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

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ABSTRACT

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.[1] 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.[2] It is entirely inert once obturated in the root canal area, thermoplastic by nature, re-treatable, and more significantly.[1]

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.[3] 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.[4]

Based on their chemical composition, sealers are divided into various groups. Epoxide and amine paste are the pastes used in epoxy resin-based sealers. In contrast to amine paste, which comprises 1-adamantane amine and TCD-diamine, epoxide paste primarily comprises calcium tungstate and zirconium oxide[5] (e.g., AH plus). Due to their beneficial physicochemical characteristics[6] and antibacterial effect, they are widely used in clinical practice.[7] When extruded into the periapical tissues, however, it does not readily resorb[8] 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[10] are composed of zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, and a thickening agent.[9–11] 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.[10,11] Tubular

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diffusion is considered to be the process by which bioceramic-based sealers bind to dentin, causing mechanical linkages to interlock,[14] resulting in the formation of a bond,[15,16] and the production of hydroxyapatite along the mineral infiltration zone.[17]

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 sealers[12,13] and bioceramic sealers[14–17] 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 review[18] 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 were different (interphase between radicular dentin and root canal filling material, the gap between sealer and gutta-percha, adaptation of sealer in sealer/dentin, sealer penetration depth). The data were analyzed using RevMan 5.4.1 software developed by the Cochrane group. Cochran's Q statistic, a chi-square test, and a threshold p-value of less than 0.10 were used to examine the data's heterogeneity.[19] The I^2 statistic,[20] as well as forest plots, were used to explore the consistency of the data. For any missing data, the study was excluded from the meta-analysis. A funnel plot was also generated to assess publication bias.

3. Results

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,[28,29] two from Thailand,[30,31] 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 canal in 11 studies,[12,16,17,21,24,25,30,32,36–38] oval in one study[14] and round in two studies.[15,35] Manual K-files were used for chemo-mechanical preparation in two studies,[16,24] and rotary file systems were used in 22 studies. Single cone obturation was performed in 10 studies[13,14,22,25,32–35,37,38] 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[16,29,33] involving 124 teeth and showed no significant difference

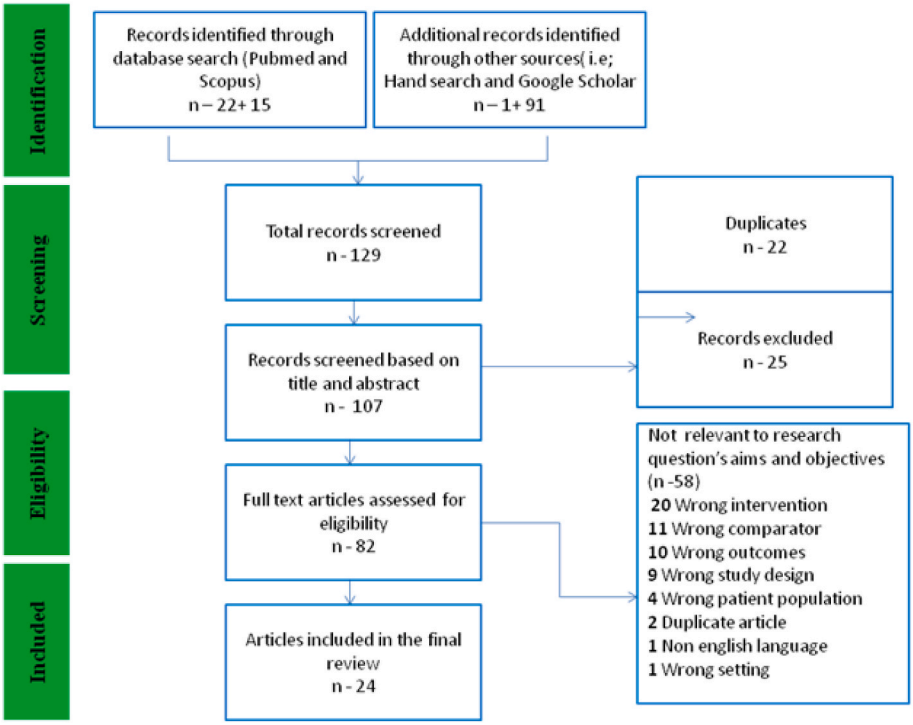

Fig. 1. Search results.

between the two groups [SMD: 1.01(95% CI: 3.25,1.23)].Stereomicroscopic evaluation was performed in seven studies[12,13,17,24,25,32,38] 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.[13,25,32,33,38] 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[12,16,17,24,29] in 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[16,24] 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[12,13,17,25,29,32,33,38] of 290 teeth and a statistically significant difference was noted between the two groups [SMD: 0.27 (93% CI: 0.72, 1.26)] favouring epoxy resin-based sealers(Fig. 4.).

A total of two studies[17,21] 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)], and no heterogeneity was observed.

Dentin sealer gap was measured in four studies[23,27,36,37] 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.[30] 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 guttapercha, 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.[16] 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,[29] which argued its ability to penetrate micro irregularities on the dentinal wall because of its greater adhesiveness. One study[33] 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 USED FOR OBTURATION	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	Horizontal dye 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	Horizontal dye penetration	6 mm
Eltair 2017	Germany	In vitro	Straight	No	SEM	Bioceramic sealer	TotalFill BC sealer	12	Epoxy resin sealer	AH Plus	12	Mtwo rotary files	Lateral Condensation & Single Cone	Sealer and Dentin gap	
Gyulbenkiyan 2020	Bulgaria	In vitro	Straight	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		Sealer and Dentin gap	
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	1.5 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 Comapction	Vertical Dye penetration	2 mm
Trivedi 2020	India	In vitro	Straight	No	Confocal Laser Scanning Microscopy	Bioceramic sealer	Bio C Sealer	20	Epoxy resin sealer	AH Plus	20	Manual K files	Lateral Condensation	Vertical Dye penetration	2–3 mm
Araghi 2020	Iran	In vitro	Straight	Yes (Indian ink)	Stereo-microscope	Bioceramic sealer	Total Fill 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 Microscopy	Bioceramic sealer	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)	Stereomicroscope	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 Microscopy	Bioceramic sealer	BC SEALER	32	Epoxy resin sealer	AH Plus	32	ProTaper rotary	Single Cone	Vertical Dye penetration	1 mm
Hasnain 2017	India	In vitro	Straight	Yes (Rhodamine B)	Stereo-microscope	Bioceramic sealer	Total Fill BC sealer	16	Epoxy resin sealer	AH Plus	16	High fiex files	Single Cone	Vertical Dye penetration	1 mm

(*continued on next page*)

Table 1 (*continued*)

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 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	Epoxy resin sealer	AH Plus	25	Protaper Rotary files	Continuous Wave Condensation	Vertical Dye penetration	2, 4, 6 mm
Rizvi 2021		In vitro	Straight	Yes (methylene blue)	Stereo-microscope	Bioceramic sealer	MTA Fillapex	16	Epoxy resin sealer	AH Plus	16	ProTaper Universal	Single Cone	Vertical Dye penetration	2 mm
Asawaworarit 2019	Thailand	In vitro	Straight	No	Fluid filtartion and SEM	Bioceramic sealer	EndoSequence BC Sealer	19	Epoxy resin sealer	AH Plus	19	ProTaper rotary	Multiple Wave Condensation	Sealing Ability	nl/s at 200 mmHg at 24 h
Salem 2018	UAE	In vitro	Round	Yes (methylene blue)	Spectrophotometer device	Bioceramic sealer	Total Fill BC sealer	20	Epoxy resin sealer	AH Plus	20	iRace rotary file	Single Cone	Apical sealing ability	Dye concentration (µg/ml)
Hegde 2015	India	In vitro		No	Spectrophotometer	Bioceramic sealer	EndoSequence BC Sealer	20	Epoxy resin sealer	AH Plus	20	Protaper Rotary files	Lateral Condensation & Single Cone	Microleakage-Glucose concentration,	mg/dl (mean ± SD)
Tanompetsanga 2018	Thailand	In vitro		No	Fluid Filtration	Bioceramic sealer	EndoSequence BC Sealer	20	Epoxy resin sealer	AH Plus	20	Mtwo rotary system	Warm Vertical Compaction	Microleakage-Fluid filtration device	mean ± SD - Nl/cmH2O.min
de Melo T 2018	Brazil	In vitro		No	Bacterial penetration model	Bioceramic sealer	EndoSequence BC Sealer	10	Epoxy resin sealer	AH Plus	10	ProTaper Universal	Cold Lateral Condensation	Sealing Ability-Bacterial penetration	% sample
Celikten 2015	Turkey	In vitro	Oval	No	Micro CT	Bioceramic sealer	EndoSequence BC Sealer	10	Epoxy resin sealer	AH Plus	10	Rotary Files	Single Cone	Root canal filling materials and voids	mean percentage values
Antunovic 2021	Austria, Croatia	In vitro	Round	No	SEM	Bioceramic sealer	TotalFill BC sealer	15	Epoxy resin sealer	AH Plus	15	ProTaper Next (PTN)	Cold Lateral Condensation	Bacterial leakage	
Wang 2018	China	In vitro		Yes (Rhodamine B)	Confocal Laser Scanning Microscopy	Bioceramic sealer	iRoot SP	10	Epoxy resin sealer	AH Plus	10	ProTaper Universal	Single Cone	Dentinal tubule penetration and filling quality	SC & WVC obt-SC selected-medians of the percentages of penetrated segment of root canal at 2, 4, and 6 mm levels

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	High risk	High risk
Ballullaya 2017	Low risk	High risk	High risk	Low risk	High risk
Celikten 2015	Low risk	High risk	Low risk	Low risk	Low 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 2018	Low risk	High risk	Low risk	Low risk	High risk
Elshinawy 2019	Low risk	High risk	High risk	Low risk	High risk
Eltair 2017	Low risk	High risk	Low risk	Low risk	High risk
Gyulbenkiyan 2020	Low risk	High risk	High risk	High risk	High risk
Hachem 2019	Low risk	High risk	High risk	Low risk	High risk
Hasnain 2017	Low risk	High risk	High risk	Low risk	High risk
Hegde 2015	Low risk	High risk	High 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	High risk	Low risk
Pawar 2014	Low risk	High risk	High risk	High risk	High risk
Rizvi 2021	Low risk	High risk	High risk	High 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	High risk	Low risk	High risk
Wang 2018	Low risk	High risk	High risk	High risk	High risk
Padmawar 2018	Low risk	High risk	High risk	Low risk	High risk

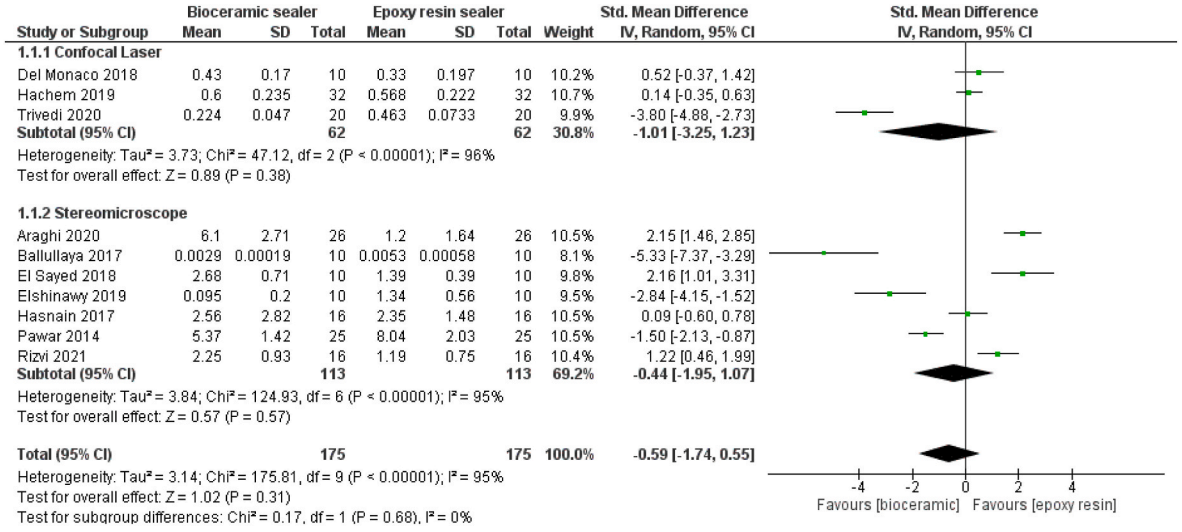

Fig. 2. Comparison of microleakage between bioceramic and epoxy-resin sealer based on imaging modalities.

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.[33] On stereomicroscopic evaluation, three studies[17,24,32] preferred bioceramic sealer and epoxy resin-based sealer,[12,13,38] 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,[16,17,24] but the opposite was found in one study,[12] and no significant differences were found in another using conventional technique.[29] 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.[39] Elshinawy et al.[32] recommended using a bioceramic sealer with a single-cone approach. In contrast, two studies[13,38] suggested using an epoxy resin sealer, and two studies[25,33] 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.[39]

A subgroup analysis based on file systems revealed that bioceramic sealer had superior sealing properties in two studies.[17,32] In comparison, epoxy resin-based sealer was preferred in four studies,[12,13,29,38] and two studies[25,33] did not differ in their sealing properties when rotary files were used. Only two studies[16,24] 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[17,21] found that the

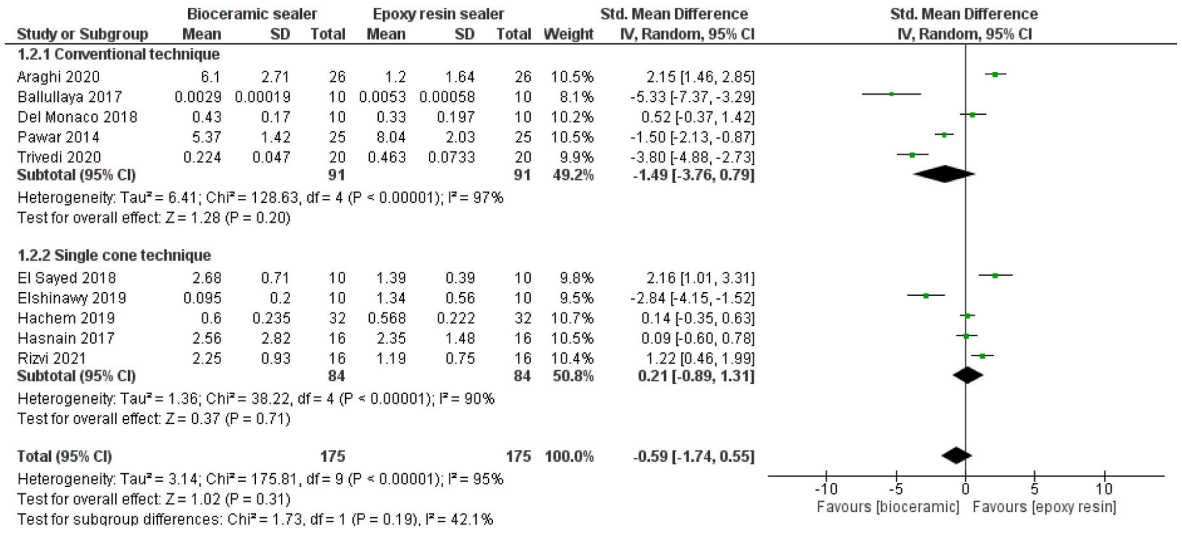

Fig. 3. Comparison of microleakage between bioceramic and epoxy-resin sealer based on obturation technique.

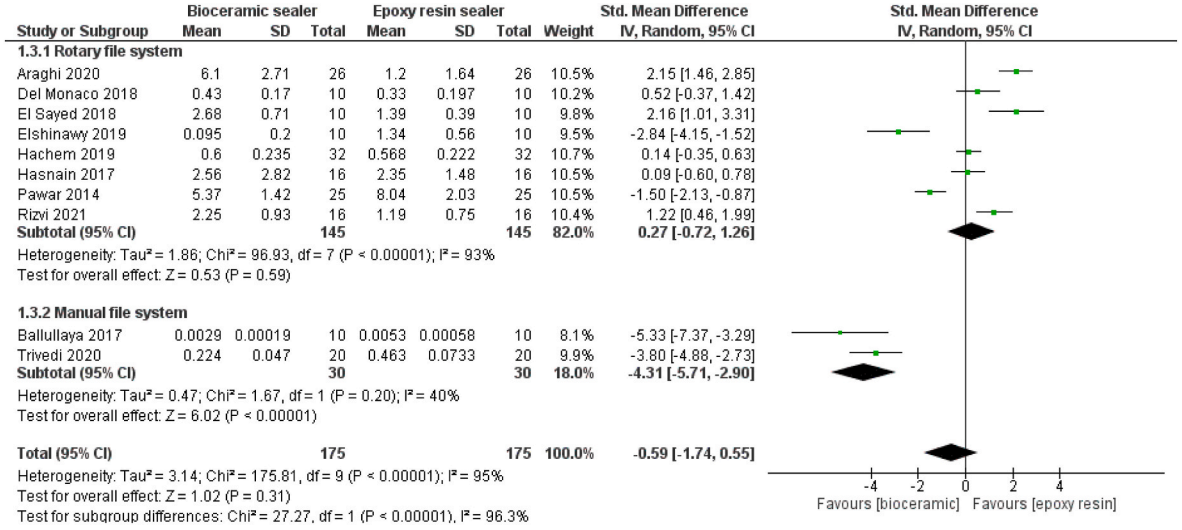

Fig. 4. Comparison of microleakage between bioceramic and epoxy-resin sealer based on file system employed.

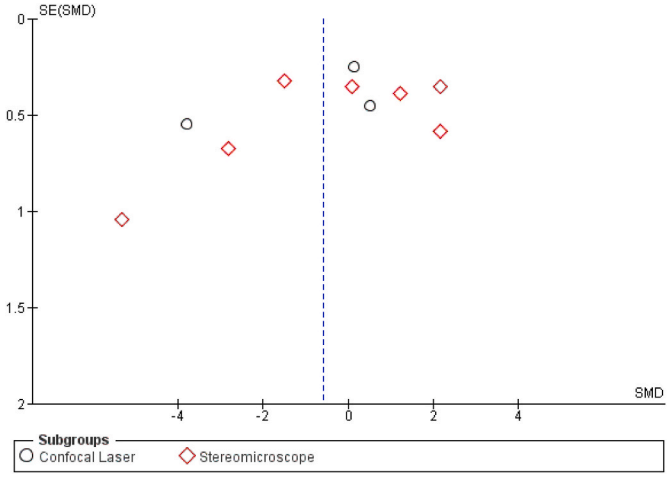

Fig. 5. Funnel plot of included studies.

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.[3]

In terms of the dentin sealer gap, three studies[23,27,37] 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.[37]

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 sub-group 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.

5. Clinical significance

The root canal system must be kept hermetically 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 JI, Bakland LK, Baumgartner JC. *Ingle's Endodontics 6*. BC Decker; 2008:1588.
2 Suresh Chandra B, Gopikrishna V. *Grossman's Endodontic Practice*. thirteenth ed. India: Wolters Kluwer; 1991:576.
3 Cohen S, Burns RC. *Pathways of the Pulp*. Mosby; 2002:1080.
4 Fisher MA, Berzins DW, Bahcall JK. An in vitro comparison of bond strength of various obturation materials to root canal dentin using a push-out test design. *J Endod*. 2007 Jul;33(7):856–858.
5 Hergt A, Wiegand A, Hülsmann M, Rödig T. AH Plus root canal sealer – an updated literature review. *Endodontic Practice Today*. 2015;9(4):245–265.
6 McMichen FRS, Pearson G, Rahbaran S, Gulabivala K. A comparative study of selected physical properties of five root-canal sealers. *Int Endod J*. 2003 Sep;36(9):629–635.
7 Leonardo MR, da Silva LA, Tanomaru Filho M, Bonifácio KC, Ito IY. In vitro evaluation of antimicrobial activity of sealers and pastes used in endodontics. *J Endod*. 2000 Jul;26(7):391–394.
8 Ricucci D, Rôças IN, Alves FRF, Loghin S, Siqueira JF. Apically extruded sealers: fate and influence on treatment outcome. *J Endod*. 2016 Feb;42(2):243–249.
9 Shokouhinejad N, Gorjestani H, Nasseh AA, Hoseini A, Mohammadi M, Shamshiri AR. Push-out bond strength of gutta-percha with a new bioceramic sealer in the presence or absence of smear layer. *Aust Endod J*. 2013 Dec;39(3):102–106.
10 Zhou H, Shen Y, Zheng W, Li L, Zheng Y, Haapasalo M. Physical properties of 5 root canal sealers. *J Endod*. 2013 Oct;39(10):1281–1286.
11 Candeiro GT de M, Correia FC, Duarte MAH, Ribeiro-Siqueira DC, Gavini G. Evaluation of radiopacity, pH, release of calcium ions, and flow of a bioceramic root canal sealer. *J Endod*. 2012 Jun;38(6):842–845.
12 Araghi S, Mirzaee SS, Soltani P, Miri S, Miri M. The effect of calcium hydroxide on the apical microleakage of canals filled with bioceramic and resin sealers. *Giornale Italiano di Endodonzia [Internet]*; 2020 Oct 26 [cited 2021 May 13];34(2). Available from: http://www.giornaleitalianoendodonzia.it/index.php/gie/article/view/164.
13 Mohamed El Sayed MAA, Al Husseini H. Apical dye leakage of two single-cone root canal core materials (hydrophilic core material and gutta-percha) sealed by different types of endodontic sealers: an in vitro study. *J Conserv Dent*. 2018 Apr;21(2):147–152.
14 Celikten B, Uzuntas CF, Orhan AI, 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):133–140.
15 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 Endodontic J*. 2021 Jan 1;11(1):66.
16 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.
17 Pawar SS, Pujar MA, Makandar SD. Evaluation of the apical sealing ability of bioceramic sealer, AH plus & epiphany: an in vitro study. *J Conserv Dent*. 2014;17(6):579–582.
18 AlShwaimi E, Bogari D, Ajaj R, Al-Shahrani S, Almas K, Majeed A. In vitro antimicrobial effectiveness of root canal sealers against Enterococcus faecalis: a systematic review. *J Endod*. 2016 Nov;42(11):1588–1597.
19 Huedo-Medina TB, Sánchez-Meca J, Marín-Martínez F, Botella J. Assessing heterogeneity in meta-analysis: Q statistic or I2 index? *Psychol Methods*. 2006 Jun;11(2):193–206.
20 Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med*. 2002 Jun 15;21(11):1539–1558.
21 Padmawar Neeta, Mopagar Viddyasagar, Vadvadgi Vinay, Mustilwar Rachita G, Joshi Saurabh, Pawar Neha. Comparative Evaluation of apical sealing ability of AH Plus, Endsequence RCS and Endorez as root canal sealers 0- an in-vitro study. *Int J Sci Res*. 2018;7(4):19–22.
22 Shinde A, Kokate S, Hegde V. Comparative assessment of apical sealing ability of three different endodontic sealers: a scanning electron microscopic study. *J Pierre Fauchard Acad (India)*. 2014 Sep 1;28(3):78–82.
23 Hegde VR, Arora NJ. Dentinal 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;32:76–80.
24 Ballullaya SV, Vinay V, Thumu J, Devalla S, Bollu IP, Balla S. Stereomicroscopic dye leakage measurement of six different root canal sealers. *J Clin Diagn Res*. 2017 Jun;11(6):ZC65–Z68.
25 Hasnain 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 Jan 1;29:146.
26 Hegde V, Arora S. Sealing ability of three hydrophilic single-cone obturation systems: an in vitroglucose leakage study. *Contemp Clin Dent*. 2015 Mar 1;6:S86–S89.
27 Mohammadian F, Farahanimastary F, Dibaji F, Kharazifard MJ. Scanning electron microscopic evaluation of the sealer-dentine interface of three sealers. *Iran Endod J*. 2017;12(1):38–42.
28 Melo T, Prado M, Hirata 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;17:1–8.
29 Jardim Del Monaco R, Tavares 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 Asawaworarit W, Pinyosopon T, Kijsamanmith K. Comparison of apical sealing ability of bioceramic sealer and epoxy resin-based sealer using the fluid filtration technique and scanning electron microscopy. *J Dent Sci*. 2020 Jun 1;15(2):186–192.
31 Tanompetsanga P, Tungsawat P. Comparison of microleakage between resin-based and bioceramic-based root canal sealers by fluid filtration technique. *Mo Dent J*. 2018;38(3):279–286.
32 Elshinawy M, Abdelaziz KM, Alqisi A, Khawshhal A, Al-Shari H, Alsalhi I. *Sealing Ability of Two Adhesive Sealers in Root Canals Prepared with Different Rotary File Systems*. vol. 16. 2019 Mar 24:21–24.
33 El Hachem R, Khalil I, Le Brun G, et al. Dentinal tubule penetration of AH Plus, BC Sealer and a novel tricalcium silicate sealer: a confocal laser scanning microscopy study. *Clin Oral Invest*. 2019 Apr;23(4):1871–1876.
34 Wang Y, Liu S, Dong Y. In vitro study of dentinal tubule penetration and filling quality of bioceramic sealer. *PLoS One*. 2018;13(2), e0192248.
35 Salem AS, Saleh ARM, Elmasmari HAA. In vitro assessment of apical leakage of bioceramic endodontic sealer with two obturation techniques. *Open Dent J*. 2018;12(1):1162–1168.
36 Eltair M, Pitchika V, Hickel R, Kühnisch J, Diegritz C. Evaluation of the interface between gutta-percha and two types of sealers using scanning electron microscopy (SEM). *Clin Oral Invest*. 2018 May;22(4):1631–1639.
37 Gyulbenkiyan Elvira, Gusiyska Angela, Vassileva Radosveta, Elena Dyulgerova. Scanning electron microscopic evaluation of the sealer/dentine interface of two sealers using two protocols of irrigation. *J IMAB*. 2020;26(1):2887–2891.
38 Rizvi Ramla. Evaluation of apical sealing ability of Bioceramic and AH plus root canal sealers, an in-vitro study. *J Liaquat Uni Med Health Sci*. 2021:1–8.
39 Shipper G, Ørstavik D, Teixeira FB, Trope M. An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon). *J Endod*. 2004 May;30(5):342–347.