Root Canal Filling with Calcium Silicate-Based Sealer: A Scoping Review

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Abstract

The three-dimensional root canal filling prevents the diffusion of microorganisms and provides a seal of the root canal system. This is achieved by combining gutta percha cones and endodontic cement. Recently, calcium silicate-based sealers (CSBS) have been developed and extensively compared with conventional cements. Indeed, obturation with CSBS presents some particularities but seems to be fast and often considered less complex to implement compared to conventional obturation techniques.

The articles studied in this literature review were selected from: PubMed, Scopus, Science Direct, and Cochrane and limited to a period from 2017 to 2022. Articles were filtered after eliminating duplicates, reading the abstract and the full text. Of the 2284 articles selected, 29 were considered relevant.

This review paper aimed to assess the effectiveness of different obturation techniques with CSBS, allowing for a better therapeutic approach.

Review (J Int Dent Med Res 2023; 16(2): 848-858)

Keywords: Calcium silicate-based sealer, bioceramic sealers, root canal obturation, Gutta Percha (GP), conventional sealers endodontics.

Received date: 17 January 2023 **Accept date:** 09 February 2023

Introduction

The main objective of root canal treatment is the disinfection of the root canal system and the healing and/or protection of the desmodontal space, which can only be achieved with a three-dimensional obturation, and the quality of root canal adhesive filling by endodontic sealer and gutta-percha depends on treatment methods of canal.[1]

Root canal filling prevents the spread of microorganisms and seals the root canal system. It has been modified in various ways, from the use of a solid material to the use of gutta percha cones in combination with cements for a hermetic sealing of the root canal system.

Different types of cements have been developed, such as zinc oxide eugenol, epoxy resin, glass ionomer cement and silicone cements. New formulations of calcium silicate-based cements (CSBS), often called bioceramic cements (BC), have been extensively studied by comparing their properties with those of conventional cements (zinc oxide eugenol and epoxy resin).

Concerning CSBS, there are many formulations available (Endosequence BC sealer, Totalfill BC sealer, BioRoot RCS, IRoot SP, MTA Fillapex, ProRoot and EndoSeal MTA...) which, unlike conventional root canal cements, CSBS are hydraulic, hygroscopic with a particular setting process. CSBS have interesting properties, including biocompatibility and bioactivity as well as antimicrobial properties. Inappropriate use can have a negative impact on the obturation, and therefore on the outcome of the root canal treatment.[2]

This review paper aimed to assess the effectiveness of different obturation techniques with CSBS, allowing for a better therapeutic approach.

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Materials and methods

Definition of the research question

The objective of this study was answer the main research question:
What is the particularity of filling with calcium

silicate cements (CSBS) compared to filling with conventional cements?

Research strategy

We adopted an electronic search strategy based on a systemic query of 4 databases: PubMed, Scopus, Science Direct and Cochrane.

We used 6 keywords: Calcium silicate-based sealer, Bioceramic sealers, Root canal obturation, Gutta Percha (GP), Conventional sealers and endodontics. These terms were used separately and cross-referenced to identify articles for review after inclusion. The Mesh desciptors/terms used are shown in Table 1.

Eligibility criteria of the articles

The eligibility criteria were determined in accords with the scheme of the patient/intervention/comparison/outcome study (PICO) question, inclusion, and exclusion criteria Table 2.

After a thorough review of all publications, the following data were extracted: name of authors, date of publication, objectives of the study, type and size of sample, root canal anatomy, irrigation solutions used, type of cement used, obturation technique used and the main results.

Inclusion and Exclusion Criteria of Eligible Studies

1) Main inclusion criteria

The articles included in the search are articles:

- Meeting the objectives of the study.
- Published between 2017 and 2022.
- Regarding human clinical studies and in vitro studies.

2) Main exclusion criteria

- Publications written in languages other than English.
- Studies conducted on animals.

Results

Material selection procedure and flow chart

From the 4 search engines, our search strategy identified 2284 articles. 1842 duplicates were eliminated. Among the 442 remaining articles, a first reading based on titles and "pre-selection" abstracts was performed. This sorting allowed the elimination of 350 articles that were not directly related to the subject. Then, concerning the 92 articles retained, the third level of sorting was applied. Indeed, a critical reading of the full text articles was carried out and left 29 articles that met the research objective. In the end, 29 articles were included as relevant documents to our research (Figure 1).

Features of the items included

A total of 29 studies were included in our review:

15 in vitro studies, 4 literature reviews, 3 systematic reviews, 3 clinical trials, 1 randomized clinical trial, 1 prospective study, 1 descriptive study, and 1 retrospective Cohort study (Table 3,4).

Discussion

Calcium silicate based sealers (CSBS) are widely used in endodontics. There is a wide variation in clinical practice, both in the steps prior to root canal obturation (irrigation, drying.) and in the obturation itself.[30]

Calcium silicate-based sealers or bioceramic cements are essentially composed of di- or tricalcium silicates, calcium phosphate, calcium hydroxide and zirconium oxide as a radio-opacifier. They are available in three forms: an injectable pre-mixed fluid form, a "powder + liquid" form to be mixed and a more pasty pre-mixed form called "putty".

CSBCs have interesting physicochemical and biological properties.

They are hydraulic, hygroscopic with a particular setting process.[32,33] CSBS are biocompatible, non-cytotoxic, non-genotoxic and bioactive.[19] Their properties are significantly different depending on the formulation[18] and often affected by the heat of the hot filling. [27,29]

In this literature review, several studies reported comparable or even superior characteristics of CSBS to conventional cements[21,23], with higher bond strength and sealing[6,15,34,35] with antimicrobial properties on Enterococcus Foecalis biofilms[8,24].

Root canal filling procedure with CSBS

Final Irrigation

Potential interactions between the final irrigant and CSBS must be taken into account. Indeed, Chlorhexidine or EDTA and CSBS decrease the adhesion of the cement to the intracanal dentin surface,[34,36] also the interaction between sodium hypochlorite (NaOCl) and bismuth oxide (Bi_2O_3) in ProRoot MTA generates a dyschromia.[37,38]

To increase the bond strength of CSBS, rinsing with 5% glycolic acid + saline, or rinsing

with 17% EDTA and green tea have been shown to be effective.[34] In addition, cement penetration into the dentinal tubules can be enhanced by rinsing with 2.5% NaOCl + 9% HEDP + distilled water.[16,17,39] Penetration increases significantly with ultrasonic activation.[17,28]

Finally, it seems appropriate to perform a final rinse with sterile water to remove the last irrigant before drying the root canal.[2]

Drying

CSBS need water to initiate the hydration reaction that conditions the setting process .[40] Therefore, desiccation of the intracanal dentin should be avoided in order to gently dry the canal before filling.[41]

Studies recommend the use of sterile paper tips with or without a combination of intracanal mini-aspiration to "dry without drying", without dehydrating the dentinal surfaces.[41,42] Indeed, a moderate drying is necessary in order to avoid the chalky aspect of the dentinal surface characteristic of the dehydration of the latter. While this is easy to control in the access cavity, it is difficult to control inside the canal. The canal is sufficiently dried, if the 3 to 4 mm of the end of the paper tip is wet after the paper cone is removed. This indicates that there is sufficient moisture to initiate the hydration of the calcium silicate hydraulic cement. [43,44]

Intracanal clinical application of CSBS

CSBS can be delivered into canals using different methods: by injecting the material using special rotary instruments, by coating the master cone to be inserted into the canal, or by using a file to apply the material into the walls and inside the canal. The Cpoint can be an alternative to the gutta percha cone. [9]

Premixed CSBS are typically delivered into the canal with a syringe, placed gently, the canal walls are covered with cement using a small file or GP cone. Regarding "powder-liquid" formulations such as BioRoot™ RCS, the cement should be mixed according to the manufacturer's instructions and inserted into the canal using a gutta tip. The freshly mixed material can also be administered using small plastic syringes and cannulas. [45]

Filling techniques with calcium silicate sealants

CSBS can be used with all root canal filling techniques. Using cold lateral compaction, hot vertical compaction or single-cone techniques.

The presence of voids in root canal fillings have a negative impact on the results of primary root canal treatment.[46] The presence of voids between the root canal filling and the dentin facilitates the movement of bacteria corono-apically or vice versa, resulting in reinfection or persistent apical periodontitis.[47]

In this review, several studies have highlighted the void volume following root canal fillings with CSBS compared to void volumes with conventional cements. (Table 5) summarizes the studies and synthesizes these results:

CSBS and thermoplastic gutta percha filling

A modification of the properties of CSBS subjected to temperature elevation has been reported. Indeed, an increase in temperature (> 100 ◦C) can lead to a change in the physical properties of CSBS, including their fluidity, their setting time and their adhesion to the dentinal walls.[45,48]

BioRoot™ RCS is heat sensitive and should be used with cold filling techniques.[17,49] Indeed, the physical properties of BioRoot™ RCS are affected by heat and from a temperature of 87°C, the cement hardens and the evaluation of its physical properties is impossible. This can be explained by the rate of water absorption and the start of the setting reaction. BioRoot™ RCS is mixed with water, and heating will lead to evaporation of the water justified by the loss of weight of BioRoot™ RCS, resulting in a hardening of the cement.[48] Many materials (such as Endosequence® BC Sealer™ HiFlow® and EndoSequence® BC Sealer™) can be used with hot filling techniques at elevated temperatures without restrictions.[49-51] However, additional studies are needed to clarify the impact of heat on each CSBS formulation. [52]

CSBS and single cone technique

The contribution of calcium silicate-based sealers seems to compensate for the disadvantages of this technique with conventional cements. [53] Their hydrophilicity and bioactivity allow them to truly adhere chemically to the root canal walls, thus avoiding the formation of micro-spaces between dentin and the gutta-percha cone in the long term. The master cone generates a hydraulic pressure in the canal, which allows a better distribution of cement in the canal space, irregularities and isthmuses, and facilitates the penetration of cement into the dentin tubules. This allows for a one-piece 3D obturation, [54] obtained thanks to

the spreading property of CSBS, their tightness and their viscosity adapted in such a way that they would propagate even in the free spaces which would not have been prepared mechanically. [55]

The filling with the single-cone technique associated with bioceramic cement, although it seems to be more operator-dependent than the other techniques, reaches a success rate of 90.9%. [31,56] Studies included in this review have shown less post-operative symptoms with CSBS cements, or at least equivalent to post-obturation pain with conventional cements [57] with similar quality of root canal obturation.[28] However, age, gender, root type, sealer extrusion and assessment time point were significantly related to postoperative pain. [26]

Advantages of root canal filling with CSBS

Indications related to root canal anatomy and tooth position

Intra-root canal penetration of fullers used in the compaction technique is not always feasible with conservative or even ultraconservative access cavities. A single-cone root canal filling with calcium silicates simplifies the procedure while allowing preservation of healthy coronal tissue.

Root canal ramifications are also technically difficult to manage, especially during root canal filling. In this case, the single-cone technique in combination with a CSBS facilitates the obturation after a long and tedious session. On the other hand, conventional compaction techniques should be preferred in the presence of flattened, wide and irregular canals.

The curvature of the root can sometimes make obturation by hot compaction techniques very delicate. In these cases, a single-cone filling is appropriate. The same is true for teeth with malposition or for patients with a reduced mouth opening.

Indications related to biological imperatives:

The healing of apical periodontitis involves complex mechanisms related to the quality of the treatment performed by the practitioner but also to the patient's immune system.

The use of CSBS for root canal filling in association with GP allows to optimize or even accelerate the healing of apical periodontitis because of their biocompatibility, bioactivity, antibacterial character and their waterproofness. Indeed, in the study by S. Alsubait et al.,[8] included in our review showed that CSBS have antimicrobial effects on E. faecalis biofilms. In this study, the antibacterial activity of BioRoot RCS was significantly higher than Totalfill BC and AH Plus after 30 days of exposure. [8] For the same reasons, CSBS can also be indicated in certain situations of perforation or root resorption.

Limitations of CSBS

Re-intervention of the filling with CSBS

During retreatment, all of the filling material must be removed to promote the chances of healing and lesion recovery. It is therefore important that the endodontic cements used can be easily removed in case of retreatment. However, not all CSBS can be removed by conventional retreatment techniques.[58] This is because the material is very hard once it has set. However, a study included in this review showed the same quality of root canal removal with similar remnant of filling materials on the split canal wall after removal procedure. The time required for removal of filling materials is longer for CSBS.[57]

Apical permeability is difficult to achieve after root canal disobturation, in the presence of short fillings compared to the work length.[59] The presence of the CSBS at the level of the apical master cone could make root canal retreatment more difficult and increase the risk of blockage or even perforation.[58]

In consideration of the potential difficulty associated with endodontic retreatment of teeth filled with CSBS, the adjustment of the master cone to the working length should be as precise as possible.60

Conclusions

CSBSs have shown good overall performance compared to conventional cements, but there are significant differences between its different formulations.

The excellent biological and physico-chemical properties of calcium silicates have been demonstrated in numerous scientific studies implying an increasing clinical use of these biomaterials in endodontics. However, the discrepancies in the results of in vitro studies, the lack of in vivo studies and the limited number of case reports require discussion and do not allow for an evaluation of the long-term efficacy of

these cements, nor for clarification of the clinical results associated with their use. In addition, the inability to remove these root canal cements during retreatment is the main disadvantage of the use of these new cements. Indeed, these new cements do not seem to meet Grossman's last criterion: "to be soluble in common solvents if it is necessary to remove it"

Concerning the final irrigation, potential interactions between CSBSs and irrigation solutions must be considered, as the latter may negatively affect the properties of the cements.

As far as drying is concerned, it should be moderate, drying without drying out.

CSBCs used for root canal obturation are used in combination with gutta-percha and most often in a single-cone technique. This obturation technique appears to be fast, atraumatic and is often considered less complex to perform compared to conventional obturation techniques.

Nevertheless, several additional specific points remain to be studied their antigenic/mutagenic action and their long-term efficacy.

In the future, more clinical investigations will therefore be necessary for these new biomaterials to be modified and developed to overcome the few remaining challenges in the search for the ideal cement.

Declaration of Interest

The authors report no conflict of interest.

Database	Search strategy
Pubmed Scopus Science direct Cochrane	· Calcium silicate-based sealer AND root canal obturation AND endodontics. · Calcium silicate-based sealer AND root canal obturation. · Calcium silicate-based sealer AND conventional sealers. · Calcium silicate-based sealer AND conventional sealers AND gutta percha. · Calcium silicate-based sealer AND bioceramic sealers AND endodontics. · Calcium silicate-based sealer AND root canal obturation AND endodontics AND conventional sealers.

Table 1. Database and search method.

Participants (P)	The number of patients (in vivo study) or teeth (in vitro).
Intervention (I)	Root canal filling with CSBS using the following techniques: single-cone technique (MC), cold hydraulic condensation technique (CHF) and thermoplastic technique (TP)
Comparison (C)	Comparison of obturation with CSBS to obturation with conventional cements.
Outcomes/Results (O)	Obtaining results of a very varied nature, namely: - The success rate for CSBS; - Postoperative pain; - Parameters influencing the tightness; - Techniques for better three-dimensional root canal filling.

Table 2. PICO criteria for study selection.

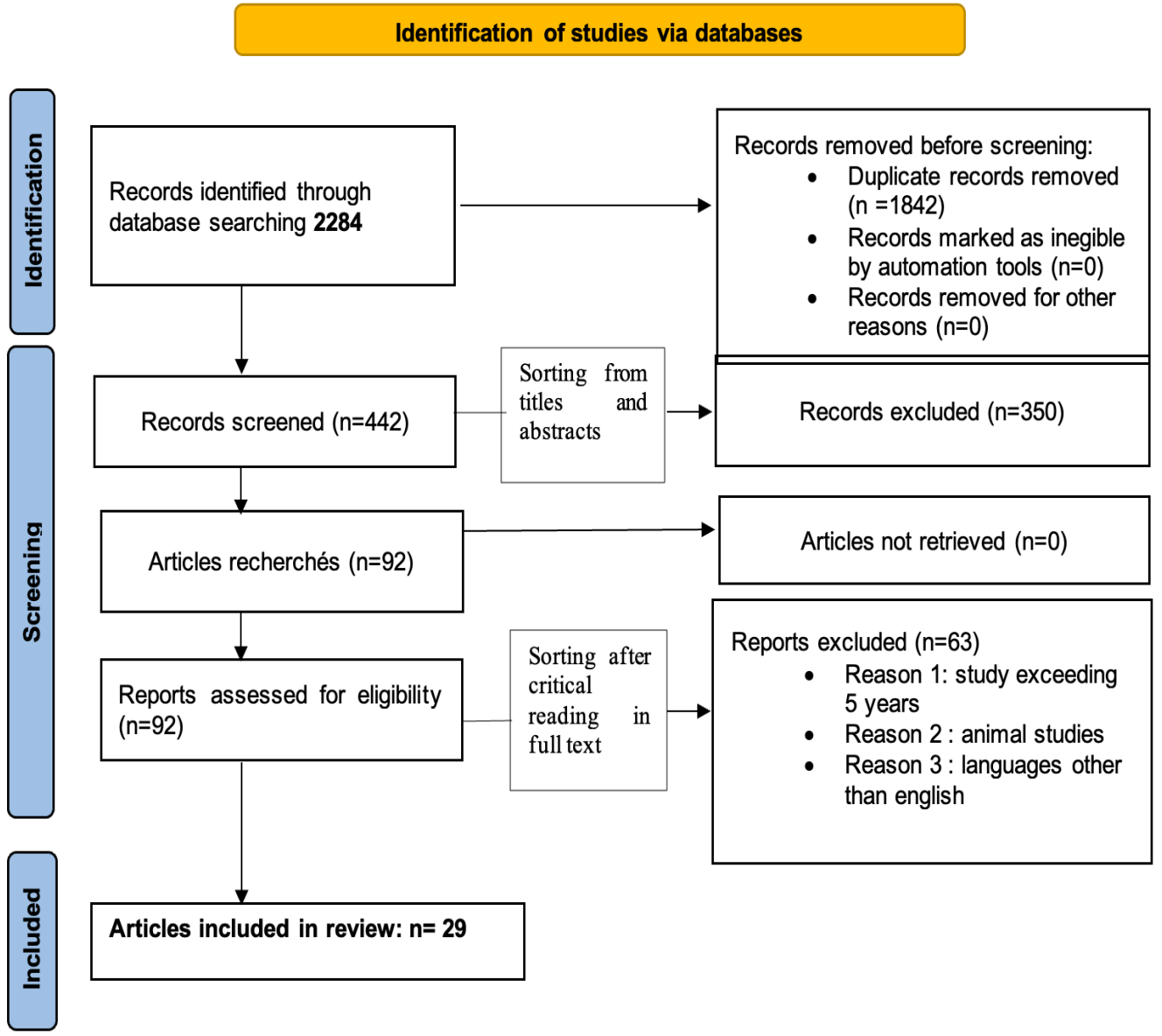

Figure 1. Flow diagram.

Auteur/ Year	Titre
C. Veeramachaneni et al.[3] 2022	Comparative evaluation of push-out bond strength of bioceramic and epoxy sealers after using various final irrigants
P-A. Ruth et al.[4] 2021	Root Canal Filling Quality Comparison of a Premixed Calcium Silicate Endodontic Sealer and Different Carrier-Based Obturation Systems.
R. Nesello et al.[5] 2022	Effect of bioceramic root canal sealers on the bond strength of fiber posts cemented with resin cements
J-A. Kim et al.[6] 2018	Root Canal Filling Quality of a Premixed Calcium Silicate Endodontic Sealer Applied Using Gutta-percha Cone-mediated Ultrasonic Activation
A. Srivastava et al.[7] 2019	Evaluation of push-out bond strength of BioRoot RCS and AH plus after using different irrigants: An in vitro study
S. Alsubait et al.[8] 2019	Comparison of the antibacterial activity of calcium silicate- and epoxy resin-based endodontic sealers against Enterococcus faecalis biofilms: a confocal laser-scanning microscopy analysis
R. Somani et al.[9] 2019	Hermetic Seal in Obturation: An Achievable Goal with Recently Introduced Cpoint
AO. Santos-Junior et al.[10] 2020	Effect of obturation technique using a new bioceramic sealer on the presence of voids in flattened root canals
De PJP Silva et al.[11] 2021	Quality of Root Canal Filling Using a Bioceramic Sealer in Oval Canals: A Three-Dimensional Analysis
E. Pedulla et al.[12] 2020	Root fillings with a matched-taper single cone and two calcium silicate–based sealers: an analysis of voids using micro-computed tomography
E. Moccia et al.[13] 2020	Evaluation of the root canal tridimensional filling with warm vertical condensation, carrier-based technique and single cone with bioceramic sealer: A micro-CT study
S-Y. Kim et al.[14] 2021	Effects of Ultrasonic Activation on Root Canal Filling Quality of Single-Cone Obturation with Calcium Silicate-Based Sealer
G. Sfeir et al.[15] 2018	Impact of the Root Canal Taper on the Apical Adaptability of Sealers used in a Single-cone Technique: A Micro-computed Tomography Study
S. Ismail et al.[16] 2021	Influence of dual rinse irrigation on dentinal penetration of a bioceramic root canal sealer: A Conofocal microscopic Analysis
D. Eid et al.[17] 2021	Impact of Warm Vertical Compaction on the Sealing Ability of Calcium Silicate-Based Sealers: A Confocal Microscopic Evaluation

Table 3. In vitro studies included from the research strategy.

G. Sfeir et al.[18] 2021	Calcium Silicate-Based Root Canal Sealers: A Narrative Review and Clinical Perspectives	**Literature review**
M. Lim et al.[19] 2020	Calcium silicate-based root canal sealers: a literature review	
G. De-Deus et al.[20] 2021	Methodological proposal for evaluation of adhesion of root canal sealers to gutta-percha	
A.P. Kunjan et al.[21] 2020	Calcium silicate-based cements in endodontics	
M.S. Nivedhitha et al.[22] 2021	Postoperative pain associated with resin and bioceramic based sealers: A systematic review.	**Systematic review**
LHS. Almeida et al.[23] 2017	Are Premixed Calcium Silicate–based Endodontic Sealers Comparable to Conventional Materials?	
D. Donnermeyer et al.[24] 2018	Endodontic sealers based on calcium silicates: a systematic review	
S.R. Kim et al.[25] 2019	Efficacy and retrievability of root canal filling using calcium silicate-based and epoxy resin-based root canal sealers with matched obturation techniques	**Clinical trials**
YH. Yu et al.[26] 2021	Comparing the incidence of postoperative pain after root canal filling with warm vertical obturation with resin-based sealer and sealer-based obturation with calcium silicate-based sealer	
J. Heran et al.[27] 2020	The single cone obturation technique with a modified warm filler	
J-H. Kim et al.[28] 2022	Clinical Efficacy of Sealer-based Obturation Using Calcium Silicate Sealers: A Randomized Clinical Trial	**Randomized clinical trial**
T.B.M. Antunes et al.[29] 2021	Heating stability, physical and chemical analysis of calcium silicate-based endodontic sealers	**Prospective study**
M. Guivarch et al.[30] 2020	An international survey on the use of calcium silicate-based sealers in non-surgical endodontic treatment	**Descriptive study**
E.A. Chybowski et al.[31] 2018	Clinical Outcome of Non-Surgical Root Canal Treatment Using a Single-cone Technique with Endosequence Bioceramic Sealer: A Retrospective Analysis	**Retrospective Cohort Study**

Table 4. Other items included from the search strategy.

Author/ year/type of study	Sample	Intervention	Comparison and evaluation of volume of voids	Results
De PJP Silva et al.[11] 2021 In vitro	38 human Mono radicular premolars with oval canals	**Groupe 1 :** EndoSequence BC sealer + single cone **Groupe 2:** EndoSequence BC sealer + Cold lateral compaction	Micro-CT: in the total length + in the apical 5mm of each canal	Less than 16% voids for both techniques with no statistically significant difference between them for the total canal length and for the apical 5 mm
E. Pedulla et al.[12] 2020 In vitro	48 human monoradicular mandibular premolars	**Groupe 1:** GuttaFlow + single cone **Groupe 2:** BioRoot RCS Cold + single cone	Micro-CT before and after canal obturation.	Root canals filled with a matched-taper single cone and GuttaFlow Bioseal had significant less voids than those with BioRoot RCS, except at the apical 1 mm.
S-Y. Kim et al.[14] 2021 In vitro	36 permanent monoradicular human premolars	**-Groupe 1:** AH Plus+ CW (continuous wave) **-Groupe 2:** EndoSequence BC + MC **-Groupe 3:** EndoSequence BC + MC + ultra-sonic activation	Micro-CT at the apical, middle, and coronal levels	Improved shutter quality with CSBS and ultra-sonic activation
J. Heran et al.[27] 2020 In vitro	- -	- AH Plus - BioRoot RCS - GuttaFlow - Prototype: a mixture of tricalcium silicate cement and 30% zirconium oxide	Microcomputed tomography	All sealers tested were **affected by the heat generalized distribution of voids** for all sealers.
AO. Santos-Junior et al.[10] 2020 In vitro	24 wide distal canals of the mandibular molars	-Single cone -Technique thermoplastic (TP)	Micro-CT before and after canal obturation	**In cervical/middle thirds:** Voids with TP < single-cone technique **In the apical third:** No difference in the percentage of voids using either technique

Table 5. Description of studies assessing the presence of voids with bioceramic sealers.

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