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Clinical utility properties of new endodontic silicate-based sealers: a systematic review

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ABSTRACT

Introduction: Filling in the root canal system plays a key role in the success of endodontic treatment. New silicate-based sealers have recently been introduced on the market to improve the properties of sealers used in these treatments. Before performing endodontic treatment, it is always useful to know the properties of different sealers.

Objectives: The aim of this study was to review the literature and compare the clinically useful properties of new silicate-based sealers with those of conventional epoxy resin-based cements.

Methods: After establishing the adapted research question, a literature review was carried out in two databases (Medline via Pubmed and Wiley Library via Cochrane Library) combining MeSH (Medical Subject Headings) and free terms. A manual electronic search was also performed. The clinically useful properties selected were discolouration, sealing capacity, radiopacity, setting time and solubility.

Results: Of the 224 potential studies obtained, 20 were selected for reading of the full text. Another 4 studies were selected after manual electronic searching of which 2 were excluded, leaving 22 studies for inclusion in the review. The following physical properties were analysed: 2 for tooth discolouration; 4 for sealing ability; 11 for radiopacity; 9 for setting time; and 12 for solubility; 9 of the articles evaluated several properties.

Conclusions: No differences in tooth discolouration were observed between silicate-based and resin sealers. No differences in sealing ability were observed in most of the studies consulted. All sealers analysed showed radiopacity values within the recommended standards. Both setting time and solubility depended on the type of sealer; with some of the silicate-based sealers having higher solubility than the resin-based.

KEYWORDS

Sealing; Endodontic sealers; Bioceramic sealers; Resin sealers.

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INTRODUCTION

After shaping and cleaning the route canal system, complete sealing is needed for success in endodontic treatment[1]. The materials used regularly for sealing are gutta-percha and sealing cements[2]. Sealing cements are substances capable of penetrating between the sealer material and root canals[3]. There are different types on the market, however, despite having many of the properties described by Grossman, they do not have them all[4]. They can be classified according to their main components[5]: Zinc oxide eugenol, calcium hydroxide, glass ionomer, silicone, resin and bioceramic cements[6].

Currently, those composed of resins are used most, with the epoxy resin cement AH Plus™, being considered the Gold Standard[3,7]. However, this cement has a series of limitations, which are possible cytotoxicity, mutagenicity and inflammatory response[8]. Another limitation is its lack of bioactive properties[9]. Therefore, new types of sealant called bioceramic cements[10] have recently arrived on the market. These cements are based on the biological properties of MTA[11] and include calcium silicates, phosphates and hydroxide as well as zirconium oxide as a radiopacifier[12]. The development of bioceramic cements has been based on obtaining good biocompatibility; however, these cements must also have adequate physical properties[4].

One of the issues that has gained importance in recent years is aesthetics[7]. The aesthetic result of root canal treatment is important, especially in the anterior region[13], as some remains of sealant cement can be left behind, despite the access cavity being adequately prepared and cleaned with alcohol[14]. Sealing capacity is another property of new sealant cements considered important[5]. The dimensional changes of the root canal system, and the lack of adhesion of gutta-percha, make a complete seal necessary to obtain. Thus, adaptation of the sealant cement is a factor that influences the microfiltration and reinfection of the root canal system[15]. Another property considered essential is radiopacity, as it means clinicians can distinguish between the materials used and adjacent anatomical structures[16], as well as evaluate the quality of the root canal filling[17].

Another physical property the clinician must take into account is setting time. Slow or incomplete setting can lead to greater tissue irritation[18], while too short a setting time can reduce working time by complicating and interfering with the sealing process[19]. Therefore, the setting time must be long enough to allow easy handling, especially for sealing techniques that require more time[20]. Solubility is another property that has special relevance when evaluating sealant cements[21]. Dissolution of the sealant cement can interfere with the quality of the root canal treatment and trigger an inflammatory response of the periapical tissues[21,22]. There may also be a vacuum between the sealer material and the root canal, increasing infiltration over time[21]. Therefore, sealant cements have low solubility[22].

It is important to know the physical properties of the different resin based cements on the market. The objective of this systematic review was to analyse the scientific evidence behind the different properties of clinical significance of silicate-based sealants - such as dental discoloration, sealing capacity, radiopacity, setting time and solubility - and compare them with conventional resin cements.

MATERIAL AND METHODS

Considering the non-clinical nature of studies in the bibliography, the following PICO research question was applied to carry out this review: *Do silicate-based cements have better properties of discolouration, sealing, radiopacity and solubility compared with conventional epoxy resin-based cements in teeth or samples?* (see Figure).

The bibliographic search was carried out in the Medline databases via Pubmed and the Wiley Online Library via the Cochrane Library. MeSH terms (Medical Subject Headings) were combined with free terms, in single or multiple combinations using Boolean operators. In vitro studies published between 2015 and 2021 were included. The last search was performed on January 31, 2021. Studies that evaluated cements that were not marketed or with changes in the composition of marketed cements were excluded. Studies comparing changes in physical properties or sealing techniques were also excluded. The search equations used applied in the English language are described in Table 1. In addition, a manual electronic search was carried out in the Journal of Endodontics, International Journal of Endodontics, Australian Endodontic Journal and Iranian Endodontic Journal.

A preliminary selection of the articles made by title and abstract was then done. Duplicate articles were discarded. Full-text articles were then obtained, excluding articles that did not meet the established criteria. Manually selected articles were added and those that did not meet the established criteria were excluded. The selected articles were grouped according to the property analysed. Those articles that analysed more than one property were identified and included in the corresponding groups. Taking into account the nature of the review, the properties of the studies were summarised descriptively.

RESULTS

The article selection flowchart is seen in the Figure. The initial search provided 224 studies with no duplicate articles found. After evaluating the study titles and abstracts in the initial search, 204 studies were excluded as they did not meet the inclusion criteria, leaving 20 studies for reading of the full text. To these were added 4 studies obtained via a manual electronic search. After reviewing the full text of the 24 studies, 2 were excluded for not including a comparative epoxy resin group[23,24]. Therefore, the final number of articles included in the literature review for data extraction was 22. These studies were grouped according to the property analysed (Table 2): 2 discolouration (A); 4 sealing capacity (B); 11 radiopacity (C); 9 setting time (D); and 12 solubility (E). 9 articles analysed various properties.

DISCUSSION

The selected articles evaluated different physical properties of the new silicate-based endodontic sealant cements. Standardised methodologies had to be established to evaluate the different cement properties so the results could be reproduced and reliable comparisons of the data made[19].

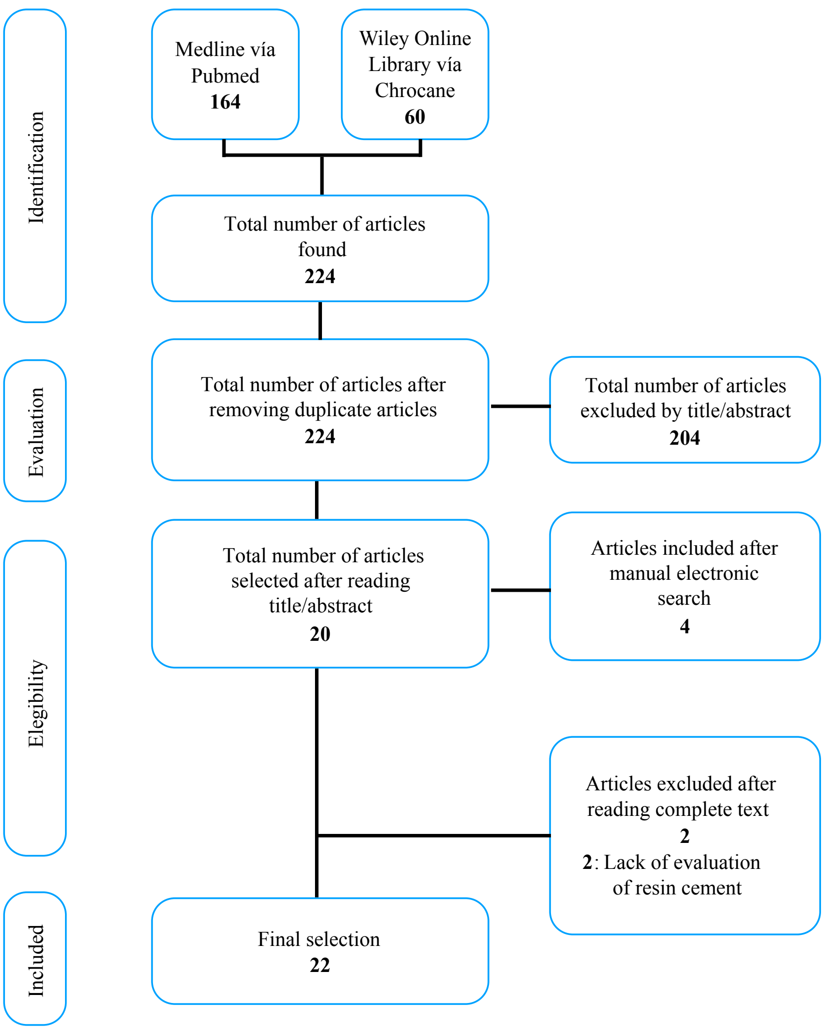

Figure. Flow diagram of study selection process.

Discolouration of dental tissue

The studies that looked at discoloration evaluated the same resin-based cement, AH Plus™[7,14]. However, they evaluated different silicate-based cements, including Endo-Seal™[14], MTA Fillapex™ and iRoot™ SP[7]. They evaluated the discolouration of 100 teeth between both studies, using both bovine[14] and human[7] teeth. Both studies used CIE-Lab system spectrophotometry to evaluate the discolouration, applying different evaluation periods: 0-2 months[14] and 0-6 months[7].

The results obtained in the two studies showed no significant differences in discolouration between the cements analysed and the AH Plus™ resin-based cement. However, Forghani et al.[7] observed a progressive discolouration of all cements during the first 3 months after placement, with a tendency to decrease during the second trimester and up to the 6th month of evaluation.

Sealing capacity

There were 4 studies that evaluated the sealing of the new silicate-based cements[5,15,25,26]. One study evaluated BioRoot™ RCS[5], two analysed Endosequence™ BC Sealer[15,25] and one studied iRoot™ SP[26]. All studies compared with AH Plus™ resin cement.

No differences were found in the sealing capacity between silicate-based and epoxy resin-based cements in 3 of the studies[5,15,26]. However, Endosequence™ BC Sealer silicate-based cement was considered better than epoxy resin cement in one of the studies[25].

Radiopacity

There were 11 silicate-based cement studies[9,16,17,19,20,27-32] that compared the radiopacity with epoxy resin-based cements. The silicate-based cements analysed were: EndoSequence™ BC Sealer[16], EndoSeal™ MTA[16,28], TotalFill™ BC Sealer[9,30], BioRoot™ RCS[20,29,31], MTA Fillapex™[16,20,31,32], Sealer Plus™ BC[17,19,27] and BioC™ Sealer[9]. All studies evaluated AH Plus™ epoxy resin-based cement. In addition, 2 studies also evaluated the epoxy resin-based cements ADSEAL™, Radic-Sealer™[16] and Sealer Plus™[32].

The American National Institute of Standards and the American Dental Association (ADA) establish a minimum radiopacity of 3.00 mm Al in their specification number 57 for the year 2000[33]. The standard established by the International Organisation for Standardisation (ISO) 6878 also specifies a radiopacity greater than or equal to or 3 mm Al[31]. All cements evaluated had radiopacity values within the recommended ISO standards.

In most studies, AH Plus™ cement had higher radiopacity values than the silicate-based cements BioRoot™ RCS[29,31], TotalFill™ BC[9,30], Bio-C™ Sealer[9], Endosequence™ BC Sealer[16], Sealer Plus™ BC[17,19,27], MTA Fillapex™[9,30,32] and Endoseal™[28]. However, other studies found no significant differences between AH Plus™ and BioRoot™ RC, MTA Fi- llapex™[20] and EndoSeal™ MTA[16]. In studies that also analysed other resin-based cements, the silica-based cements radiopacity results were similar. The MTA Fillapex™ had lower radiopacity than Sealer Plus™[9], Pulp Canal Sealer™[31], Radic-Sealer™ y AD Seal™[16] resin cements.

Similarly, the BioRoot™ RCS cement had a lower radiopacity than the Pulp Canal Sealer™[31]. Meanwhile, the Endosequence™ BC Sealer cement also had a lower

Table 1. Search equations.

Database	Evaluation
Medline (via Pubmed)	((Tooth [Mesh] OR specimen) AND/OR ("Epoxy Resins"[Mesh] OR tricalcium silicate endodontic sealer OR calcium-silicate based sealer) AND ("tooth discolouration"[Mesh] OR discolouration OR sealing OR radiopacity OR setting time OR solubility))
Cochrane	(MeSH descriptor: [Tooth] AND/OR MeSH descriptor: [Root Canal Filling Materials])

radiopacity than the Radic Sealer™. However, the Endosequence™ BC Sealer had a greater radiopacity than the AD Seal™[16].

When evaluating differences in the radiopacity of silicate-based cements, the results between studies differ depending on the cements analysed. One study observed greater radiopacity with MTA Fillapex™ than with BioRoot™ RCS[31]. However, no difference was found between either cement in another study[20], nor between Bio-C™ Sealer and TotalFill™ BC Sealer[9]. The only study that analysed 3 silicate-based cements[16] had different radiopacity values for the cements, with EndoSeal™ MTA being the highest, followed by Endosequence™ BC Sealer then MTA Fillapex™. The differences in radiopacity could be caused by the presence of different radiopacifying agents in the composition of the cements[16].

Setting time

The 9 selected studies[9,17-20,27,29,30,32] evaluated the setting time using needles inserted into the cement models, as established by the IS0 6876[19] ANSI/ADA 57[27] standard.

The following silicate-based cements were evaluated: BioRoot™ RCS[20,29]; Sealer Plus™[17,18,27]; TotalFill™ BC Sealer, Bio-C™ Sealer[9,18,30] and MTA Fillapex™[20,32]. In all studies, the setting time results of the silicate-based cements were compared with AH Plus™ epoxy resin cement. One study also analysed Sealer Plus™[32].

Two studies analysed the setting time of BioRoot™ RCS[20,29]. Both found that BioRoot™ RCS had a lower setting time than the resin-based cement AH Plus™[20,29]. In one of the two studies[20], they also evaluated the setting time of MTA Fillapex™ cement, which was completed after 1 week, the evaluation period established in the study. In another study, MTA Fillapex™ had a longer setting time than AH Plus™ and Sealer Plus™ cements™[32].

Three studies evaluated Sealer Plus™ BC[17,19,27] silicon-based cement. As with the results observed with BioRoot™ RCS cement, Sealer Plus™ BC also had a lower setting time than AH Plus™ epoxy resin cement[17,19,27]. Two studies[18,30] analysed TotalFill™ BC Sealer. In both, the setting time of the silicate-based cement was lower than that of AH Plus™. However, the two studies that analysed Bio-C™ Sealer cement differed in their results. One study had the AH Plus™ cement with a shorter working time than Bio-C™ Sealer[9], while the other study[18] had AH Plus™ epoxy resin-based cement with a longer setting time than Bio-C™ Sealer.

When analysing the setting time of silicate-based cements, one study[20] found no differences between BioRoot™ RCS and MTA Fillapex™ cements, while two studies found a shorter setting time for Bio-C™ Sealer with respect to the TotalFill™ BC Sealer[9,18]. In one of the studies[18], this cement did not set after the 25 days established under the study conditions.

Solubility

There were 12 articles that compared the solubility of sealant cements with epoxy resin cements[5,9,17,19,20,27,28,30,34-37].

The selected studies analysed silicate-based cements: BioRoot™ RCS[20,34,37]; MTA Fillapex™[20,32,34-37]; TotalFill™ BC Sealer[9,30,34]; Sealer Plus™ BC[17,19,27,33]; Bio-C™ Sealer[9] and Endoseal™[28]. All studies used AH Plus™ resin cement as the control group. Two articles analysed the properties of Obturys™[34] and Sealer Plus™[32]. Differences were observed between the different silicate-based cements and the evaluation periods, in relation to the resin-based cements. The BioRoot™ RCS cement had greater solubility than the AH Plus™[20,34,37] and Obturys™[34]. The Bio-C™ Sealer also had greater solubility than the AH Plus™[9]. Similarly, the TotalFill™ BC Sealer cement obtained greater solubility than the AH Plus™ resin cement in most of the periods analysed in the different studies[9,30,34]. However, in the first evaluation period of one study[34], no significant differences were observed between BioRoot™ RCS and the resin-based cements AH Plus™ and Obturys™. In most of the studies and periods analysed for MTA Fillapex™ cement, greater solubility was found compared to

Table 2. Review articles evaluating the sealant cement properties, (A) discolouration, (B) sealing, (C) radiopacity, (D) setting time and (E) solubility, according to the methodology described.

(A). Discolouration

Author/year	Evaluation	Silicate-based sealing cement	Resin-based sealing cement
Forghani et al.[7] (2016)	Discolouration	MTA Fillapex™ iRoot™ SP	AH Plus™
Lee et al.[14] (2016)	Discolouration	EndoSeal™ MTA	AH Plus™

(B). Sealing

Author/year	Evaluation	Silicate-based sealing cement	Resin-based sealing cement
Viapiana et al.[5] (2016)	Sealing	BioRoot RCS™	AH Plus™
Zhang et al.[26] (2017)	Sealing	iRoot™ SP	AH Plus™
Huang et al.[15] (2018)	Sealing	Endosequence™ BC Sealer	AH Plus™
Asawaworarit et al.[26] (2020)	Sealing	Endosequence™ BC Sealer	AH Plus™

(C). (C) Radiopacity

Author/year	Evaluation	Silicate-based sealing cement	Resin-based sealing cement
Lim et al.[27] (2015)	Radiopacity	EndoSeal™	AH Plus™
Khalil y cois.[29] (2016)	Radiopacity	BioRoot™ RCS	AH Plus™
Prüllage et al.[20] (2016)	Radiopacity	BioRoot RCS™, MTA Fillapex™	AH Plus™
Tanomaru-Filho et al.[28] (2017)	Radiopacity	TotalFill™ BC Sealer™	AH Plus™
Lee et al.[16] (2017)	Radiopacity	EndoSeal™ MTA, MTA Fillapex™, Endosequence™ BC Sealer	AH Plus™ ADSEAL™ Radic-Sealer™
Siboni et al.[30] (2017)	Radiopacity	BioRoot™ RCS, MTA Fillapex™	AH Plus™ Pulp Canal Sealer™
Mendes et al.[19] (2018)	Radiopacity	Sealer Plus™ BC	AH Plus™
Vertuan et al.[17] (2018)	Radiopacity	Sealer Plus™ BC	AH Plus™
Zordan-Bronzel et al.[9] (2019)	Radiopacity	Bio-C™ Sealer, TotalFill™ BC Sealer	AH Plus™
Tanomaru-Filho et al.[31] (2019)	Radiopacity	MTA Fillapex™	AH Plus™ Sealer Plus™
Silva et al.[32] (2020)	Radiopacity	Sealer Plus™ BC	AH Plus™

(D). etting time

Author/year	Evaluation	Silicate-based sealing cement	Resin-based sealing cement
Khalil et al.[29] (2016)	Setting time	BioRoot™ RCS	AH Plus™
Prüllage et al.[20] (2016)	Setting time	BioRoot™ RCS, MTA Fillapex™	AH Plus™
Tanomaru-Filho et al.[28] (2017)	Setting time	TotalFill™ BC Sealer	AH plus™
Vertuan et al.[17] (2018)	Setting time	Sealer Plus™ BC	AH Plus™
Mendes et al.[19] (2018)	Setting time	Sealer Plus™ BC	AH Plus™
Tanomaru-Filho et al.[31] (2019)	Setting time	MTA Fillapex™	AH Plus™ Sealer Plus™
Zordan-Bronzel et al.[9] (2019)	Setting time	Bio-C™ Sealer, TotalFill™ BC Sealer	AH Plus™
Silva et al.[18] (2020)	Setting time	Bio-C™ Sealer, TotalFill™ BC Sealer	AH Plus™
Silva et al.[32] (2020)	Setting time	Sealer Plus™ BC	AH Plus™

(E). Solubility

Author/year	Evaluation	Silicate-based sealing cement	Resin-based sealing cement
Lim et al.[27] (2015)	Solubility	Endoseal™	AH Plus™
Prüllage et al.[20] (2016)	Solubility	BioRoot™ RCS MTA Fillapex™	AH Plus™
Silva Almeida et al.[23] (2017)	Solubility	MTA Fillapex™	AH Plus™
Tanomaru-Filho et al.[28] (2017)	Solubility	TotalFill™ BC Sealer	AH Plus™
Mendes et al.[19] (2018)	Solubility	Sealer Plus™ BC	AH Plus™
Urban et al.[36] (2018)	Solubility	BioRoot™ RCS MTA Fillapex™	AH Plus™
Vertuan et al.[17] (2018)	Solubility	Sealer Plus™ BC	AH Plus™
Torres et al.[35] (2019)	Solubility	MTA Fillapex™	AH Plus™
Elayssy et al.[34] (2019)	Solubility	MTA Fillapex™ BioRoot™ RCS TotalFill™ BC Sealer	AH Plus™ Obturys™
Zordan-Bronzel et al.[9] (2019)	Solubility	Bio-C™ Sealer, TotalFill™ BC Sealer	AH Plus™
Tanomaru-Filho et al.[31] (2019)	Solubility	TotalFill™ BC Sealer	AH Plus™
Silva et al.[32] (2020)	Solubility	Sealer Plusv BC	AH Plus™

resin cements[20,32,34,35,37]. However, one study observed greater solubility for MTA Fillapex™ compared to AH Plus™ at 2 hours of evaluation[20]. Different studies found no solubility differences between both cements in the first minute of evaluation[20], at 24 hours[34] and after a week[34,36]. However, studies that analysed longer evaluation periods found the solubility of the MTA Fillapex™ cement was superior to that of the resin cement[32,35,37]. Meanwhile, the silicate-based Sealer Plus™ BC obtained contradictory results: in one study[19] it had greater solubility than AH Plus™, but no differences were found in 2 studies[17,27]. Similarly, the only study that analysed Endoseal™[28] found no differences in solubility with respect to AH Plus™ resin cement in the period analysed.

When evaluating the solubility between the different silicate-based cements, different results were observed between the different evaluation periods. The Bio-C™ Sealer cement had greater solubility than the TotalFill™ BC Sealer[9]. In one study, no significant differences were observed in the different periods between TotalFill™ BC Sealer, MTA Fillapex™ and BioRoot™ RCS cements, except for the first evaluation period (24 hours), in which BioRoot™ RCS cement had greater solubility than MTA Fillapex™[34]. However, the solubility of both cements differs between studies, as can be observed from the greater solubility of MTA Fillapex™ with respect to BioRoot™ RCS[20], as well as the greater solubility of BioRoot™ RCS cement in relation to MTA Fillapex™[37]. More research would be necessary to analyse the long-term solubility of both cements.

CONCLUSIONS

Taking into account the lack of long-term clinical studies and the limitations of in vitro studies, the physical properties of new silicate-based sealing cements can guide the dentist when carrying out the selection of sealing cement.

No differences in tooth discolouration between silicate-based and epoxy resin-based cements were observed. Neither were differences observed in sealing between both types for most of the studies selected. Both epoxy resin-based cements and silicate-based cements had radiopacity values within recommended ISO standards. The setting time of silicate-based cements in comparison with resin cements varied as a function of cement type. Although solubility varied as a function of cement type and evaluation period, some of the silicate-based cements showed higher solubility than resin-based cements.

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