Review Article

EFFICACY OF CALCIUM SILICATE-BASED SEALERS IN ROOT CANAL TREATMENT: A SYSTEMATIC REVIEW

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ABSTRACT

The purpose of this study was to assess the efficacy of calcium silicate-based sealers using a systematic review methodology. The literature search was done online, focusing on websites such as Google Scholar, Biomedical Central, Science Direct, Pub Med, CINAHL, and Medline. There is a need for future research to pay attention to these areas. The included sources need to be peer-reviewed journals. The articles should be reports arising out of primary research. The articles of priority were full-text articles. Sources of information published have to be within the last five years. The participants were patients with deep dental carriers who need root canal treatment. The intervention was calcium silicate-based sealers. The evaluation of 11 articles yielded several observations. Firstly, calcium silicate-based sealers are found to be viable alternatives to conventional sealers, albeit with a few weaknesses that should be considered. Secondly, the effectiveness of a particular calcium silicate-based sealer depends on the chemical formula. Thirdly, this efficacy can be best deduced from the lenses of two concepts: safety and versatility. The paper performed a systematic review to ascertain the efficacy of calcium silicate-based sealers. The research found that calcium silicate-based sealers are viable alternatives to conventional sealers. Therefore, the intervention has a high level of safety and versatility.

Key words: Calcium-based sealers, Efficacy, Dental caries, Systematic review, Root canal treatment.

Introduction

With the growing acknowledgment of health as a critical determinant of sustainable development, the stakeholders find themselves pressured to prioritize various underlying aspects. Oral health, especially teeth, lends itself to the subject as one of the areas that deserve attention. Indeed, statistics are documented and they affirm the problematic nature of the aspect. For instance, over 3.9 billion people across the world have oral health problems [1]. Tooth decay (dental caries) affects at least 44 percent of the global population, rendering it the most prevalent of all health conditions. It is estimated that at least 60 percent of the population of schoolchildren and 100 percent of adults across the world suffer from some level of tooth decay. The condition is often characterized by substantial discomfort and pain, in addition to eating and sleep disruption, chronic and acute infection, disfigurement, and reduced quality of life. It is also revealed that this health problem affects many other aspects of individual life, including self-esteem and sociability. Even more appalling, treating oral diseases, especially those affecting teeth, ranks fourth among the most expensive intervention processes in healthcare contexts. For example, at least US$110 billion in the United States is spent on oral care each year. In the European Union, annual health expenditure on oral health is over €79 billion, overshadowing the money spent on other troubling chronic conditions such as respiratory illnesses and cancer [1]. Overall, the problematic nature of the condition justifies the need to research evidence-based practices that would lessen the plight of affected patients. Calcium silicate presents itself as a new, potentially viable sealer, but its efficacy is yet to be effectively qualified. This paper conducts systematic research to ascertain the efficacy of calcium silicate-based sealers.

Literature review

The literature facing the subject is documented but it does not effectively resolve the underlying questions. Notwithstanding, it succeeds in providing the basis for conceptualizing the breadth of the topic while unearthing the controversies and gaps that help frame the underlying issues in a better way and justify the criticality of the research. Literature is laden with various themes that can be conveniently classified into three sections: nature of root canal treatment; types of sealers, merits and demerits; and conceptualizing cost-effectiveness/efficacy of the intervention.

Nature of root canal treatment procedure

The literature on root canal treatment describes it as a procedure with several steps that must be followed to deliver desired outcomes. Lokhande *et al*. (2019) particularly offer an elaborate description of the procedure, noting that the obturation begins with cleaning and removing all substrates from the canal [2]. This procedure is then followed by further sterilization and shaping the canal to create a logical cavity for effective filling. The canal is then filled with a

biocompatible material. The overall process of filling and sealing the canal cavity aims at avoiding further infection and associated propagation, a process broadly referred to as the root call obturation. The creation of fluid-tight seals on the apical foramen, followed by obliteration of the pulp space with aim of preventing fluid percolation into the canal, is particularly a critical step in the obturation process. This process is also important because it creates an enabling biological environment for the healing of the periapical tissues. The overall success of the endodontic treatment is the obturation that creates a fluid-tight seal. On the other hand, poor obturation is often accompanied by apical leakage, entry of microorganisms, and toxins, which negate the essence of treatment. Leakages can be so costly that they may warrant tooth removal. According to Kikly *et al*. (2020), to prevent this problem, the obturation of the root canal should involve the use of an appropriate sealer [3]. Overall, this discussion presents root canal treatment as a demanding and delicate process in which great care must be taken at every stage. However, particular emphasis is placed on the sealing process, which implies that the choice of sealing agent matters a great deal.

Types of sealers, merits, and demerits

A plethora of literature also covers types of sealers, merits, and demerits. In a nutshell, the topic is progressive, evidenced by researches and discoveries of new sealing agents, for which their efficacy must be assessed to qualify their viability. More elaborate, Lim *et al*. (2020) note epoxy resin-based sealers are currently the most popular, with the AH Plus formula taken as the gold standard [4]. Notwithstanding, this agent has several weaknesses such as cytotoxicity, inflammatory responses, hydrophobicity, and mutagenicity. Because of these weaknesses, several other alternative sealants, especially calcium silicate-based sealers, have been sought because of their relative hydrophilicity and biocompatibility. Nevertheless, choosing a particular sealer to use is not always straightforward, as several factors need to be considered. For instance, considering the hydrophilic conditions of the root canals, water solubility, and resorption are critical parameters of their stability. Sealers that display reduced micro-leakage but elevated push-out bond strength must also be able to withstand dynamic tooth conditions. In essence, while calcium silicate-based sealers are promising candidates, their efficacy is yet to be rigorously studied. In the same vein, Jafari and Jafari (2017) acknowledge that new generations of endodontic sealers, especially those based on calcium silicate such as EndoSequence BC, iRoot SP, MTA-Angelus, MTA Fillapex, Total Fill BC, Endo CPM, ProRoot Endo sealers, have been developed [5]. They are advantageous because of flowability and film thickness, but their property of high solubility remains an issue of concern. To this end, the literature review highlights that, whereas the breakthroughs leading to novel discoveries of alternative sealants are worth celebrating, it is still too early to conclude whether calcium silicate-based sealers must fully replace the conventional sealers. The merits of new sealers are largely debatable. There is a need to conduct a follow-up study to determine its relative efficacy.

Conceptualizing cost-effectiveness/efficacy of sealants

As can be inferred from the preceding section of the literature review, deducing the efficacy of a particular sealer is not simple, as several dimensions should be considered. Concerning efficacy, several concepts have been mentioned. These concepts include cytotoxicity, inflammatory responses, hydrophobicity, mutagenicity, hydrophilicity, biocompatibility, flowability, and film thickness [4, 5]. An objective conceptualization of these concepts creates an allowance to argue that, as far as efficacy is concerned, what particularly matters is the relative utility of a particular sealer judged from various conventional indicators of desired treatment outcomes, such as the ability to:

- Optimize health outcomes such as improved quality of life, reduced pain, and patient satisfaction with care;
- Minimize harm and risks of complications related to the procedure;
- Reduced costs of condition management in the short and long-term.

Aim of the study

The study aims to ascertain the efficacy of calcium silicate-based sealers and make related recommendations to practice. To accomplish this aim, several objectives are considered.

Objectives

- Does the use of calcium-silicate-based sealers result in quality care outcomes in patients in a randomized controlled trial compared to the alternatives?
- Does the use of calcium-silicate-based sealer procedure reduce the harm and risks of complications in patients in a randomized controlled trial compared to the alternatives?
- Does the use of calcium-silicate-based sealers have short and long-term cost-effectiveness in patients in randomized controlled trials compared to the alternatives?

Materials and Methods

The literature search was done online. The search strategy was guided by the objectives. The following pairs of keywords were used.

1. Calcium-silicate-based sealers, the impact of the quality of care outcomes, quality of life, reduced pain, patient satisfaction.
2. Calcium-silicate-based sealers, harm, risks, comparison.
3. Calcium-silicate-based sealers, cost-effectiveness, comparison.
4. Calcium-silicate-based sealers, efficacy, comparison.
5. Epoxy resin-based sealers, calcium-silicate-based sealers, comparison.

The search words were entered into search engines of Google and other websites such as Google Scholar,

Biomedical Central, Science Direct, Pub Med, CINAHL, and Medline. The number of targeted articles was 100. It was anticipated that the search would yield many sources with different characteristics, some of which may diminish the validity and reliability of the research if considered for review. In this regard, the inclusion and exclusion criterion was developed to guide the process of identifying valid sources of information. It was centered on the following rules:

i. The included sources need to be peer-reviewed journals. Other common sources of information such as trade publications, magazines, blogs, and newspapers were not considered for review.
ii. The articles should be reports arising out of primary research. Systematic reviews were excluded. The scope of designs was open to cover quantitative and qualitative studies. Theoretical discussions and general discussion sources such as books were excluded, too.
iii. The articles of priority were full-text articles. Abstracts and summaries were excluded.
iv. Sources of information published within the last five years (2016, 2017, 2018, 2019, and 2020) were prioritized. Articles published earlier than 2016 were excluded.

Cochrane risk of bias assessment

According to the Cochrane Risk of Bias Assessment Table (Appendix C), the chosen studies did not have performance bias/blinding (participants and personnel) and detection bias/ blinding (outcome assessment). However, all the studies had a low risk for attrition bias/ incomplete outcome data [6-14]. Additionally, concerning the selection biases like random sequence generation and allocation concealment, **Table 1** indicates that the studies had low risk. The same low risk was also witnessed for reporting bias such as selective reporting.

Table 1. Cochrane Risk of Bias Assessment

	Performance bias/Blinding (participants and personnel)	**Detection bias/ Blinding (outcome assessment)**	**Attrition bias/ incomplete outcome data**	**Selection bias/ Random sequence generation**	**Selection bias/ Allocation concealment**	**Reporting bias/Selective reporting**
Kharouf *et al*. (2020)	-	-	Low risk	Low risk	Low risk	Low risk
Zaki *et al*. (2018)	-	-	Low risk	Low risk	Low risk	Low risk
Lozano *et al*. (2017)	-	-	Low risk	Low risk	Low risk	Low risk
Lee *et al*. (2019)	-	-	Low risk	Low risk	Low risk	Low risk
Tanomaru-Filho *et al*. (2020)	-	-	Low risk	Low risk	Low risk	Low risk
Tek & Turker (2020)	-	-	Low risk	Low risk	Low risk	Low risk
Reszka *et al*. (2016)	-	-	Low risk	Low risk	Low risk	Low risk
Sungur *et al*. (2016)	-	-	Low risk	Low risk	Low risk	Low risk
Mendes *et al*. (2018)	-	-	Low risk	Low risk	Low risk	Low risk

Results and Discussion

Overall, the research generated 100 articles. However, 45 articles were found to be non-peer-reviewed and excluded. Out of the remaining 55, 20 articles were found to be report research arising out of second research such as systematic or Cochrane reviews. Therefore, they were excluded. A further evaluation revealed that out of the 25 remaining articles, 13 had been published before 2016. Upon exclusion on this basis, 11 articles were finally considered for review **(Figure 1)**.

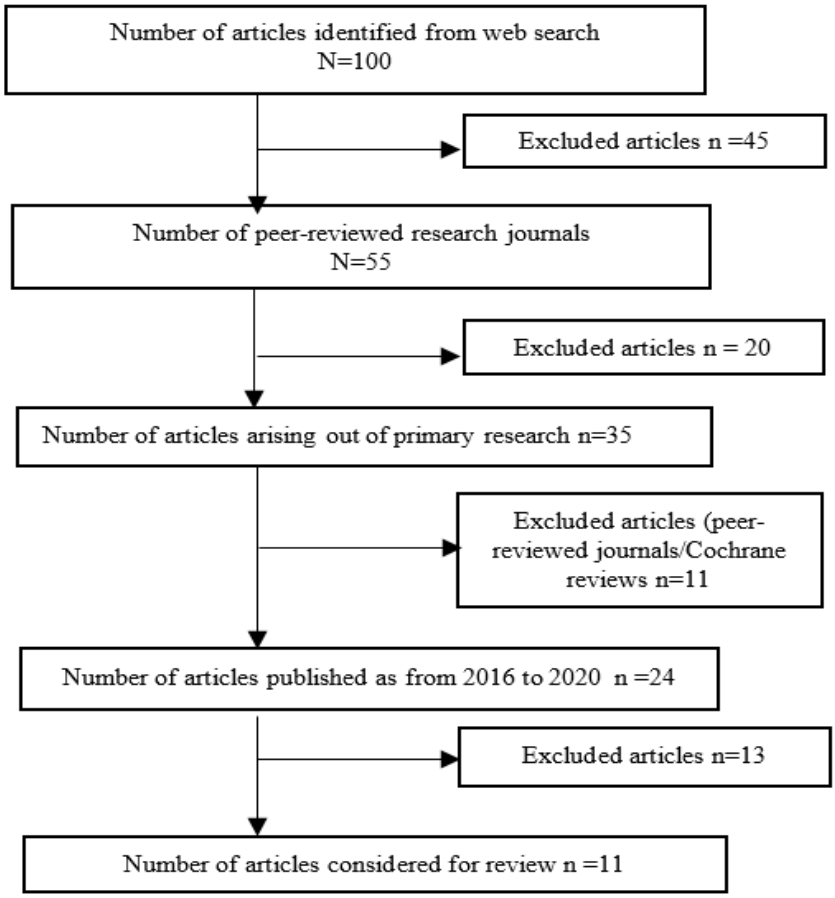

Figure 1. PRISMA Flow Chart

Table 2. Study findings

Author/s/ Citation	Aim	Type of Study	Methodology	Data Analysis	Findings	Conclusion
Kharouf *et al.* (2020)	To assess the physical and chemical properties, filling ability, and antibacterial property of a premixed calcium silicate-based sealer (CA) compared to powder–liquid bioceramic sealer (BS)	Randomized controlled trial experiment	Ceraseal (CS) and BioRoot (BR) materials were prepared in line with the industrial standards and subjected to laboratory analysis	One-way variance analysis	A significantly lower percentage of voids were found on calcium silicate compared to bio-ceramic sealers. Meanwhile, bio-ceramic sealers were characterized by a higher PH, lower flowability, rough surface, reduced water contact values, and higher solubility. However, the responses to compressive strength were found to be comparable. Finally, there was no evident antibacterial effect for both sealers after 3 hours. However, after 24 and 72 hours, bioceramic sealers posted a higher antibacterial activity.	Kharouf *et al.* (2020) conclude that bioceramic sealers can be effective in controlling bacterial growth. However, calcium silicate sealers tend to have superior properties concerning filing and lower solubility
Zaki *et al.* (2018)	To evaluate the periapical healing process following the use of calcium silicate healers compared to calcium-hydroxide sealers	Randomized controlled trial experiment	The study used a sample of 70 two upper premolars root canals obtained from six dogs. These teeth were assigned to different treatment groups.	ANOVA and Mann–Whitney U tests	The study was unable to find statistically significant differences in peri-apical inflammatory infiltrates and mineralization scores between the treatment groups subjected to the calcium silicate and calcium-hydroxide sealers. Although calcium silicate sealers showed quick healing, this rate was not statistically significant.	Zaki *et al.* (2018) concluded that both calcium silicate healers and calcium-hydroxide are effective in promoting peri-apical healing in equal measure.

Lozano *et al.* (2017)	To examine the calcium silicate (MTA Fillapex and BC TotalFill) sealers) sealers' cytocompatibility nature in comparison with epoxy resin-based sealer (AH Plus), focusing on the responses of assayed human ligament stem cells.	Randomized controlled trial experiment	Assayed human periodontal ligament stem cells were prepared and randomly assigned to different treatment groups	One-way analysis of variance (ANOVA)	The assayed human periodontal ligament stem cells showed high proliferation rates when exposed to TotalFill BC Sealer eluates than when exposed to AH Plus and MTA Fillapex. Also, the cytotoxicity of TotalFill BC was relatively limited when compared to AH Plus and MTA Fillapex	Different sealers have particular levels of cytocompatibility. TotalFill BC presents itself as the most cytocompatible sealer, rivaling AH Plus and MTA Fillapex sealers.
Lee *et al.* (2019)	To examine the impact of calcium silicate-based sealers (EndoSeal MTA, Nano-ceramic Sealer, and Wellroot ST) on tissue inflammation, cell viability, and osteogenic potentials, in comparison with epoxy resin-based sealers (AH-Plus, AD Seal)	Randomized controlled trial experiment	Assayed human periodontal ligament stem cells were prepared and randomly assigned to different treatment groups.	One-way analysis of variance (ANOVA)	The study reports AH-Plus recorded the lowest cell viability in fresh media. However, in the set media, there were quantifiable differences in the impact on cell viability. Well root ST posted the highest levels of cell adhesion and morphology and elevated expressions of IL-6 and IL-8. AD Seal, together with all the calcium silicate sealers, evidenced high expressions of mesenchymal stem cell markers. Finally, the expression of ALP mRNA was particularly marked for all the cases in which the studied calcium silicate-based sealers were applied.	Lee *et al*. (2019) concluded that calcium silicate-based sealers tend to be more biocompatible than other forms of sealers such as epoxy resin-based. However, follow-up research using in vivo methods is needed to validate the findings.
Tanomaru-Filho *et al.* (2020)	To assess the filing, apical extrusion and flow abilities of calcium silicate-based sealers (Bio-C Sealer, Sealer Plus BC, and Neo MTA Plus) compared to epoxy resin (AH Plus) sealer.	Randomized controlled trial experiment	The evaluation of the flow was based on the ISO 6876/2012 standard. The analysis entailed calculating the percentage of voids and the apical extrusion of the sealers.	ANOVA	The findings showed Bio-C sealers had the highest flow, while NeoMTA had the lowest. Meanwhile, AH Plus registered the highest percentage of voids compared to Plus BC and Bio-C sealers.	Plus BC and Bio-C sealers have high flow and desired filling ability. However, they have high volumes of apical extrusion. In contrast, while NeoMTA Plus post less sealer extrusion, it is characterized by reduced flows and more voids. These strengths and weaknesses should inform the choice of sealers to use.
Tek & Turker (2020)	To examine the obturation properties of sealers MTA, Biodentine, Total Fill BC compared with warm gutta-percha (WGP).	Randomized controlled trial experiment	40 extracted maxillary central incisor teeth were obtained and randomly assigned to different treatment groups and assessed using micro-computed tomography.	ANOVA	The results showed that Total Fill BC sealers in the bulk-fill form had the highest void percentages. Biodentine had the lowest percentage of voids. Meanwhile, a combination of WGP and Total Fill BC RCS recorded the lowest percentage of voids compared to other types of sealers but did not overshadow biodentine.	The study concludes that it is not possible yet to have void-free sealers. Notwithstanding, biodentine lends itself to the obturation process as the most effective sealer for dealing with voids.

Reszka *et al.* (2016)	To study the chemical properties of calcium silicate-based sealers (BioRootRCS and Well-Root ST) in comparison with MTA Fillapex, and epoxy resin-based sealers.	Randomized controlled trial experiment	Sealers were prepared based on the instructions of the manufacturers. These sealers were then packed in cylindrical molds, placed in an incubator, and studied after 73 hours using an electron microscope and x-ray analyses.	ANOVA	Bioroot RCS and Well-Root ST sealers recorded high peaks of calcium, zirconium, oxygen, carbon, silicon, and chlorine. Besides, Well-Root ST was also characterized by titanium, sodium, magnesium, and aluminum peaks. The MTA Fillapex sealer showed the silicon peak, while AHPlus was defined by tungsten and zirconium peaks.	The study concluded that BioRoot RSC was purer than other sealers. Other sealers had a high degree of potentially poisonous metals that need to be further researched.
Sungur *et al.* (2016)	To compare the sealing properties of epoxy, calcium silicate-based, and methacrylate resin-based sealers of root fillings derived from the single-cone technique.	Randomized controlled trial	The study involved the extraction of 8 human teeth. These specimens were randomly assigned to different treatment groups	Kruskal-Wallis and Mann-Whitney U test	Root fillings of epoxy and methacrylate-based sealer treatment were found to be equally effective.	Fluid transport significantly varies with the type of sealer used. However, root fillings treated with epoxy or methacrylate-based sealers tend to be more effective.
Mendes *et al.* (2018)	To assess the physical and chemical behaviors of calcium silicate-based sealer in comparison with epoxy-resin sealer	Randomized controlled trial	The study assessed PH and the release rates of calcium. The sealers were first placed in polyethylene tubes and then immersed in de-ionized water.	variance analysis, Student-T and Tukey tests	Compared to AH Plus, Sealer Plus BC had the highest calcium ion release rate. Meanwhile, bioceramic sealer showed some level of radioactivity, but lower setting time and flow.	Sealer BC registered the desired physicochemical properties but had inferior solubility rates.

A look at the included studies presents calcium silicate-based sealers as viable alternatives to the conventional sealers, albeit with a few weaknesses that should be considered. Moreover, much of the derivative findings reveal that the effectiveness of a particular calcium silicate-based sealer depends on the formula. This effectiveness can be best deduced from the lenses of two concepts: Safety and versatility. These concepts are discussed in the sections below.

Safety

In this case, safety refers to the ability of a sealer to minimize harm to the patient. It is one of the markers of quality intervention. The reviewed studies examine the issue of the safety of calcium silicate-based sealers from different perspectives.

In one way, this safety is assessed in terms of peri-apical healing rates. For example, a study by Zaki *et al*. (2018) sought to evaluate the periapical healing process following the use of calcium silicate healers compared to calcium-hydroxide sealers [7]. The study was unable to find statistically significant differences in peri-apical inflammatory infiltrates and mineralization scores between the treatment groups subjected to the calcium silicate and calcium-hydroxide sealers. Although calcium silicate sealers showed quick healing, this rate was not statistically significant. The researchers concluded that both calcium silicate healers and calcium-hydroxide are effective in promoting periapical healing in equal measure **(Table 2)**.

The safety is also assessed in terms of cytocompatibility. This focus is seen in a study by Lozano *et al*. (2017), which sought to examine the calcium silicate (MTA Fillapex and BC TotalFill) sealers' cytocompatibility nature vs [8]. epoxy resin-based sealer (AH Plus), focusing on the responses of assayed human ligament stem cells. According to the findings, the assayed human periodontal ligament stem cells showed higher proliferation rates when exposed to TotalFill BC Sealer eluates than when exposed to AH Plus and MTA Fillapex. Besides, the cytotoxicity of TotalFill BC was relatively limited when compared to AH Plus and MTA Fillapex. Consequently, it was concluded that different sealers have particular levels of cytocompatibility. Notwithstanding, TotalFill BC presented itself as the most cytocompatible sealer, rivaling AH Plus and MTA Fillapex sealers.

Another study investigating safety based on the dimension of cell compatibility is Lee *et al*. (2019) [9]. This study examined the impact of calcium silicate-based sealers (EndoSeal MTA, Nano-ceramic Sealer, and Wellroot ST) on

tissue inflammation, cell viability, and osteogenic effects, in comparison to epoxy resin-based sealers (AH-Plus, AD Seal). The research found that AH-Plus recorded the lowest cell viability in fresh media. However, in the set media, there were quantifiable differences in the impact on cell viability. Wellroot ST posted the highest levels of cell adhesion and morphology and elevated expressions of IL-6 and IL-8. AD Seal, together with all the calcium silicate sealers, posted high expressions of mesenchymal stem cell markers. Finally, the expression of ALP mRNA was particularly marked for all the cases in which the studied calcium silicate-based sealers were applied. In their conclusion, Lee *et al*. (2019) affirmed that calcium silicate-based sealers tend to be more biocompatible than other forms of sealers such as epoxy resin-based **(Table 2)** [9].

Safety has also been examined from the lenses of constituting substances. In particular, Reszka *et al*. (2016) examined the chemical composition of calcium silicate-based sealers (BioRootRCS and Well-Root ST) in comparison with MTA Fillapex and epoxy resin-based sealers [12]. Their findings indicated that Bioroot RCS and Well-Root ST sealers recorded high peaks of calcium, zirconium, oxygen, carbon, silicon, and chlorine. Well-Root ST was also characterized by titanium, sodium, magnesium, and aluminum peaks. The MTA Fillapex sealer showed the silicon peak, while AHPlus was defined by tungsten and zirconium peaks. The study concluded that BioRoot RSC was purer than other sealers. Other sealers had a high degree of potentially poisonous metals that need to be checked.

Versatility

In this case, versatility refers to the ability of sealers to withstand various physical and chemical processes. The more versatile a sealer is, the more desired the outcomes of dental treatment is, as the patient will not have to visit the dentists. A great deal of the featured studies assessed the relative versatility of the calcium silicate-based sealers, focusing on an array of physical and chemical properties.

One such study is by Kharouf *et al*. (2020), which sought to assess the physical and chemical properties, filling ability, and antibacterial property of a premixed calcium silicate-based sealer (CA) compared to powder–liquid bioceramic sealer (BS) [6]. This study reported that a significantly lower percentage of voids were found on calcium silicate-based sealers compared to bio-ceramic types. Meanwhile, bio-ceramic sealers were characterized by a higher PH, lower flowability, rough surface, reduced water contact values, and higher solubility. However, the responses to compressive strength for all sealers were found to be comparable. Finally, there was no evident antibacterial effect for both sealers after 3 hours. However, after 24 and 72 hours, bioceramic sealers posted a higher antibacterial activity. The study concluded that bioceramic sealers can be effective in controlling bacterial growth. However, calcium silicate sealers tend to have superior properties concerning filing and lower solubility.

The versatility of sealers is also examined based on metrics such as apical extrusion and flow abilities, in addition to the number of voids. For instance, Tanomaru-Filho *et al*. (2020) sought to research the filing, apical extrusion and flow abilities of calcium silicate-based sealers (Bio-C Sealer, Sealer Plus BC, and Neo MTA Plus) compared to epoxy resin (AH Plus) sealers [10]. Their findings showed that Bio-C sealers had the highest flow, while NeoMTA had the lowest. Meanwhile, AH Plus registered the highest percentage of voids compared to Plus BC and Bio-C sealers. In their conclusion, they laud Plus BC and Bio-C sealers as having high flow and desired filling ability. However, they fault them for having high volumes of apical extrusion, suggesting the need to first consider which properties ought to be prioritized when using these sealers.

In the same vein, Tek and Turker (2020) examined the obturation properties of sealers MTA, Biodentine, Total Fill BC compared with warm gutta-percha (WGP) [11]. The derivative results showed that Total Fill BC sealers applied in its bulk-fill form had the highest void percentages. In contrast, Biodentine had the lowest percentage of voids. Meanwhile, a combination of WGP and Total Fill BC RCS recorded the lowest percentage of voids compared to other types of sealers but did not overshadow biodentine. The study concluded that while it is not possible yet to have a perfect sealer, biodentine lends itself to the obturation process as the most promising agent for dealing with voids.

Meanwhile, Sungur *et al*. (2016) sought to compare the sealing properties of epoxy, calcium silicate-based, and methacrylate resin-based sealers of root fillings derived from the single-cone technique [13]. They find that the effectiveness of root fillings subjected to epoxy and methacrylate-based sealer treatment were comparable. Finally, Mendes *et al*. (2018) sought to assess the physical and chemical behaviors of calcium silicate-based sealer in comparison with epoxy-resin sealer [14]. The research focused on properties such as PH and ion release rates. Their study concluded that compared to AH Plus, Sealer Plus BC had the highest calcium ion release rate. Meanwhile, bioceramic sealer showed some level of radioactivity, but lower setting time and flow.

Missing links/weaknesses

Although the included articles are articulate on the merits and demerits of calcium silicate-based sealers compared to other alternatives, various areas remain addressed. As a result, it is not yet possible to confidently qualify the efficacy of this sealer. To begin with, many of these studies are in vitro. There is a need for in vivo studies to ascertain the extent to which the findings can be generalized. Secondly, there is a lack of studies addressing cost-effectiveness, pain, and patient satisfaction directly. All cannot be directly satisfied by the versatility and safety-focused studies.

Limitations

Concerning the outcome level, the patient population in the meta-analysis is not the same across the studies. The quality

of the studies also varied as randomization was not adequate in all trials. Some of the observed effects might be explained by publication and reporting bias. Smaller trials are analyzed with less methodological vigor compared to larger studies.

Conclusion

In conclusion, this paper aimed to conduct a systematic review to ascertain the efficacy of calcium silicate-based sealers. The review is done at the backdrop of the concern that, although calcium silicate presents itself as a potentially viable sealer, its efficacy is yet to be effectively qualified. The literature search was done online, considering websites such as Google Scholar, Biomedical Central, Science Direct, Pub Med, CINAHL, and Medline. Upon subjection to inclusion and exclusion criteria, 11 articles were considered for review. The assessment of these articles presents several outstanding themes. Firstly, calcium silicate-based sealers are viable alternatives to conventional sealers, albeit with a few weaknesses that should be considered. Secondly, the effectiveness of particular calcium silicate-based sealers depends on their chemical formula. Thirdly, this effect can be best deduced from the lenses of two concepts: safety and versatility.

Recommendations for future studies

Despite the reported positive findings lauding calcium silicate-based sealers, many of these studies are in vitro. Secondly, the studies addressing cost-effectiveness, pain, and patient satisfaction directly are lacking. There is a need for future studies to address these weaknesses. The funding is needed from the government research training program scholarships and other private and public institutions to support the research.

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