



Evaluation of the Radiopacity, pH, and Calcium Ion Release of Calcium Silicate and Epoxy Resin-based Endodontic Cements

Milagros Judith Loyola-Cano ^{a*} , Carmen Rosa García-Rupaya ^b

^a Endodontist, Private Practice, Chimbote, Peru; ^b Academic Department of Oral Medicine and Maxillofacial Surgery, Cayetano Heredia Peruvian University, Faculty of Stomatology, Lima, Peru

Article Type: Original Article

Received: 25 Jul 2025

Accepted: 29 Sep 2025

Published: 14 Oct 2025

Doi: 10.22037/iej.v20i1.48935

*Corresponding author: Milagros Judith Loyola-Cano, Private Practice, Specialist in Endodontics in Chimbote, Peru.

E-mail: loyolacanomilagros@gmail.com

Abstract

Introduction: Endodontic cements are essential materials for achieving successful root canal treatment. Therefore, they must present adequate physicochemical properties to ensure optimal clinical performance. This study aimed to evaluate radiopacity, pH, and calcium ion release of calcium silicate- and epoxy resin-based cements/sealers. **Materials and Methods:** Four materials were evaluated: Vioseal, AH-Plus, AH-Plus Bioceramic Sealer, and MTA Angelus. Ten cylindrical specimens (10 mm diameter, 1 mm height) per group were prepared for each tested property, totaling 80 samples. The same specimens were used for pH and calcium ion release, while separate specimens were used for radiopacity. All samples were stored at 37°C and 95% humidity. Radiopacity was assessed by digital radiography using an aluminum step wedge (1-10 mm). pH was measured at 1, 7, and 14 days using a calibrated digital pH meter. Calcium ion release was determined using atomic absorption spectrophotometry. Data were analyzed using Kruskal-Wallis and Dwass-Steel-Critchlow-Fligner post hoc tests ($P < 0.05$). **Results:** Vioseal and AH-Plus showed the highest radiopacity values (9.98 ± 0.42 mm Al and 10.00 ± 0.38 mm Al, respectively), while AH-Plus Bioceramic Sealer (9.04 ± 0.28 mm Al) and MTA Angelus (4.72 ± 0.40 mm Al) showed lower values. Regarding pH, AH-Plus Bioceramic presented the highest and most sustained alkaline value (up to 12.5), and AH-Plus the lowest (6.25 ± 0.26). In calcium ion release, Vioseal showed the highest release on day 7 (29.4 ± 3.12 ppm), while AH-Plus Bioceramic Sealer also peaked on day 7 (18.60 ± 5.54 ppm); MTA Angelus presented its highest release on day 1 (11.80 ± 1.00 ppm). **Conclusion:** All evaluated cements/sealers met the ISO 6876 standard for radiopacity. Calcium silicate-based cements showed an alkaline pH and sustained calcium ion release, whereas Vioseal presented an initially high and transient release.

Keywords: Calcium Silicate Cement; Calcium Ions; Endodontic Sealer; Epoxy Resin; pH; Radiopacity

Introduction

Three-dimensional obturation of the root canal system is a critical phase of endodontic treatment, as it enables a hermetic seal of the canal, prevents reinfection, and promotes periapical healing [1, 2]. To achieve this, an endodontic cement with adequate physicochemical properties is required [2, 3]. For this study, the term endodontic cements will be used to refer collectively to both sealers and repair materials.

Over the years, various cements with different chemical compositions have been developed [3]. Epoxy resin-based

cements are recognized for their good radiopacity, adhesion, prolonged stability, and some antibacterial activity [4], which have positioned them as the gold standard for many years [5, 6]. In contrast, calcium silicate-based cements have gained relevance in modern clinical practice due to their ability to release calcium ions and exhibit alkaline pH, which contribute to their antibacterial effect, biocompatibility, and bioactivity, thereby supporting tissue repair [7].

Radiopacity is essential for proper visualization of the obturation, allowing clinical monitoring and identification of potential errors before or after endodontic treatment [8].



Alkaline pH provides cements with antimicrobial activity through the denaturation of bacterial proteins and disruption of the cytoplasmic membrane [9]. Likewise, calcium ion release promotes hydroxyapatite formation, enhances integration with surrounding tissues, and reinforces the apical seal [10].

Previous studies have demonstrated that calcium silicate and epoxy resin-based cements exhibit adequate radiopacity, allowing for proper radiographic visualization. However, they differ in the presence of alkaline pH and the ability to release calcium ions, which is characteristic of calcium silicate-based cements and contributes to their antimicrobial effect and bioactivity [11]. These properties have been associated with the ability to promote hard tissue formation, which is beneficial in reparative procedures such as furcal and periapical repair [12].

Although several studies have evaluated the radiopacity, pH, and calcium ion release of various endodontic cements [13, 14], it remains essential to confirm these properties under controlled conditions to predict their clinical behavior. Furthermore, it is necessary to assess materials with new or less-studied formulations [15], such as Vioseal, an epoxy resin-based cement whose composition includes calcium phosphate [16], a component associated with bioactive properties that may contribute to the formation of remineralized tissue, which is clinically relevant in reparative endodontic procedures [12]. Therefore, the present study aimed to evaluate the radiopacity, pH, and calcium ion release of calcium silicate- and epoxy resin-based endodontic cements under standardized conditions.

Materials and Methods

An *in vitro* experimental study was conducted; therefore, no human or animal subjects were involved. The protocol was reviewed and registered with the University Research Regulatory Affairs Directorate (DUARI) of Universidad Peruana Cayetano Heredia under the code CAR-DUARI-O-298-24. The study was designed to evaluate three physicochemical properties of endodontic sealers: radiopacity, pH, and calcium ion release.

Four commonly used clinical endodontic cements were selected (Table 1): Vioseal (Spident, Seoul, Korea), AH-Plus (Dentsply, De Trey GmbH, Konstanz, Germany), AH-Plus Bioceramic Sealer (Dentsply De Trey GmbH, Konstanz, Germany), and MTA Angelus (Angelus, Londrina, PR, Brazil).

Ten specimens were prepared per group. The sample size was determined using the formula for comparison of means, based on the results of a pilot test, which indicated a minimum of six specimens per group. However, to ensure statistical robustness, ten samples per group were used for each evaluated property ($n=10$), resulting in a total of 80 specimens.

The same specimens were used for the evaluation of pH and calcium ion release, while separate specimens were used for radiopacity assessment. Only samples with smooth surfaces and free of visible bubbles or porosities were included. Samples with structural irregularities were excluded from the analysis.

Sample preparation

The cements were manipulated according to the manufacturer's instructions and placed into acrylic ring molds (10 mm in diameter and 1 mm in height) [5, 8], positioned on a glass slab covered with cellophane film. A second glass slab, also covered with cellophane [8], was placed on top, and a 1 kg weight was applied for 10 sec to level the surfaces and eliminate excess material. The samples were then placed in an incubator at 37 °C and 95% humidity for 24 h to ensure complete and homogeneous setting of all sealers [17]. After setting, the specimens were removed from the molds, and their thickness was verified using a digital caliper (Mitutoyo, Tokyo, Japan). The samples were then randomly coded by an independent researcher to ensure evaluator blinding. Specimens intended for radiopacity testing were stored dry, while those used for pH measurement and calcium ion release were immersed in deionized distilled water and incubated at 37 °C with 95% humidity for 24 h before experimental evaluation [8, 17].

Radiopacity evaluation

Approved samples were placed on a digital radiographic film alongside a 10-step aluminum step wedge, with thicknesses ranging from 1 to 10 mm (1 mm increments per step), which was

Table 1. Description of the evaluated endodontic cements

Cement	Type	Batch	Composition
Vioseal (Spident, Seoul, Korea)	Epoxy resin	VS23053	Base: oligomeric epoxy resin and ethylene glycol salicylate; Catalyst: poly (1,4-butanediol) bis (4-aminobenzoate), and calcium phosphate
AH-Plus (Dentsply, De Trey GmbH, Konstanz, Germany)	Epoxy resin	2405000719	Paste A: bisphenol A zirconium oxide, bisphenol F epoxy resin, calcium tungstate, iron oxide, and silica; Paste B: N, N-dibenzyl-5-oxanoadiamine-1,9, calcium tungstate, and zirconium oxide
MTA Angelus (Angelus, Londrina, PR, Brazil)	Calcium silicate	69284	Bismuth oxide, tricalcium silicate, dicalcium silicate, calcium sulfate dihydrate, tricalcium aluminate, and tetracalcium aluminoferrite
AH-Plus Bioceramic Sealer (Dentsply, De Trey GmbH, Konstanz, Germany)	Calcium silicate	K1230609	Zirconium dioxide, tricalcium silicate, dimethyl sulfoxide, lithium carbonate, and thickening agents

used as a reference material. According to ISO 6876, endodontic sealers must exhibit radiopacity greater than 3.0 mm Al [18]. Radiographic exposure was performed using an X-ray device (Gnatus, Ribeirão Preto, Brazil) at 70 kV, 8 mA, and a focal distance of 400 mm. The obtained images were processed using ImageJ software (National Institutes of Health, Bethesda, MD, USA). First, the optical density of the aluminum step wedge was measured by selecting regions of interest (ROIs) in the central area of each thickness, using uniform dimensions across all steps. From the obtained data, a calibration curve was generated correlating optical density values with aluminum thickness in millimeters (mm Al). Subsequently, a logarithmic regression was applied to these data using Microsoft Excel, generating an equation of the form $y=a \cdot \ln(x)+b$, where y represents the gray value and x the thickness in millimeters of aluminum. This equation was calculated using the least squares method, providing a coefficient of determination ($R^2=0.9956$).

Next, the optical density of each cement sample was measured by selecting a central ROI of identical dimensions for all specimens. Using the previously obtained equation, each gray value was converted into millimeters of aluminum. This procedure enabled the standardized and quantitative determination of the radiopacity of the tested sealers [8, 17].

pH measurement procedure

The procedure was carried out under controlled conditions in the laboratories of the Faculty of Chemistry and Chemical Engineering at the Universidad Nacional Mayor de San Marcos. Each sample was placed in a polyethylene test tube containing 10 mL of deionized distilled water [19], sealed and previously coded by a researcher not involved in the study. The samples were stored in an incubator at 37 °C and 95% humidity throughout the experimental period. The pH measurements were performed at 1, 7, and 14 days [17], with each measurement conducted in triplicate at each interval [20]. The mean of the three measurements per sample was then calculated for each evaluation period in order to ensure the reproducibility and reliability of the results. At each time point, the deionized water in contact with the sample was transferred to a sterile beaker. A fresh volume of deionized water was then added to the same test tube containing the sample, thus maintaining consistent experimental conditions. The transferred solution was manually agitated for 5 sec [21, 22]. The pH was measured using a digital pH meter (Milwaukee Instruments, MW151 MAX, WI, USA), equipped with a hydrogen ion-sensitive electrode and displaying readings with two decimal digits. The device was calibrated before each measurement using standard buffer solutions.

Calcium ion (Ca^{2+}) release measurement procedure

The procedure was carried out under controlled conditions in the laboratories of the Faculty of Chemistry and Chemical Engineering at the Universidad Nacional Mayor de San Marcos. Each sample was placed in a polyethylene test tube containing 10 mL of deionized distilled water, sealed with parafilm, and previously coded by a researcher not involved in the study. The samples were stored in an incubator at 37 °C and 95% humidity throughout the experimental period.

Calcium ion (Ca^{2+}) release was measured at 1, 7, and 14 days [22], with each measurement performed in triplicate [20]. The average of the three readings per sample was calculated for each time point to ensure the reproducibility and reliability of the results. At each evaluation point, the deionized water in contact with the sample was transferred to a sterile beaker. A fresh volume of deionized water was then added to the same tube containing the sample, thereby preventing the accumulation of calcium ions in the same test tube and ensuring independent measurements at each interval. This methodology allowed experimental conditions to remain constant.

The transferred solution was manually agitated for 5 sec [21, 22]. The concentration of released calcium ions was determined using an atomic absorption spectrophotometer (AA6800; Shimadzu, Tokyo, Japan). This analytical equipment operates by introducing the liquid sample into a graphite furnace and heating it to achieve atomization. During this process, atoms in the sample absorb light at a specific wavelength. The level of absorbed light is directly related to the concentration of the ion in the solution, enabling quantification through a calibration curve. The spectrophotometer was calibrated before each measurement interval using calcium standard solutions.

Statistical analysis

The normality of the data corresponding to each physicochemical property (radiopacity, pH, and calcium ion release) was evaluated using the Shapiro-Wilk test. As the assumption of normal distribution was not satisfied ($P<0.05$), the non-parametric Kruskal-Wallis test was employed, which is suitable for comparing medians among multiple groups with non-normally distributed data. To determine pairwise differences between groups, the Dwass-Steel-Critchlow-Fligner post hoc test was applied.

A 95% confidence level was used, and statistical significance was set at $P<0.05$.

Results

Vioseal and AH-Plus cements exhibited the highest radiopacity values, with 9.98 ± 0.42 mm and 10.00 ± 0.38 mm, respectively.

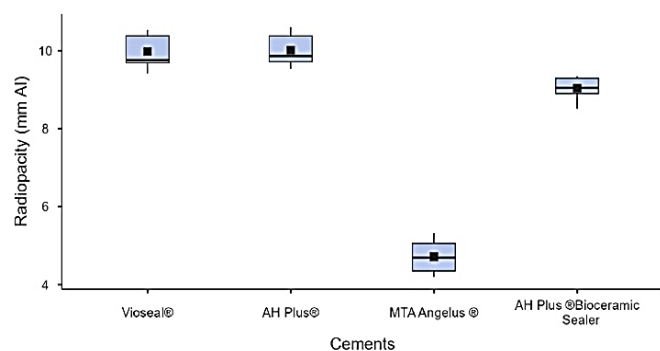


Figure 1. Comparison of the radiopacity of endodontic cements. Boxes represent the interquartile range, the horizontal line indicates the median, the black square represents the mean, and radiopacity was expressed in millimeters of aluminum (mm Al)

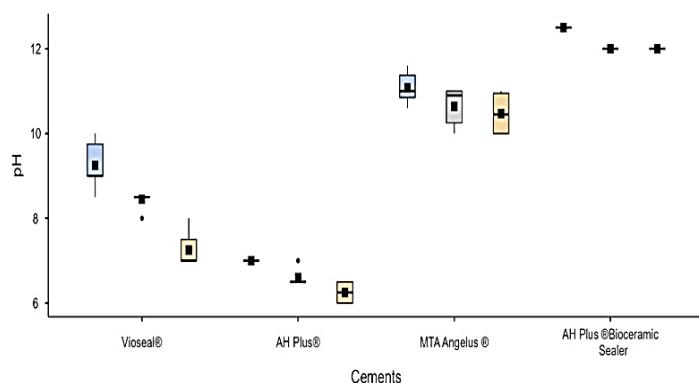


Figure 2. Comparison of the pH values of the endodontic cements evaluated at 1, 7, and 14 days. Boxes represent the interquartile range, the horizontal line indicates the median, the black square represents the mean, and the black dots correspond to outliers. pH was measured using deionized water at each experimental time point

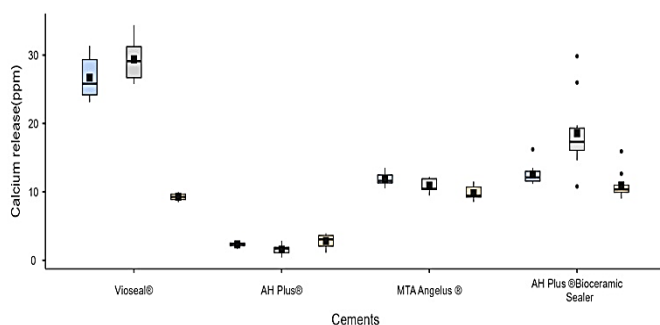


Figure 3. Comparison of calcium ion release (ppm) from the endodontic cements evaluated at 1, 7, and 14 days. Boxes represent the interquartile range, the horizontal line indicates the median, the black square represents the mean, and the black dots correspond to outliers. Calcium ion release was measured using spectrophotometry in deionized water at each experimental time point

In contrast, MTA Angelus, a calcium silicate-based cement, showed the lowest radiopacity (4.72 ± 0.40 mm Al), which was significantly different from the other evaluated cements ($P < 0.05$) (Table 2, Fig. 1).

Regarding pH behavior over the 1-, 7-, and 14-day periods, AH-Plus Bioceramic Sealer exhibited the highest and most sustained pH values (12.00 ± 0.00), while AH-Plus consistently showed the lowest values, reaching 6.25 ± 0.26 on day 14. Statistically significant differences were found among all cements at each evaluation period ($P < 0.05$) (Table 3, Fig. 2).

Regarding calcium ion release, Vioseal showed the highest concentrations at both day 1 (26.7 ± 3.12 ppm) and day 7 (29.4 ± 3.12 ppm), followed by AH-Plus Bioceramic Sealer at day 7 (18.60 ± 5.54 ppm). In contrast, AH-Plus exhibited the lowest calcium release at all evaluated time points, with a final value of 2.82 ± 0.96 ppm on day 14 ($P < 0.05$) (Table 4, Fig. 3).

Discussion

This study evaluated the radiopacity, pH, and calcium ion release of calcium silicate and epoxy resin-based endodontic cements. The results showed that calcium silicate-based sealers exhibited a sustained alkaline pH and continuous calcium ion release throughout the evaluation periods. In contrast, epoxy resin-based cements demonstrated significantly higher radiopacity compared to calcium silicate-based cements. These differences may significantly influence the clinical performance of the material and, therefore, the selection of the most appropriate cement, depending on the characteristics of each clinical case [23].

Radiopacity is a critical property of endodontic cements, as it enables their localization on radiographic examinations, facilitates the identification of potential defects, and supports postoperative monitoring factors that contribute to the clinical success of the treatment [8, 24].

In this study, all evaluated cements exceeded the minimum threshold of 3 mm Al established by ISO 6876:2012 [17], thereby ensuring their clinical acceptability. The methodology employed, based on the aluminum millimeter scale (mm Al), has been widely used in previous studies [23].

However, significant differences in radiopacity values were observed among the groups. Epoxy resin-based cements (AH-Plus and Vioseal) exhibited the highest radiopacity values, while calcium silicate-based cements (MTA Angelus and AH-Plus Bioceramic) showed lower values.

The findings of the present study are consistent with those reported by Tanomaru-Filho *et al.*, [24] who observed a radiopacity of 9.50 ± 0.30 mm Al for AH-Plus, which was higher

than that reported for calcium silicate-based cements. Additionally, Quaresma *et al.* [25] reported a radiopacity value of 9.17 ± 0.06 mm Al for the same sealer, which was also higher than that observed for AH-Plus Bioceramic, whose radiopacity was lower than its epoxy-based counterpart.

The high radiopacity of AH-Plus is associated with its formulation, which includes zirconium oxide and calcium tungstate in high proportions as radiopacifying agents. These compounds, due to their high atomic number, enhance the material's ability to absorb X-rays, producing radiographic images with greater contrast [11, 17]. This behavior may represent a clinical advantage by facilitating radiographic assessment of the root canal filling, particularly in cases where precise visualization of the material is required [8].

The relationship between chemical composition and radiographic behavior has been confirmed by previous studies using energy-dispersive spectroscopy (EDS), which identified the presence of these heavy oxides in the AH-Plus matrix. This may explain its significantly higher radiopacity compared to the bioceramic cements evaluated [26, 27].

Nevertheless, the radiographic performance of AH-Plus Bioceramic remains clinically acceptable. This finding may be attributed to formulation-related factors, particularly its 50-75% zirconium oxide content, a compound that acts as a radiopacifying agent and contributes significantly to its radiopacity, regardless of the sealer's base composition [6, 28].

MTA Angelus exhibited the lowest radiopacity among all sealers evaluated in this study. This limited radiopacity has also been reported by other authors, who attribute it to its lower concentration of bismuth oxide (20%) [29]. Although its clinical use remains valid, its low radiopacity may hinder its radiographic detection and differentiation from surrounding tissues [11].

Regarding pH, calcium silicate-based cements showed sustained alkaline values throughout the entire evaluation period, in contrast to epoxy resin-based cements. This behavior can be explained by the presence of calcium oxides and phosphate compounds, which release hydroxyl ions that raise the pH of the environment, contributing to their antibacterial activity [30]. In particular, AH-Plus Bioceramic exhibited a pH of 12 on day 14, demonstrating its ability to maintain an alkaline environment in the early stages.

Table 2. Description and comparison of the radiopacity of endodontic cements

	Mean (SD)*	Median	Minimum	Maximum
Vioseal	9.98 ^a (0.42)	9.76	9.42	10.50
AH-Plus	10.00 ^a (0.38)	9.87	9.54	10.60
MTA Angelus	4.72 ^b (0.40)	4.69	4.20	5.32
AH-Plus Bioceramic Sealer	9.04 ^c (0.28)	9.05	8.51	9.35

*Different lowercase letters indicate statistically significant differences according to the Kruskal-Wallis test and the Dwass-Steel-Critchlow-Fligner post-hoc test at a significance level of $P=0.05$

Table 3. Description and comparison of the pH of endodontic sealers analyzed at 1, 7, and 14 days

pH			
	1 day (SD)	7 days (SD)	14 days (SD)
Vioseal	9.25 (0.54) ^{Aa}	8.45 (0.16) ^{Ba}	7.25 (0.35) ^{Ca}
AH-Plus	7.00 (0.00) ^{Ab}	6.60 (0.21) ^{ABb}	6.25 (0.26) ^{Bb}
MTA Angelus	11.10 (0.34) ^{Ac}	10.60 (0.44) ^{ABc}	10.50 (0.47) ^{Bc}
AH-Plus Bioceramic Sealer	12.50 (0.00) ^{Ad}	12.00 (0.00) ^{Bd}	12.00 (0.00) ^{Bd}

Different lowercase letters indicate significant differences between sealers; different uppercase letters indicate significant differences between evaluation times (Kruskal-Wallis test and Dwass-Steel-Critchlow-Fligner post-hoc test)

Table 4. Description and comparison of calcium ion (Ca^{2+}) release (ppm) from endodontic sealers analyzed at 1, 7, and 14 days

Ca^{2+} (ppm)			
	1 day (SD)	7 days (SD)	14 days (SD)
Vioseal	26.7 (3.12) ^{Aa}	29.4 (3.12) ^{Aa}	9.28 (0.51) ^{Ba}
AH-Plus	2.32 (0.35) ^{Ab}	1.57 (0.74) ^{Ab}	2.82 (0.98) ^{Ab}
MTA Angelus	11.80 (1.00) ^{Ac}	10.90 (0.98) ^{Ac}	9.83 (1.02) ^{Aa}
AH-Plus Bioceramic Sealer	12.5 (1.51) ^{Ad}	18.60 (5.54) ^{Bd}	10.9 (2.03) ^{Aa}

Different lowercase letters indicate significant differences between sealers; different uppercase letters indicate significant differences between evaluation times (Kruskal-Wallis test and Dwass-Steel-Critchlow-Fligner post-hoc test)

These results are consistent with those reported by Kawak *et al.* [30] who evaluated the same sealer for up to 28 days and recorded a pH above 11 during the initial weeks. Complementarily, Souza *et al.* [31] also observed elevated pH values (10.5 to 11) at 7 days for AH-Plus Bioceramic, which were significantly higher compared to epoxy resin-based cements.

Previous studies have indicated that a sustained alkaline environment, such as that generated by calcium silicate-based cements, has been associated with reduced microbial viability and the stimulation of biological repair processes [32].

In the case of MTA Angelus, a sustained alkaline behavior was observed, with statistically significant differences across the evaluated time points. These findings are consistent with those reported by Nashibi *et al.* [32] who described that this cement maintains an adequate alkaline pH, although lower than that observed in newer-generation bioceramic cements.

In contrast, AH-Plus exhibited the lowest pH values in the study (6.25), results that are consistent with its non-bioactive epoxy resin-based composition. This characteristic represents a disadvantage compared to calcium silicate-based cements, as it may not adequately support root canal disinfection [5, 32].

In the present study, AH-Plus Bioceramic showed an abrupt decrease in calcium ion release from day 14 onward. This behavior is consistent with the findings of Zamparini *et al.* [33] also observed a significant decline in this cement starting at the same time point, which persisted through day 28 of evaluation.

This pattern was also documented by Raman *et al.* [34] reported that AH-Plus Bioceramic exhibited lower calcium ion release compared to other calcium silicate-based cements, which was attributed to its low tricalcium silicate content (5.15%). This decrease may also be explained by the formation of surface precipitates and the reduction of soluble calcium-containing compounds in the cement, as previously described in earlier studies [16, 35].

The decrease in calcium ion release is clinically relevant, as adequate and sustained calcium release is essential to promote bioactivity [36], including hydroxyapatite formation, tissue regeneration, biological sealing, and remineralization processes that contribute to proper healing in endodontic treatments [33].

Calcium ion release is a distinguishing feature of calcium silicate-based cements, attributed to their hydrophilic nature and the presence of calcium-containing compounds in their formulation [36].

Unlike previous studies, which reported higher calcium ion release from calcium silicate-based sealers compared to epoxy resin-based cements [19, 27], the present investigation detected

high calcium ion release on days 1 and 7 from Vioseal, an epoxy resin-based cement. Remarkably, its release exceeded that of the calcium silicate-based cements AH-Plus Bioceramic and MTA Angelus. This behavior is atypical for an epoxy-based cement.

Previous research has documented those compounds, such as calcium phosphate, when in contact with aqueous environments, may dissociate and release calcium ions [37]. This phenomenon may explain the behavior observed in Vioseal, whose formulation includes calcium phosphate, as reported in previous studies [16]. This initial dissociation of the compound could result in an intense but transient calcium ion release, as observed in the results of the present study.

In this study, a standardized volume of 10 mL of deionized water was used uniformly for each sample, following the methodology reported in previous studies [38-40]. This volume was sufficient to fully cover the specimens and maintain stable experimental conditions.

Although no published studies currently provide an in-depth analysis of the physicochemical properties and composition of Vioseal, the findings of this investigation suggest that this sealer should be further studied in future research.

Therefore, the findings of the present investigation provide updated insights into the physicochemical properties of endodontic sealers with different compositions, particularly by demonstrating that Vioseal, an epoxy resin-based cement, exhibited an initial calcium ion release even higher than that of calcium silicate-based sealers. This unusual behavior may open new lines of research regarding the influence of specific components, such as calcium phosphate, on the bioactivity profile of epoxy-based cements that are not traditionally considered bioactive.

From a clinical perspective, these results may offer objective criteria for selecting endodontic cements based on their radiopacity, pH, and calcium ion release. Such evidence-based decision-making would allow clinicians to choose the most appropriate material according to the specific therapeutic needs of each case, and may also serve as a foundation for future investigations focused on evaluating hybrid or non-conventional formulations.

Conclusion

All evaluated endodontic cements met the minimum radiopacity criteria required by ISO 6876:2012. Calcium silicate-based cements exhibited alkaline pH values and sustained calcium ion release throughout the evaluation period,

while Vioseal, an epoxy resin-based cement, showed an initial release of calcium ions at the beginning of the observation period. Although these findings provide relevant information on the physicochemical properties of the tested cements, further research is needed to determine their clinical implications, considering that this study was conducted under *in vitro* conditions.

Acknowledgements

None.

Conflict of interest

None.

Funding support

None.

Authors' contributions

Conceptualization: MJL-C; Methodology: MJL-C; Formal Analysis and Investigation: MJL-C; Writing-Original Draft Preparation: MJL-C; Writing-Review and Editing: MJL-C/CRG-R; Supervision: CRG-R. All authors read and approved the final manuscript.

References

- Schilder H. Filling root canals in three dimensions. *Dent Clin North Am*. 1967;723-44.
- Sobhnamayan F, Adl A, Shojaee NS, Zarei Z, Emkani A. Physical and Chemical Properties of CEM Cement Mixed with Propylene Glycol. *Iran Endod J*. 2017;12(4):474-80.
- Branstetter J, von Fraunhofer JA. The physical properties and sealing action of endodontic sealer cements: a review of the literature. *J Endod*. 1982;8(7):312-6.
- Baras BH, Melo MAS, Thumbigere-Math V, Tay FR, Fouad AF, Oates TW, et al. Novel Bioactive and Therapeutic Root Canal Sealers with Antibacterial and Remineralization Properties. *Materials (Basel)*. 2020;13(5).
- Khalil I, Naaman A, Camilleri J. Properties of Tricalcium Silicate Sealers. *J Endod*. 2016;42(10):1529-35.
- Chen JH, Raman V, Kuehne SA, Camilleri J, Hirschfeld J. Chemical, Antibacterial, and Cytotoxic Properties of Four Different Endodontic Sealer Leachates Over Time. *J Endod*. 2024;50(11):1612-21.
- Komabayashi T, Colmenar D, Cvach N, Bhat A, Primus C, Imai Y. Comprehensive review of current endodontic sealers. *Dent Mater J*. 2020;39(5):703-20.
- Sen HG, Helvacioğlu-Yigit D, Yilmaz A. Radiopacity evaluation of calcium silicate cements. *BMC Oral Health*. 2023;23(1):491.
- de Vasconcelos BC, Bernardes RA, Cruz SM, Duarte MA, Padilha Pde M, Bernardineli N, et al. Evaluation of pH and calcium ion release of new root-end filling materials. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2009;108(1):135-9.
- Donnermeyer D, Bürklein S, Dammascchke T, Schäfer E. Endodontic sealers based on calcium silicates: a systematic review. *Odontology*. 2019;107(4):421-36.
- Sarunket C, Banomyong D, Vibulcharoenkitja P, Sutimuntanakul S. Radiopacity of Portland Cement and Calcium Silicate-Based Cement with Different Mixed Ratios of Radiopacifiers. *Eur Endod J*. 2022;7(1):52-7.
- Candeiro GT, Correia FC, Duarte MA, Ribeiro-Siqueira DC, Gavini G. Evaluation of radiopacity, pH, release of calcium ions, and flow of a bioceramic root canal sealer. *J Endod*. 2012;38(6):842-5.
- Zebadúa-Castellanos CH, Marín-Miranda M, Guerrero Ibarra J, Flores-Ledesma A, García-Briseño K, Bucio-Galindo L, et al. Evaluación de pH, fraguado y resistencia a la compresión de dos cementos MTA comerciales y un MTA de reciente desarrollo. *Revista Odontológica Mexicana*. 2022;26(1):51-62.
- Retana-Lobo C, Tanomaru-Filho M, Guerreiro-Tanomaru JM, Benavides-García M, Hernández-Meza E, Reyes-Carmona J. Push-Out Bond Strength, Characterization, and Ion Release of Premixed and Powder-Liquid Bioceramic Sealers with or without Gutta-Percha. *Scanning*. 2021;2021:6617930.
- Cardinali F, Camilleri J. A critical review of the material properties guiding the clinician's choice of root canal sealers. *Clin Oral Investig*. 2023;27(8):4147-55.
- Hamdy TM, Galal MM, Ismail AG, Saber S. Physicochemical properties of AH plus bioceramic sealer, Bio-C Sealer, and ADSeal root canal sealer. *Head Face Med*. 2024;20(1):2.
- Standardization I, Standardization I. ISO 6876: Dental Root Canal Sealing Materials. ISO Geneva. 2001.
- Ashraf H, Mortezaipoor N, Jabari S, Zadsirjan S, Tabatabai FS. Evaluation of Chemical and Physical Properties of an Experimental Endodontic Sealer in Comparison with AH-26 and AH-Plus. *Iran Endod J*. 2020;15(3):183-7.
- Zordan-Bronzel CL, Esteves Torres FF, Tanomaru-Filho M, Chávez-Andrade GM, Bosso-Martelo R, Guerreiro-Tanomaru JM. Evaluation of Physicochemical Properties of a New Calcium Silicate-based Sealer, Bio-C Sealer. *J Endod*. 2019;45(10):1248-52.
- Katakidis A, Sidiropoulos K, Koulaouzidou E, Gogos C, Economides N. Flow characteristics and alkalinity of novel bioceramic root canal sealers. *Restor Dent Endod*. 2020;45(4):e42.
- Villa N, Santos VVD, Costa UMD, Mendes AT, Duarte PHM, Rosa RAD, et al. A New Calcium Silicate-Based Root Canal Dressing: Physical and Chemical Properties, Cytotoxicity and Dentinal Tubule Penetration. *Braz Dent J*. 2020;31(6):598-604.
- Park MG, Kim IR, Kim HJ, Kwak SW, Kim HC. Physicochemical properties and cytocompatibility of newly developed calcium silicate-based sealers. *Aust Endod J*. 2021;47(3):512-9.
- Malka VB, Hochscheidt GL, Larentis NL, Grecca FS, Fontanella VR, Kopper PM. A new in vitro method to evaluate radio-opacity of endodontic sealers. *Dentomaxillofac Radiol*. 2015;44(5):20140422.
- Tanomaru-Filho M, Cristine Prado M, Torres FFE, Viapiana R, Pivoto-João MMB, Guerreiro-Tanomaru JM. Physicochemical Properties and Bioactive Potential of a New Epoxy Resin-based Root Canal Sealer. *Braz Dent J*. 2019;30(6):563-8.
- Quaresma SAL, Alves Dos Santos GN, Silva-Sousa AC, Camargo

- RV, Lopes-Olhê FC, Silva-Sousa YTC, et al. Physicochemical properties of calcium silicate cement based endodontic sealers. *J Mech Behav Biomed Mater*. 2024;151:106400.
26. Mann A, Zeng Y, Kirkpatrick T, van der Hoeven R, Silva R, Letra A, et al. Evaluation of the Physicochemical and Biological Properties of EndoSequence BC Sealer HiFlow. *J Endod*. 2022;48(1):123-31.
 27. Malta CP, Santi SS, Barcelos RCS, Zanatta FB, Bier CAS, Morgental RD. Premixed calcium silicate-based root canal sealers have better biological properties than AH Plus: A systematic review and meta-analysis of in vivo animal studies and in vitro laboratory studies. *J Conserv Dent Endod*. 2024;27(4):345-59.
 28. Salehimehr G, Nobahar S, Hosseini-Zijoud S-M, Yari S. Comparison of physical & chemical properties of Angelus MTA and new endodontic restorative material. *J Applied Pharma Sci*. 2014;4(7):105-9.
 29. Camilleri J, Atmeh A, Li X, Meschi N. Present status and future directions: Hydraulic materials for endodontic use. *Int Endod J*. 2022;55 Suppl 3(Suppl 3):710-77.
 30. Kwak SW, Koo J, Song M, Jang IH, Gambarini G, Kim HC. Physicochemical Properties and Biocompatibility of Various Bioceramic Root Canal Sealers: In Vitro Study. *J Endod*. 2023;49(7):871-9.
 31. Souza LC, Neves GST, Kirkpatrick T, Letra A, Silva R. Physicochemical and Biological Properties of AH Plus Bioceramic. *J Endod*. 2023;49(1):69-76.
 32. Nashibi S, Amdjadi P, Ahmadi S, Hekmatian S, Torshabi M. Physical, chemical and biological properties of MTA Angelus and novel AGM MTA: an in vitro analysis. *BMC Oral Health*. 2025;25(1):145.
 33. Zamparini F, Siboni F, Prati C, Taddei P, Gandolfi MG. Properties of calcium silicate-monobasic calcium phosphate materials for endodontics containing tantalum pentoxide and zirconium oxide. *Clin Oral Investig*. 2019;23(1):445-57.
 34. Raman V, Camilleri J. Characterization and Assessment of Physical Properties of 3 Single Syringe Hydraulic Cement-based Sealers. *J Endod*. 2024;50(3):381-8.
 35. Maharti ID, Rosseti R, Asrianti D, Herdianto N, Rianti W. Calcium Silicate-Based Sealers: Apatite Deposition on Root Canal Dentin and pH Variation Analysis. *Eur J Dent*. 2025;19(2):374-81.
 36. Sfeir G, Zogheib C, Patel S, Giraud T, Nagendrababu V, Bukiet F. Calcium Silicate-Based Root Canal Sealers: A Narrative Review and Clinical Perspectives. *Materials (Basel)*. 2021;14(14).
 37. Chambilla-Torres K, Sánchez-Tito MA. Efecto antimicrobiano de tres cementos selladores endodónticos frente a *Streptococcus mutans*, *Enterococcus faecalis* y *Candida albicans*. *Int J Odontostomat*. 2021;15(3):610-5.
 38. Sanz JL, López-García S, Rodríguez-Lozano FJ, Melo M, Lozano A, Llena C, et al. Cytocompatibility and bioactive potential of AH Plus Bioceramic Sealer: An in vitro study. *Int Endod J*. 2022;55(10):1066-80.
 39. Zamparini F, Prati C, Taddei P, Spinelli A, Di Foggia M, Gandolfi MG. Chemical-Physical Properties and Bioactivity of New Premixed Calcium Silicate-Bioceramic Root Canal Sealers. *Int J Mol Sci*. 2022;23(22).
 40. Lee JK, Kwak SW, Ha JH, Lee W, Kim HC. Physicochemical Properties of Epoxy Resin-Based and Bioceramic-Based Root Canal Sealers. *Bioinorg Chem Appl*. 2017;2017:2582849.

Please cite this paper as: Loyola-Cano MJ, García-Rupaya CR. Evaluation of the Radiopacity, pH, and Calcium Ion Release of Calcium Silicate and Epoxy Resin-Based Endodontic Cements. *Iran Endod J*. 2025;20(1): e40. Doi: 10.22037/iej.v20i1.48935.