to have been reported for such a study.
Criteria for the judgement of 'Unclear risk' of bias.	Insufficient information to permit judgement of 'Low risk' or 'High risk'. It is likely that the majority of studies will fall into this category.
OTHER BIAS **Bias due to problems not covered elsewhere in the table.**	
Criteria for a judgement of 'Low risk' of bias.	The study appears to be free of other sources of bias.

Criteria for the judgement of 'High risk' of bias.	There is at least one important risk of bias. For example, the study: • Had a potential source of bias related to the specific study design used; or • Has been claimed to have been fraudulent; or • Had some other problem.
Criteria for the judgement of 'Unclear risk' of bias.	There may be a risk of bias, but there is either: • Insufficient information to assess whether an important risk of bias exists; or • Insufficient rationale or evidence that an identified problem will introduce bias.

5.5 QA tool for non-randomised studies:- Newcastle-Ottawa quality assessment scale: cohort study

ITEM	STARS
Selection	
Representativeness of the exposed cohort	
Truly representative of the average community	
Somewhat representative of the average community	
Selected group of users	
No description of the derivation of the cohort	
Selection of the non-exposed cohort	
Drawn from the same community as the exposed cohort	
Drawn from a different source	
No description of the derivation of the cohort	
Ascertainment of exposure	
Secure record	
Structured interview	
Written self-report	
No description	
Comparability	

Comparability of cohorts based on the design or analysis	
Study controls for	
Study controls for any additional factors	
Outcome	
Assessment of outcome	
Independent blind assessment	
Record linkage	
Self-respect	
No description	
Was follow-up long enough for outcome to occur	
Yes	
No	
Adequacy of follow-up of cohorts	
Complete follow-up up- all subjects accounted for	
Subjects lost to follow up unlikely to introduce bias	
Follow up rate high	
No statement	

Stars are pre-rewarded in the NOS and are used to indicate quality elements. A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability. The NOS handbook must be referred to for the interpretation of the NOS scale.

(Boland et al, 2001)

5.6 Record of all included studies

No	Reference	Included at screening	Obtained paper	Included in selection
1				
2				
3				
4				
5				
6				
7				
8				

5.7 Appendix 6.0: PRISMA Flow diagram for illustrating the search strategy