Are Premixed Calcium Silicate–based Endodontic Sealers Comparable to Conventional Materials? A Systematic Review of *In Vitro* Studies

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Abstract

Introduction: This study aimed to compare the physicochemical and biological properties of premixed calcium silicate–based endodontic sealers with other conventional root canal filling materials by systematically reviewing laboratory studies. **Methods:** The search was conducted in 3 databases (Medline via PubMed, Scopus, and Web of Science) following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Two reviewers independently selected the studies and extracted the data. The properties of interest were bond strength, radiopacity, pH, solubility, setting and working time, dimensional change, flow, calcium ion release, antimicrobial activity, biocompatibility, and cytotoxicity. **Results:** From 2636 potentially eligible studies, 31 were selected for full-text analysis, and 27 were included in the review. Premixed calcium silicate–based endodontic sealers followed the ISO 6876:2012 requirements for most physicochemical properties except for solubility. The target sealers also presented favorable biological findings when compared with conventional sealers. **Conclusions:** Despite the lack of well-designed long-term clinical trials, the target premixed calcium silicate–based sealers show good physicochemical and biological properties *in vitro*. In general, the results were similar or better than conventional endodontic sealers as observed in *in vitro* and *in vivo* animal studies. *(J Endod 2017;43:527–535)*

Key Words

Calcium silicate-based sealer, EndoSequence BC, iRoot SP, root canal filling material, root canal sealer

Significance

There are still few *in vitro* studies and no long-term clinical trials about premixed calcium silicate–based endodontic sealers' properties. This systematic review compared the physicochemical and biological properties of calcium silicate–based sealers with those of conventional sealers.

Bioceramic-based materials have been recently introduced as root repair cements (1, 2) and root canal sealers (3, 4). Bioceramic products may include alumina and zirconia particles, bioactive glass, calcium silicates, hydroxyapatite, and resorbable calcium phosphates in their formulation (5). In general, these materials are biocompatible, nontoxic, non-shrinking, and chemically stable within the biological environment (4, 6, 7). They also have the ability to form hydroxyapatite during the setting process and ultimately create a bond between dentin and the filling material (3, 4).

There are 2 premixed calcium silicate–based sealers with similar chemical composition, iRoot SP (Innovative Bioceramics, Vancouver, BC, Canada) and EndoSequence BC (Brasseler USA, Savannah, GA). In addition to antibacterial activity (8, 9), they have shown cytocompatibility (6), good sealing ability (3), and good bonding to root canal dentin even under various conditions of dentin moisture (10, 11).

Mineral trioxide aggregate (MTA) Fillapex (Angelus, Londrina, PR, Brazil) has been denominated a bioaggregate (12) or bioceramic-based sealer (13). However, it is a calcium silicate–containing endodontic sealer that is based on salicylate resin and other resinous components (14). MTA Fillapex has alkaline pH and antibacterial activity (15), but it has demonstrated irritating effects on subcutaneous connective tissue (16) and bone tissue (17). Thus, despite the presence of MTA, this material may not have biological advantages.

The epoxy resin–based sealer AH Plus (Dentsply DeTrey GmbH, Konstanz, Germany) is the gold standard sealer regarding physical properties, and it has shown higher bond strengths to dentin than other root canal sealers (18). AH Plus has been widely used for approximately 2 decades, exhibiting low solubility and disintegration (19) as well as adequate dimensional stability (7). However, this sealer has shown no bioactive properties (14) or osteogenic potential (20).

Premixed calcium silicate–based endodontic products have been introduced to the market for their biological advantages, mainly their bioactivity potential (21, 22). However, up to now, there are few independent publications about their laboratory properties and no long-term clinical trials. In this context, the aim of this study was to compare the physicochemical and biological properties of these relatively novel

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root canal sealers with those of other conventional sealers by systematically reviewing *in vitro* and *in vivo* animal studies in the literature.

Materials and Methods

This systematic review was carried out according to the guidelines of Cochrane Handbook for Systematic Reviews of Interventions (23), following the 4-phase flow diagram of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (24). This report is based on the PRISMA statement. Despite being a systematic review that is based on laboratory studies, the question of research was adapted from the PICO framework: Population – specimens or animals from *in vitro* and *in vivo* animal studies; Intervention and Comparison – use of premixed calcium silicate–based endodontic sealers versus conventional sealers; Outcome – chemical, physical, or biological properties.

Study Selection and Search Strategy

Medline via PubMed, Scopus, and Web of Science databases were searched. The inclusion criteria were *in vitro* or *in vivo* animal studies that compared the properties of premixed calcium silicate–based endodontic sealers (bioceramic sealers) with those of conventional sealers. Only EndoSequence BC and iRoot SP were considered in the scope of this study because they are premixed materials mainly composed of calcium silicate with potential bioactivity. Non-premixed sealers with different compositions were considered conventional sealers. To be included in this review, the article should have reported at least 1 comparison of specific chemical, physical, or biological characteristics between at least 1 premixed calcium silicate–based endodontic sealer and 1 conventional material, irrespective of the method of analysis. The following properties of interest were considered: bond strength to root dentin, radiopacity, pH, solubility, setting and working time, dimensional change, flow, Ca^{+2} release, antimicrobial activity, biocompatibility, or cytotoxicity. The exclusion criteria comprised articles that evaluated other properties of calcium silicate–based endodontic sealers (eg, sealing ability), articles that tested other bioceramic materials than the target sealers (EndoSequence BC/iRoot SP), or when no comparison between bioceramic and conventional sealers was present.

Date limit was set from 2009, when these specific premixed calcium silicate–based endodontic sealers were developed, to 2016. The last search was carried out in June 2016 with no language restriction. The references of all eligible articles were also hand-searched. A wide search strategy was used to avoid missing information: ("endodontic sealer" OR "root canal sealer"). Literature search results were de-duplicated by using EndNote X7 software (Thomson Reuters, New York, NY). Two independent reviewers (L.H.S.A., R.D.M.) initially screened the titles of all identified studies. If the title indicated possible inclusion, the abstract was carefully appraised, and the articles considered eligible for the review (or in case of doubt) were selected for full-text reading. Discrepancies were resolved by discussion with a third reviewer (F.G.P.)

Data Collection and Analysis

A standardized outline was used for data extraction that was based on the characteristics of the studies and groups tested. Articles were grouped according to the tested property, and the following items were registered: sample size, method of analysis, results (means and standard deviations), and conclusions. The authors were contacted in case of any missing or unpublished data; these studies were only included if the missing information was provided. Considerable heterogeneity was present in the selected studies regarding the research design, methods, outcome variables, and data variability. Because meta-analysis was considered inappropriate, the characteristics of studies were summarized descriptively.

Results

The flowchart of the systematic review is shown in Figure 1. The screening of titles and abstracts initially resulted in 31 articles, and 1 additional article was found by hand-searching. The studies comparing the target sealers only with root repair cements were excluded in this stage. Five articles were excluded after full-text reading because 2 studies did not sufficiently describe their statistical tests or findings (11, 25), 1 study did not compare the sealers (26), and 2 studies used other bioceramic materials than the target sealers (27, 28).

In total, 27 studies were included in this review and processed for data extraction. Supplemental Table 1 shows, in alphabetical order, the commercial name and chemical composition of the materials used in the included studies in comparison with the target calcium silicate–based endodontic sealers (EndoSequence BC/iRoot SP).

Physical-Chemical Properties

Data for the physical-chemical properties are shown in Table 1. Nine studies on bond strength were included (13, 18, 29–35). In comparison with AH Plus, bioceramic sealers showed similar bond strength values in 6 studies (18, 29–32, 34), higher values in 2 studies (33, 35), and lower values in only 1 study (13).

Two studies on radiopacity were included (36, 37), and all tested materials, including EndoSequence BC, exhibited radiopacity higher than the 3-mm aluminum thickness as requested by ISO 6876:2012 (38). With regard to pH values, the bioceramic sealers presented higher pH values than the conventional materials in the 3 included studies (7, 8, 36).

Three studies on solubility were included (7, 10, 14). In 2 studies (7, 10), the bioceramic sealers met the American National Standards Institute/American Dental Association (ANSI/ADA) requirements (39) for solubility (<3%), with similar or higher percentages than AH Plus but lower than Sealapex. In contrast, in the third study (14), iRoot SP did not fulfill ANSI/ADA recommendations, and AH Plus or MTA Fillapex also did not.

Only 1 study was included for working time, setting time, and dimensional change (7). EndoSequence BC had the highest working time and lower values of setting time than other sealers but higher than GuttaFlow. The bioceramic sealer showed slight expansion in accordance with ISO 6876:2012 (38).

Two studies on sealer flow were included (7, 36). In both, the bioceramic sealer (EndoSequence BC) was in conformity with ISO 6876:2012 recommendations (38). Its values were higher than most of the conventional materials (eg, AH Plus) but lower than MTA Fillapex. Concerning Ca^{+2} release, 2 studies were included (14, 36); the bioceramic sealers (EndoSequence BC/iRoot SP) showed higher levels of Ca^{2+} release, when compared with other sealers.

Biological Properties

Data for the biological properties are shown in Table 2. Five studies on antimicrobial activity were included (8, 9, 33, 40, 41). One of these studies used a direct contact test (DCT) against *Candida albicans* and suggested that the bioceramic sealer (iRoot SP) exhibits antifungal activity (41) because it is effective in its freshly mixed form. However, AH Plus showed the highest antifungal effect. In a study using the DCT against *Enterococcus faecalis*, the bioceramic sealer (EndoSequence BC) showed similar antibacterial effect of AH Plus (33).