Comparison of the sealing ability of bioceramic sealer against epoxy resin based sealer: A systematic review & meta-analysis

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Objective: This systematic review and meta-analysis aimed to evaluate if bioceramic sealers had superior sealing properties to epoxy resin-based sealers.

Methodology: A systematic search was performed in the following databases: MEDLINE Ovid (from 1946 onwards), Scopus, Google Scholar, EBSCO, and a hand search of references of included articles was also done. In vitro and ex vivo studies were included. Risk of bias was assessed, and quantitative synthesis was performed for microleakage measured using vertical dye penetration, horizontal dye penetration, and dentin-sealer gap. Summary effect was reported as Standardized Mean Difference with 95% CI. Subgroup analysis was performed based on the imaging modalities, the obturation techniques, and the file systems employed.

Results: A total of 24 studies were included. Meta-analysis demonstrated no significant difference between the sealing ability of bioceramic sealer and epoxy resin-based sealer when measured using the microleakage tests [SMD -0.59(95%CI: 1.74,0.55)]. Subgroup analysis revealed no significant differences except when manual K-files were used. Heterogeneity was low when sub-group analysis was done.

Conclusion: Bioceramic sealers and epoxy resin-based sealers both exhibited comparable sealing ability.

1. Introduction

The fundamental goal of endodontic therapy is to completely debride the root canal space and achieve 3-Dimensional obturation. Over the years, none of the materials have demonstrated perfect results in producing such a seal. A universally accepted “gold standard” filling material in endodontics presently in use is Gutta-percha, with commendable properties of non-toxicity and biocompatibility. It is entirely inert once obturated in the root canal area, thermoplastic by nature, re-treatable, and more significantly. However, gutta-percha has failed to establish a proper hermetic seal due to the lack of adhesiveness of the gutta-percha to the canal wall dentin. This drawback has instilled the importance of incorporating sealers or cement during obturation, filling the spaces between the canal wall dentin and the obturating material interface. It may also be used to fill in the accessory canals, canal irregularities, and minor discrepancies. Various adhesive filling solutions have been developed in an attempt to achieve a “secondary monoblock” within the root canal, in which the core material, sealing agent, and root canal dentin create a single cohesive unit. Based on their chemical composition, sealers are divided into various groups. Epoxy and amine paste are the pastes used in epoxy resin-based sealers. In contrast to amine paste, which comprises 1-adamantanamine and TCD-diamine, epoxide paste primarily comprises calcium tungstate and zirconium oxide (e.g., AH plus). Due to their beneficial physicochemical characteristics and antibacterial effect, they are widely used in clinical practice. When extruded into the periapical tissues, however, it does not readily resorb and can bring about a short-term inflammatory response. “Bioceramic sealers” which are dimensionally stable, have been created to seal root canal spaces. These injectable and premixed hydrophilic calcium silicate and phosphate-based sealers are composed of zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, and a thickening agent. Bioceramic-based sealers use the moisture naturally present in the dentinal tubules to commence and complete their setting reaction because they are hydrophilic and insoluble.
Sealers are crucial in lowering microleakage by filling the spaces between root dentin and gutta-percha. Numerous in-vitro and in-vivo investigations present inconsistent and ambiguous results about the proper selection of sealers, ultimately deciding the treatment outcome. Epoxy resin-based sealers14,15 and bioceramic sealers13–16 were typically suggested in the investigations on different sealers. Assimilation of all available information from the literature on these materials can assist the practitioner in executing void-free endodontic therapy. Thus, this systematic review and meta-analysis aimed to compare the sealing ability of bioceramic sealers and epoxy-resin-based sealers.

2. Methods

This review included in-vitro and ex-vivo studies done on obturated single-rooted permanent teeth with fully formed root apices. Teeth free of caries, cracks, fractures, resorption, and multiple canals were included. Epoxy resin-based sealers were considered the control group, and bioceramic sealers as the intervention group. The outcome was sealing ability measured in terms of microleakage (in mm) using the dye penetration method. Any technique (Stereomicroscope, Scanning Electron Microscopy, Micro CT) used for image analysis was included. The review protocol was registered with PROSPERO (ID: CRD42021244565).

The electronic databases searched included MEDLINE Ovid (from 1946 onwards), Scopus, Google Scholar, EBSCO. No restrictions were imposed on the date and country of publication, but only studies published in English were included in the review. In addition, a hand search of references of included articles was also done. The search strategy used was ((sealing ability) OR (microleakage) OR (sealing potential) AND ((AH plus) OR (epoxy resin)) AND (bioceramic sealer) OR (endosequence) OR (BC)).

The obtained articles were imported to Covidence for further screening. Two authors (RR and KR) independently removed duplicates from the acquired data and reviewed the remaining articles based on title and abstract. A third author (KV) resolved any conflicts. The full text of included articles was then retrieved and examined for eligibility based on inclusion/exclusion criteria. Studies that did not match the criteria for inclusion were eliminated. All the databases listed were searched in March 2021. For the time period under consideration, there was no lower limit.

Two reviewers (RR and KR) used a Microsoft Excel sheet to extract data for each included study, which included publication details such as year of publication and journal, country of origin, details of teeth included, sample size, type of sealer used, study design (in-vitro or ex-vivo), details of the outcomes reported, results of the intervention, file systems used, and obturation technique. Two review authors (RR and KR) independently assessed the risk of bias for each included study. As no standardized tools were available for assessing the risk of bias for in-vitro studies, a tool from a similar systematic review18 was adopted and customized to the study requirements. The following parameters were assessed and graded for calculating the risk of bias: (i) presence of control group, (ii) description of sample size calculation, (iii) root canal procedure performed by a single operator, (iv) use of sealer material according to manufacturer’s instructions and (v)blinding of outcome assessor. If the authors reported the parameter, the article had a Y (yes) for that specific parameter; if it was not possible to find the information, the article received an N (no). The articles that reported 1–2 of the above items were classified as high risk of bias, 3 as medium risk, and 4–5 as low risk.

For quantitative synthesis, the data were divided into categories based on the diverse microleakage approaches used, such as vertical dye penetration, horizontal dye penetration, and dentin-sealer gap. Vertical dye penetration was split into groups based on the method of analysis (Stereomicroscope and Confocal Laser Scanning Microscope), the kind of obturation (Single cone and Lateral condensation), the file system employed (Rotary and Manual), and the level of horizontal dye penetration (4 mm and 6 mm). Microleakage was also measured using the dentin-sealer gap.

The treatment effect for each study was summarized using the standardized weighted-mean differences (SMD) as the outcome measures. A comparison between sealing ability measured in terms of microleakage (in mm) using the dye penetration method. Any technique (Stereomicroscope, Scanning Electron Microscopy, Micro CT) used for image analysis was included. The review protocol was registered with PROSPERO (ID: CRD42021244565).

The search results retrieved a total of 129 studies. After removing duplicates, 107 articles were included for the title and abstract screening. Among them, 25 articles were excluded as they were irrelevant. Among the 82 articles included for full-text screening, 24 articles were selected for qualitative synthesis. Finally, 16 articles were included for quantitative synthesis (Fig. 1.).

Out of the 24 studies included, eight were from India,16,17,21–26 two from Iran,12,27 two from Brazil,26,28 two from Thailand,18,31,32 one study each from Egypt,13 Saudi Arabia,32 Lebanon,33 Turkey,14 Austria,15 China,34 United Arab Emirates,35 Germany,36 and Bulgaria.37 All the studies were conducted in-vitro with a sample size ranging from 10 to 26. The included teeth had a straight channel in 11 studies,12,16,17,21,24,25,30,32,36–38 oval in one study14 and round in two studies.15,35 Manual K-files were used for chemo-mechanical preparation in two studies,16,35 and rotary file systems were used in 22 studies. Single cone obturation was performed in 10 studies,13,14,19,22,25,27,35–37,38 and a conventional technique (continuous wave compaction, lateral condensation, vertical condensation) was adopted in 13 studies. The outcome measured was microleakage in 18 studies using a scanning electron microscope, stereomicroscope, confocal laser scanning microscope, bacterial penetration, bacterial leakage, root canal filling materials and voids percentage, dentinal tubule penetration, and filling quality, sealing ability and apical sealing ability. No ex-vivo studies were retrieved (Table 1.).

Of the 58 studies excluded, 20 studies were excluded due to wrong intervention, 11 had wrong comparator, 10 had wrong outcomes, nine had wrong study design, four had a wrong patient population, two were duplicate articles not identified in the screening stage, one was non-English language article, and one was conducted in a different setting.

According to the risk of bias assessment, the methodology’s operator count was not disclosed in 70.84% of the research. The use of sealer in accordance with the manufacturer’s instructions was not documented in almost 50% of research, and blinding of outcome assessors was not mentioned in 87.5% of investigations. The mechanism used to determine the sample size was not disclosed in any studies (Table 2.).

Quantitative synthesis was conducted based on outcome measures, and the results were further divided based on different methodological approaches. In 10 investigations, including 350 teeth, the vertical dye penetration technique was utilized to quantify microleakage. Based on the approach used to evaluate the results, there was no statistically significant difference between the epoxy resin-based sealer and the bioceramic sealer (SMD: 0.59 (95% CI: 1.74, 0.55)) with a 95% statistical heterogeneity. A subgroup analysis was done based on the imaging modalities used. A confocal laser scanning microscope was used in three studies involving 124 teeth and showed no significant difference.
between the two groups [SMD: 1.01 (95% CI: 3.25, 1.23)]. Stereomicroscopic evaluation was performed in seven studies involving 226 teeth. No significant differences were observed between bioceramic sealers and epoxy resin-based sealers [SMD: 0.44 (95% CI: 1.95, 1.07)] (Fig. 2). A comparable subgroup analysis was conducted depending on the various obturation processes used. In five investigations, single cone obturation was done consisting of 168 teeth with no significant difference in the study groups [SMD: 0.21 (95% CI: 0.89, 1.31)]. Conventional technique of obturation was done in five studies involving 182 teeth. However, no significant differences were noted between the two groups. [SMD: 1.49 (95% CI: 3.76, 0.79)] (Fig. 3). The various file systems used for chemo-mechanical preparation were also the subject of a third subgroup study. In two investigations including 60 teeth, manual K files were employed, and the results showed a statistically significant difference favoring bioceramic sealers over epoxy resin-based sealants (SMD: 4.31; 95% CI: 5.71, −2.90). 40% (moderate) heterogeneity was detected. Rotary files were used in eight studies of 290 teeth and a statistically significant difference was noted between the two groups [SMD: 0.27 (93% CI: 0.72, 1.26)] favoring epoxy resin-based sealers (Fig. 4).

A total of two studies measured microleakage in terms of horizontal dye penetration. This was sub-grouped based on the depth of dye penetration, and analysis was carried out at 4 mm and 6 mm depths. At 4 mm with 100 teeth, a significant difference was found between both the groups [SMD: -0.88 (95% CI: -1.41, -0.36)] favoring bioceramic sealers. The heterogeneity observed was 37%. At 6 mm with 100 teeth, a significant difference was found among the bioceramic sealer, and epoxy resin-based sealer [SMD: 1.13 (95% CI: 1.56, −0.71)]. In all, no heterogeneity was observed.

Dentin sealer gap was measured in four studies involving 104 teeth with no statistically significant difference between the two groups [SMD: 2.08 (95% CI: 4.32, 0.15)]. A funnel plot was generated, which revealed no publishing bias (Fig. 5).

4. Discussion

The ability of a root canal sealer to prevent external connection with the periapical tissue determines its apical sealing capacity. It is not always feasible to achieve a hermetic root canal closure because of issues with flow, consistency, setting characteristics, solubility, and root canal wall adherence. The lifetime of the root canal-treated tooth depends on achieving a “fluid-tight seal,” which, if not done, can be a critical factor in endodontic failure.

This systematic review was carried out to compare the sealing ability of two sealers and thus included a traditional (epoxy resin-based) and novel (bioceramic) material. The bioceramic sealer can form a chemical bond with the root dentin wall, obliterating the micro-space, which can be a possible portal of entry for microorganisms. Despite having greater particle size, viscosity, and flow characteristics, the overall results of the meta-analysis findings showed no discernible differences between the two sealers’ sealing abilities. A subgroup analysis was conducted to find any differences in the effect measure because this discovery may be related to methodological variability. Because the outcome used to measure apical microleakage was different (interphase between radicular dentin and root canal filling material, gap between sealer and gutta-percha, adaptation of sealer in sealer/dentin, sealer penetration depth), meta-analysis was carried out using Standard Mean Difference (SMD) as the effect measure. Based on imaging modalities, vertical dye penetration was divided into two categories. Confocal laser scanning microscopy (CLSM) favored bioceramic sealer in one included study. It attributed it to the more significant setting expansion achieved once inserted in the root canal and forming a covalent bond with the amino group. Another included study favored epoxy resin-based sealers, which argued its ability to penetrate micro irregularities on the dentinal wall because of its greater adhesiveness. One study showed no significant difference between the groups. CLSM uses fluorescence to measure sealer penetration along the canal circumference of each sample and reveals the sealer penetration within the dentinal tubules via the creation of high contrast points. Another advantage when using CLSM in segments is that the sealer can be visualized at various depths. It has multiple advantages over traditional wide-field optical.
Table 1
Characteristics of included studies.

| STUDY ID       | COUNTRY  | STUDY DESIGN | TYPE OF CANAL | DYE PENETRATION | METHOD OF OUTCOME | INTERVENTION GROUP | BRAND | SAMPLE SIZE | CONTROL GROUP | BRAND | SAMPLE SIZE | FILE SYSTEM | OBTURATION TECHNIQUE | OUTCOME MEASURED | APICAL MEASUREMENT |
|----------------|----------|--------------|---------------|-----------------|-------------------|---------------------|-------|--------------|-----------------|-------|--------------|-------------|----------------------|-------------------|---------------------|
| Shinde 2014    | India    | In vitro     | No            | SEM             | Bioceramic sealer | EndoSequence BC Sealer | 15    | Epoxy resin sealer | AH Plus | 15    | Protaper Rotary files | Single Cone | Dentin-material gap   | Apical 1/3rd      |
| Padmawar 2018  | India    | In vitro     | Straight      | Yes (methylene blue) | Stereo-microscope | Bioceramic sealer | EndoSequence BC Sealer | 25    | Epoxy resin sealer | AH Plus | 25    | Protaper Rotary files | Lateral Condensation | Horizontal dye penetration | 4 mm               |
| Padmawar 2018  | India    | In vitro     | Straight      | Yes (methylene blue) | Stereo-microscope | Bioceramic sealer | EndoSequence BC Sealer | 25    | Epoxy resin sealer | AH Plus | 25    | Protaper Rotary files | Lateral Condensation | Horizontal dye penetration | 6 mm               |
| Pawar 2014     | India    | In vitro     | Straight      | Yes (methylene blue) | Stereo-microscope | Bioceramic sealer | EndoSequence BC Sealer | 25    | Epoxy resin sealer | AH Plus | 25    | Protaper Rotary files | Continuous Wave Condensation | Continuous Wave penetration | 4 mm               |
| Pawar 2014     | India    | In vitro     | Straight      | Yes (methylene blue) | Stereo-microscope | Bioceramic sealer | EndoSequence BC Sealer | 25    | Epoxy resin sealer | AH Plus | 25    | Protaper Rotary files | Continuous Wave Condensation | Continuous Wave penetration | 6 mm               |
| Eltair 2017    | Germany  | In vitro     | No            | SEM             | Bioceramic sealer | TotalFill BC Sealer | 12    | Epoxy resin sealer | AH Plus | 12    | ProTaper Universal | Single Cone | Sealer and Dentin gap | 2 mm               |
| Gyuhenkiyan 2020 | Bulgaria | In vitro     | No            | SEM             | Bioceramic sealer | TotalFill BC Sealer | 10    | Epoxy resin sealer | AH Plus | 10    | ProTaper Universal | Single Cone | Sealer and Dentin gap | 2 mm               |
| Hegde 2020     | India    | In vitro     | No            | SEM             | Bioceramic sealer | EndoSequence BC Sealer | 20    | Epoxy resin sealer | AH Plus | 20    | ProTaper          | Lateral Condensation | Sealer and Dentin gap | 1.5 mm             |
| Mohammadian 2017 | Iran     | In vitro     | No            | SEM             | Bioceramic sealer | EndoSequence BC Sealer | 10    | Epoxy resin sealer | AH Plus | 10    | ProTaper Rotary files | Lateral Condensation | Sealer and Dentin gap | 2 mm               |
| Ballullaya 2017 | India    | In vitro     | Straight      | Yes (methylene blue) | Stereo-microscope | Bioceramic sealer | EndoSequence BC Sealer | 10    | Epoxy resin sealer | AH Plus | 10    | Manual K files | Lateral Comaption | Vertical Dye penetration | 2 mm               |
| Trivedi 2020   | India    | In vitro     | No            | Confocal Laser Scanning Microcopy | Bio C Sealer | Bio C Sealer | 20    | Epoxy resin sealer | AH Plus | 20    | Manual K files | Lateral Comaption | Vertical Dye penetration | 2.3 mm             |
| Trivedi 2020   | India    | In vitro     | Straight      | Yes (Indian ink) | Stereo-microscope | Bioceramic sealer | Total Filling BC (TF BC) | 26    | Epoxy resin sealer | AH 26 | 26    | Mtwo rotary files | Lateral Condensation | Vertical Dye penetration | 2 mm               |
| Del Monaco 2018 | Brazil    | In vitro     | Circular     | Yes (Rhodamine B) | Confocal Laser Scanning Microcopy | EndoSequence BC Sealer | 10    | Epoxy resin sealer | AH Plus | 10    | Reciproc files | Vertical Condensation | Vertical Dye penetration | 3 mm               |
| El Sayed 2018  | Egypt    | In vitro     | Yes (methylene blue) | Stereo-microscope | Bioceramic sealer | EndoSequence BC Sealer | 10    | Epoxy resin sealer | AH Plus | 10    | ProTaper Universal | Single Cone | Vertical Dye penetration | 7 mm               |
| Elshinawy 2019 | Saudi Arabia | In vitro     | Straight      | Yes (methylene blue) | Stereo-microscope | Bioceramic sealer | Total Fill BC Sealer | 10    | Epoxy resin sealer | AH Plus | 10    | ProTaper Next | Single Cone | Vertical Dye penetration | 2 mm               |
| Hachem 2019    | Lebanon  | In vitro     | No            | Confocal Laser Scanning Microcopy | Bioceramic sealer | BC SEALER | 32    | Epoxy resin sealer | AH Plus | 32    | ProTaper rotary | Single Cone | Vertical Dye penetration | 1 mm               |
| Hansain 2017   | India    | In vitro     | Straight      | Yes (Rhodamine B) | Stereo-microscope | Bioceramic sealer | Total Fill BC Sealer | 16    | Epoxy resin sealer | AH Plus | 16    | High flex files | Single Cone | Vertical Dye penetration | 1 mm               |

(continued on next page)
| STUDY ID   | COUNTRY       | DESIGN | TYPE OF CANAL | DYE PENETRATION | METHOD OF OUTCOME | INTERVENTION GROUP | BRAND | SAMPLE SIZE | CONTROL GROUP | BRAND        | SAMPLE SIZE | FILE SYSTEM USED FOR OBTURATION | OBTURATION TECHNIQUE | OUTCOME MEASURED | APICAL MEASUREMENT |
|-----------|---------------|--------|---------------|-----------------|-------------------|-------------------|--------|--------------|----------------|-------------|--------------|--------------------------------|----------------------|-------------------|---------------------|
| Pawar 2014 | India         | In vitro | Yes (methylene blue) | Stereo-microscope | Bioceramic sealer | EndoSequence BC Sealer | 25     | AH Plus      | 25             | Protaper Rotary files | Continuous Wave Condensation | Single Cone | Vertical Dye penetration | 2, 4, 6 mm         |
| Rizvi 2021 | In vitro      | Straight | Yes (methylene blue) | Stereo-microscope | Bioceramic sealer | MTA Fillapex | 16     | AH Plus      | 16             | ProTaper Universal | Multiple Wave Condensation | Sealing Ability | Vertical Dye penetration | 2 mm               |
| Asawaworarit 2019 | Thailand | In vitro | No | Fluid filtration and SEM | Bioceramic sealer | EndoSequence BC Sealer | 19     | AH Plus      | 19             | ProTaper rotary | - | - | - | - |
| Salem 2018 | UAE           | In vitro | Round | Yes (methylene blue) | Spectrophotometer device | Bioceramic sealer | Total Fill BC sealer | 20     | AH Plus      | 20             | iRace rotary file | Single Cone | - | - | - |
| Hegde 2015 | India         | In vitro | No | Spectrophotometer | Bioceramic sealer | EndoSequence BC Sealer | 20     | AH Plus      | 20             | ProTaper Rotary files | Lateral Condonnation & Single Cone | Warm Vertical Compation | - | - |
| Tanompetnanga 2018 | Thailand | In vitro | No | Fluid Filtration | Bioceramic sealer | EndoSequence BC Sealer | 20     | AH Plus      | 20             | Mtwo rotary system | - | - | - | - |
| de Melo T 2018 | Brazil | In vitro | No | Bacterial penetration model | Bioceramic sealer | EndoSequence BC Sealer | 10     | AH Plus      | 10             | ProTaper Universal | Cold Lateral Condonnation | - | - | - | - |
| Celikten 2015 | Turkey       | In vitro | Oval | No | Micro CT | Bioceramic sealer | EndoSequence BC Sealer | 10     | AH Plus      | 10             | Rotary Files | Single Cone | Root canal filling materials and voids | - | - | - | - |
| Antunovic 2021 | Austria, Croatia | In vitro | Round | No | SEM | Bioceramic sealer | TotalFill BC sealer | 15     | AH Plus      | 15             | ProTaper Next (PTN) | Cold Lateral Condonnation | - | - | - | - |
| Wang 2018   | China         | In vitro | Yes (Rhodamine B) | Confocal Laser Scanning Microscopy | Bioceramic sealer | iRoot SP | 10     | AH Plus      | 10             | ProTaper Universal | Single Cone | Dentinal tubule penetration and filling quality | - | - | - | - |
microscopy and scanning electron microscopy, including the capacity to regulate the depth of field, reduce background information distant from the focus plane, and build multiple optical sections, even from thick specimens.

On stereomicroscopic evaluation, three studies preferred bioceramic sealer and epoxy resin-based sealer, respectively, whereas they revealed no significant difference. A subgroup analysis of different obturation techniques revealed that the bioceramic sealer has better sealing ability than epoxy resin sealer in three studies, but the opposite was found in one study, and no significant differences were found in another using conventional technique.

For example, the lateral condensation approach, one of the traditional techniques, does not allow for the production of a uniform sealer layer along the whole length of the canal, regardless of the sealer utilized. Elshinawy et al. recommended using a bioceramic sealer with a single-cone approach. In contrast, two studies suggested using an epoxy resin sealer, and two studies found no significant differences between the sealers. The slower setting time of the bioceramic sealer, which allows for more time for expansion and pushing the sealer toward the radicular dentinal walls, may also contribute to the single cone obturation system’s superior sealing performance.

A subgroup analysis based on file systems revealed that bioceramic sealer had superior sealing properties in two studies. In comparison, epoxy resin-based sealer was preferred in four studies, and two studies did not differ in their sealing properties when rotary files were used. Only two studies evaluated the sealing ability when manual files were used, and both favored bioceramic sealers.

At 4 mm and 6 mm depth from the apical foramen, horizontal dye penetration was also tested. Two investigations evaluated the sealing ability when manual files were used, and both favored bioceramic sealers.

| STUDY ID         | Presence of control group | Description of sample size calculation | Root canal procedure performed by a single operator | Use of sealer material according to manufacturers instructions | Blinding of outcome assessor |
|------------------|---------------------------|----------------------------------------|----------------------------------------------------|---------------------------------------------------------------|-----------------------------|
| Antunovic 2021   | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Araghi 2020      | Low risk                  | High risk                              | Low risk                                           | High risk                                                      | Low risk                    |
| Asawaworarit 2019| Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Balabulara 2017  | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Celikten 2015    | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| de Melo T 2018   | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Del Monaco 2018  | Low risk                  | High risk                              | Low risk                                          | High risk                                                      | High risk                   |
| El Sayed 2016    | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Elshinawy 2019   | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Eltair 2017      | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Gyulbenkian 2020 | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Hachem 2019      | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Hannain 2017     | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Hegde 2015       | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Hegde 2020       | Low risk                  | High risk                              | Low risk                                          | High risk                                                      | High risk                   |
| Mohammadian 2017 | Low risk                  | High risk                              | High risk                                          | High risk                                                      | Low risk                    |
| Pawar 2014       | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Rizvi 2021       | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Salem 2018       | Low risk                  | High risk                              | Low risk                                          | High risk                                                      | High risk                   |
| Shinde 2014      | Low risk                  | High risk                              | High risk                                          | High risk                                                      | High risk                   |
| Tanompetsanga 2018| Low risk                  | High risk                              | High risk                                          | High risk                                                      | High risk                   |
| Trivedi 2020     | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Wang 2018        | Low risk                  | High risk                              | High risk                                          | High risk                                                      | High risk                   |
| Pavma 2018       | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |

Table 2
Risk of bias of included studies.

| STUDY ID | Presence of control group | Description of sample size calculation | Root canal procedure performed by a single operator | Use of sealer material according to manufacturers instructions | Blinding of outcome assessor |
|----------|---------------------------|----------------------------------------|----------------------------------------------------|---------------------------------------------------------------|-----------------------------|
| Antunovic 2021 | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Araghi 2020   | Low risk                  | High risk                              | Low risk                                           | High risk                                                      | Low risk                    |
| Asawaworarit 2019| Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Balabulara 2017| Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Celikten 2015 | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| de Melo T 2018 | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Del Monaco 2018| Low risk                  | High risk                              | High risk                                          | High risk                                                      | High risk                   |
| El Sayed 2016  | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Elshinawy 2019 | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Eltair 2017    | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Gyulbenkian 2020| Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Hachem 2019    | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Hannain 2017   | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Hegde 2015     | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Hegde 2020     | Low risk                  | High risk                              | High risk                                          | High risk                                                      | High risk                   |
| Mohammadian 2017| Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Pawar 2014     | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Rizvi 2021     | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |
| Salem 2018     | Low risk                  | High risk                              | Low risk                                          | High risk                                                      | High risk                   |
| Shinde 2014    | Low risk                  | High risk                              | High risk                                          | High risk                                                      | High risk                   |
| Tanompetsanga 2018| Low risk                  | High risk                              | High risk                                          | High risk                                                      | High risk                   |
| Trivedi 2020   | Low risk                  | High risk                              | Low risk                                          | Low risk                                                      | High risk                   |
| Wang 2018      | Low risk                  | High risk                              | High risk                                          | High risk                                                      | High risk                   |
| Pavma 2018     | Low risk                  | High risk                              | High risk                                          | Low risk                                                      | High risk                   |

Fig. 2. Comparison of microleakage between bioceramic and epoxy-resin sealer based on imaging modalities.
Bioceramic sealers had better setting ability at 4 mm. They expand on setting, generating a "self-seal," and this expansion can reach up to 0.2% once the setting reaction is completed.

In terms of the dentin sealer gap, three studies found that bioceramic sealers produced a smaller gap than epoxy resin-based sealers. Properties like hydrophilicity, unshrinkable nature, and insolubility in oral fluids contribute to reduced gap formation in bioceramic sealers. Due to their inherent compositional features, they can also generate calcium hydroxide and hydroxyapatite, ensuring an excellent bond to both the dentin and the filling material.

To the best of our knowledge, this is the first review undertaken to synthesize the evidence on the sealing ability of bioceramic and epoxy resin-based sealers. One of this review’s strengths is its ability to undertake a subgroup analysis, thereby reducing the methodological heterogeneity considerably. Though both the epoxy resin-based sealer and the bioceramic sealer demonstrated comparable sealing qualities, given the statistical heterogeneity and high risk of bias concerning the standardization of methodology, the results need to be interpreted with caution.

Fig. 3. Comparison of microleakage between bioceramic and epoxy-resin sealer based on obturation technique.

Fig. 4. Comparison of microleakage between bioceramic and epoxy-resin sealer based on file system employed.

Fig. 5. Funnel plot of included studies.

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5. Clinical significance

The root canal system must be kept hermatically sealed for clinical effectiveness, so understanding the qualities of the sealer utilized is critical. Given the evidence that bioceramic and epoxy resin-based sealers have similar qualities, bioceramic sealers can be used effectively in clinical practice for void-free obturation and long-term success.

6. Conclusion

Root canal sealers, when utilized as an adjunctive substance in the obturation of root canals, have a significant impact on the success of endodontic treatment. An ideal root canal sealer should possess a perfect combination of sealing ability and biocompatibility. We can infer from the results that both epoxy resin-based sealer and bioceramic sealer have equivalent adhesion capabilities, and the operator may choose the suitable material based on other aspects.

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Declaration of competing interest

The authors do not have any financial or other competing interests to declare.

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References

1 Ingle JL, Bakland LK, Baumgartner JC. Ingle’s Endodontics 6. BC Decker; 2008:1588.
2 Suresh Chandra B, Gopikrishna V. Greenman’s Endodontic Practice. thirteenth ed. India: Wolters Kluwer; 1991:576.
3 Cohen S, Burns RC. Evaluation of antimicrobial activity of sealers and pastes used in endodontics. J Endod. 2003 Jul;30(11):1168–1175.
4 Cohen S, Burns RC. Endodontic Systems: A comparison of bond strength of three different endodontic sealers: a scanning electron microscopic study. J Endodontology. 2020;52:76–80.
5 Hegde V, Arora S. Sealing ability of three hydrophilic single-cone obturation systems: a stereomicroscopic dye penetration and filling quality of bioceramic sealer. J Endodontology. 2018;38(3):279–286.
6 Ballalayya SV, Vinay V, Thumu J, Devala S, Bollu IP, Balla S. Stereomicroscopic dye leakage measurement of six different root canal sealers. J Clin Diagn Res. 2017;11(6):ZC55–ZC58.
7 Hansain M, Bansal P, Nikhil V. An in vitro comparative analysis of sealing ability of bioceramic-based, methacrylate-based, and epoxy resin-based sealers. Endodontology. 2017;1:291-146.
8 Heide V, Arora S. Sealing ability of three endodontic sealers: an in vitro glucose leakage study. Contemp Clin Dent. 2015 Mar 1;6(2):S86–S89.
9 Mohammadian F, Farahamimastary F, Dibaji F, Khafrazifard MJ. Scanning electron microscopic evaluation of the sealer-dentine interface of three sealers. Iran Endod J. 2017;12(1):38–42.
10 Melo T, Prado M, Hírata R, Fidel S, Silva E, Sassone L. Improved sealing ability promoted by calcium silicate-based root canal sealers. Braz J Oral Sci. 2018 Jun 5;17:4–8.
11 Jardim Del Monaco R, Travares de Oliveira M, de Lima AF, et al. Influence of Nd:YAG laser on the penetration of a bioceramic root canal sealer into dentinal tubules: a confocal analysis. PLoS One. 2018;13(8), e0202295.
12 Assawaworrarit W, Pinyosopon T, Kijanamnith K. Comparison of apical sealing ability of bioceramic sealer and epoxy resin-based sealer using the fluid filtration technique and scanning electron microscopy. J Endodontology. 2020;1:186–192.
13 Jhanay P, Pintucia P, Iqbal I. Sealing ability of two Adhesive Sealers in Root Canals Prepared with Different Rotary File Techniques. J Endodontology. 2013 Dec;39(12):1160–1166.
14 Rizvi Ramla. Evaluation of apical sealing ability of Bioceramic and AH plus root canal sealers, an in vitro study. J Liaquat Univ Med Health Sci. 2021;1:5–8.
15 Shokouhinejad N, Gorjestani H, Nasseh AA, Hoseini A, Mohammadi M, Aghazadeh Z. Evaluation of antimicrobial effectiveness of root canal sealers against Enterococcus faecalis: a meta-analysis. J Endodontology. 2020;1558–1561.
16 Antunovic M, Vukmanovic L, Budimir A, Kabil E, Anic I, Bago I. Evaluation of sealing ability of four bioceramic root canal sealers and an epoxy resin-based sealer: an in vitro study. Saudi Endod J. 2021 Jan 1;11(1):66.
17 Trivedi S, Chhabra S, Bansal A, et al. Evaluation of sealing ability of three root canal sealers: an in vitro study. J Contemp Dent Pract. 2020 Mar 1;21(3):291–295.
18 Pajwar SS, Pujar MA, Makandar SD. Evaluation of the apical sealing ability of bioceramic sealer, AH plus & epoxy: an in vitro study. J Conserv Dent. 2014;17(6):579–582.
19 Celikten B, Uzunbas CF, Orhan Al, et al. Evaluation of root canal sealer filling quality using a single-cone technique in oval shaped canals: an in vitro Micro-CT study. Scanning. 2016 Apr;38(2):153–140.
20 Mohammadian F, Farahamimastary F, Dibaji F, Khafrazifard MJ. Scanning electron microscopic evaluation of the sealer-dentine interface of three sealers. Iran Endod J. 2017;12(1):38–42.
21 Ballalayya SV, Vinay V, Thumu J, Devala S, Bollu IP, Balla S. Stereomicroscopic dye leakage measurement of six different root canal sealers. J Clin Diagn Res. 2017;11(6):ZC55–ZC58.
22 Hansain M, Bansal P, Nikhil V. An in vitro comparative analysis of sealing ability of bioceramic-based, methacrylate-based, and epoxy resin-based sealers. Endodontology. 2017;1:291-146.
23 Heide V, Arora S. Sealing ability of three hydrophilic single-cone obturation systems: an in vitro glucose leakage study. Contemp Clin Dent. 2015 Mar 1;6(2):S86–S89.
24 Ballalayya SV, Vinay V, Thumu J, Devala S, Bollu IP, Balla S. Stereomicroscopic dye leakage measurement of six different root canal sealers. J Clin Diagn Res. 2017;11(6):ZC55–ZC58.
25 Mattain M, Bansal P, Nikhil V. An in vitro comparative analysis of sealing ability of bioceramic-based, methacrylate-based, and epoxy resin-based sealers. Endodontology. 2017;1:291-146.
26 Hegde V, Arora S. Sealing ability of three endodontic sealers: a scanning electron microscopic study. J Pierre Fouchard Acad (India). 2014 Sep 1;28(3):78–82.
27 Hegde VR, Arora NJ, Dental element incorporation, interfacial adaptation, and pH change induced by bioceramic sealer, mineral trioxide aggregate-based sealer, and epoxy resin-based sealer – an in vitro, scanning electron microscopy electron probe X-ray microanalysis study. Endodontology. 2020;52:76–80.
28 Elshinawy M, Abdelaziz KM, Alqisi A, Khawshhal A, Al-Shari H, Alsalhi I. Sealing ability of three hydrophilic single-cone obturation systems: a stereomicroscopic dye penetration and filling quality of bioceramic sealer. J Endodontology. 2018;38(3):279–286.
29 Jardim Del Monaco R, Travares de Oliveira M, de Lima AF, et al. Influence of Nd:YAG laser on the penetration of a bioceramic root canal sealer into dentinal tubules: a confocal analysis. PLoS One. 2018;13(8), e0202295.
30 Asawaworrarit W, Pinyosopon T, Kijanamnith K. Comparison of apical sealing ability of bioceramic sealer and epoxy resin-based sealer using the fluid filtration technique and scanning electron microscopy. J Endodontology. 2020;1:186–192.
31 Jhanay P, Pintucia P, Iqbal I. Sealing ability of two Adhesive Sealers in Root Canals Prepared with Different Rotary File Techniques. J Endodontology. 2013 Dec;39(12):1160–1166.
32 Elshinawy M, Abdelaziz KM, Alqisi A, Khawshhal A, Al-Shari H, Alsalhi I. Sealing ability of three hydrophilic single-cone obturation systems: a stereomicroscopic dye penetration and filling quality of bioceramic sealer. J Endodontology. 2018;38(3):279–286.
33 Elshinawy M, Abdelaziz KM, Alqisi A, Khawshhal A, Al-Shari H, Alsalhi I. Sealing ability of three hydrophilic single-cone obturation systems: an in vitro glucose leakage study. Contemp Clin Dent. 2015 Mar 1;6(2):S86–S89.
34 Ballalayya SV, Vinay V, Thumu J, Devala S, Bollu IP, Balla S. Stereomicroscopic dye leakage measurement of six different root canal sealers. J Clin Diagn Res. 2017;11(6):ZC55–ZC58.
35 Ballalayya SV, Vinay V, Thumu J, Devala S, Bollu IP, Balla S. Stereomicroscopic dye leakage measurement of six different root canal sealers. J Clin Diagn Res. 2017;11(6):ZC55–ZC58.
36 Ballalayya SV, Vinay V, Thumu J, Devala S, Bollu IP, Balla S. Stereomicroscopic dye leakage measurement of six different root canal sealers. J Clin Diagn Res. 2017;11(6):ZC55–ZC58.
37 Ballalayya SV, Vinay V, Thumu J, Devala S, Bollu IP, Balla S. Stereomicroscopic dye leakage measurement of six different root canal sealers. J Clin Diagn Res. 2017;11(6):ZC55–ZC58.