JHWCR JOURNAL OF HEALTH, WELLNESS AND COMMUNITY RESEARCH 3007-0570

https://doi.org/10.61919/ck32sr07

Original Article

Sealing Ability of Calcium Silicate–Based Sealers Under Different Moisture Conditions

Dr Fawad Ali Shah[1], Dr Javairia Ali[2], Saher Ahmed[3], Iqra Riaz Gillani[4], Anusheh Zafar[5], Z.H Shar[6]

[1] Assistant Professor, Khyber College of Dentistry, Peshawar, Pakistan
[2] Post Graduate Resident, Operative Dentistry and Endodontics, Khyber College of Dentistry, Peshawar, Pakistan
[3] BDS, MBA, CHPE, Lecturer Dental Materials, Hamdard University Dental Hospital, Karachi, Pakistan
[4] Bolan Medical Complex Hospital, Quetta, Pakistan
[5] Foundation University, Islamabad, Pakistan
[6] Dr M.A KAZI Institute of Chemistry, University of Sindh, Jamshoro, Pakistan

*Corresponding author: Dr Javairia Ali, javairiaali1998@gmail.com

"Cite this Article" **Received**: 08 January 2026; **Accepted**: 11 April 2026; **Published**: 18 May 2026
Author Contributions: Concept: FAS; Design: JA; Data Collection: SA, IRG; Analysis: AZ, ZHS; Drafting: FAS, JA. **Ethical Approval** was obtained from the Respective Institution. **Informed Consent**: Written informed consent was obtained from all participants; **Conflict of Interest**: The authors declare no conflict of interest. **Funding**: No external funding; **Data Availability**: Available from the corresponding author on reasonable request; **Acknowledgments**: N/A.

ABSTRACT

Background: A durable apical seal is essential for successful endodontic treatment because inadequate obturation may permit microleakage and reinfection. Calcium silicate–based sealers are hydrophilic hydraulic materials that require moisture for setting; however, the ideal intracanal moisture condition for optimal sealing remains uncertain. Objective: To evaluate the effect of different intracanal moisture conditions on the sealing ability of a calcium silicate–based root canal sealer. Methods: This in-vitro experimental study included 60 extracted permanent single-rooted human teeth with fully formed apices. After standardization of root length, canals were prepared using rotary nickel-titanium instruments and irrigated with 2.5% sodium hypochlorite, 17% EDTA, and distilled water. The specimens were randomly divided into three groups according to canal moisture condition before obturation: dry canal, slightly moist canal, and wet canal, with 20 teeth in each group. All canals were obturated using gutta-percha and a calcium silicate–based sealer with the single-cone technique. Samples were stored at 37°C and 100% humidity for seven days. Apical sealing ability was assessed using 2% methylene blue dye penetration for 48 hours, followed by longitudinal sectioning and stereomicroscopic evaluation at 20× magnification. Data were analyzed using one-way ANOVA, with significance set at $p < 0.05$. Results: The slightly moist canal group showed the lowest mean dye penetration at 0.75 ± 0.19 mm, followed by the dry canal group at 1.16 ± 0.24 mm. The wet canal group showed the highest mean dye penetration at 1.59 ± 0.25 mm. One-way ANOVA demonstrated a statistically significant difference among the three groups, indicating that intracanal moisture condition significantly affected apical leakage. Conclusion: Controlled residual moisture improved the sealing ability of the calcium silicate–based root canal sealer, whereas excessive moisture increased apical microleakage. A slightly moist canal environment may therefore be more favorable than complete dryness or visible wetness during obturation with hydraulic calcium silicate–based sealers. Keywords: Calcium silicate sealer; bioceramic sealer; intracanal moisture; root canal obturation; apical microleakage; dye penetration; endodontic sealer.

INTRODUCTION

Successful endodontic treatment depends on effective elimination of infection from the root canal system followed by three-dimensional obturation that prevents reinfection. Although gutta-percha remains the most widely used core obturation material, it does not independently bond to dentin or completely seal canal irregularities, accessory canals, and dentinal tubules (1). Root canal sealers are therefore essential for filling interfacial spaces between gutta-percha and canal walls, improving adaptation, and reducing pathways for microbial leakage. The quality of this seal is a key determinant of long-term endodontic success (2).

Calcium silicate–based sealers, often referred to as bioceramic sealers, have gained increasing attention in contemporary endodontics because of their hydrophilicity, biocompatibility, bioactivity, alkaline pH, and ability to release calcium ions. Unlike many conventional resin-based or zinc oxide eugenol–based sealers, calcium silicate materials are hydraulic; they require moisture to initiate and sustain their hydration reaction. During setting, these materials may contribute to calcium hydroxide formation, hydroxyapatite deposition, and improved interaction with dentin, which may enhance the sealer–dentin interface (3,4).

The moisture condition of the root canal before obturation is therefore particularly relevant when calcium silicate–based sealers are used. In clinical practice, complete canal dryness is difficult to achieve because dentinal tubules naturally contain fluid and irrigants are repeatedly introduced during cleaning and shaping. Although residual moisture may support the setting of hydraulic sealers, excessive fluid may dilute the sealer, impair its adaptation to dentinal walls, or create interfacial voids. Conversely, over-drying may deprive the material of the moisture required for optimal hydration (5,6).

Previous studies have reported favorable sealing ability, dentinal tubule penetration, and bioactive behavior of calcium silicate–based sealers, but the ideal intracanal moisture condition for their use remains uncertain. Some evidence suggests that limited residual moisture may improve adaptation and setting, while other findings indicate that excessive wetness can compromise physical properties and increase leakage (7,8). This uncertainty has practical importance because clinicians must decide how thoroughly canals should be dried before obturation with hydraulic sealers.

Therefore, this in-vitro study aimed to evaluate the effect of different intracanal moisture conditions on the apical sealing ability of a calcium silicate–based root canal sealer. Specifically, dye penetration was compared among dry, slightly moist, and wet canal conditions to determine which environment provided the most favorable seal.

MATERIALS AND METHODS

This in-vitro experimental study was conducted to evaluate the effect of intracanal moisture conditions on the sealing ability of a calcium silicate–based root canal sealer. The study was performed in the Department of Operative Dentistry and Endodontics at a tertiary care hospital in Peshawar, Pakistan, with laboratory support for sample preparation, obturation, storage, and microleakage assessment. Ethical approval was obtained from the Institutional Research and Ethics Committee because extracted human teeth were used as experimental samples.

A total of 60 extracted permanent human single-rooted teeth with fully formed apices were selected. The teeth had been extracted for orthodontic or periodontal reasons. Teeth with cracks, root caries, internal resorption, immature apices, previous endodontic treatment, or visible structural defects were excluded (9). After collection, the teeth were rinsed under running water to remove blood and debris, and remaining soft tissue tags were removed from the root surfaces using periodontal curettes. The samples were stored in 0.1% thymol solution at room temperature until use. Before preparation, each tooth was examined under magnification, and radiographs were taken to confirm the presence of a single canal and to exclude internal anatomical defects.

To standardize the specimens, the crowns were sectioned using a high-speed diamond disc under continuous water cooling, producing root samples of approximately 15 mm in length. Canal patency was confirmed using a #10 K-file. Working length was determined by inserting the file into the canal until its tip was visible at the apical foramen, and 1 mm was subtracted from this measurement.

Root canal preparation was performed using rotary nickel-titanium instruments according to the manufacturer's instructions. Instrumentation was completed up to a size equivalent to ProTaper F3. During canal preparation, irrigation was performed with 2.5% sodium hypochlorite after each instrument. After completion of shaping, the smear layer was removed by irrigating the canals with 17%

EDTA for one minute (10). A final rinse with distilled water was then performed to remove residual irrigants. The canals were dried with absorbent paper points before allocation to the experimental groups.

The prepared teeth were randomly divided into three groups of 20 samples each according to the intracanal moisture condition before obturation. In the dry canal group, canals were dried thoroughly with sterile absorbent paper points until no visible moisture remained. In the slightly moist canal group, canals were gently dried with paper points while avoiding complete desiccation, leaving a small amount of residual moisture on the canal walls. In the wet canal group, canals were left visibly moist after irrigation, with only minimal removal of excess irrigant before obturation.

All canals were obturated using a calcium silicate–based bioceramic sealer and gutta-percha with the single-cone technique. The sealer was handled according to the manufacturer's instructions and introduced into the canal using a lentulo spiral to promote distribution along the canal walls. A gutta-percha cone corresponding to the final preparation size was coated with sealer and inserted to the predetermined working length. Excess gutta-percha was removed coronally using a heated instrument, and the coronal access was sealed with temporary restorative material.

After obturation, all samples were stored at 37°C in 100% humidity for seven days to allow the sealer to set under controlled conditions. The sealing ability was then assessed using the dye penetration method. The external root surfaces were coated with two layers of nail varnish, leaving the apical 2 mm exposed to permit dye entry only through the apical region. The specimens were immersed in 2% methylene blue dye for 48 hours (11). After dye exposure, the samples were rinsed thoroughly under running water to remove excess surface dye.

Each specimen was sectioned longitudinally using a diamond disc to expose the filled root canal. Dye penetration from the apical end toward the coronal direction was examined under a stereomicroscope at 20× magnification. The maximum linear extent of dye penetration was measured in millimeters using a digital caliper. The recorded dye penetration value represented the degree of apical microleakage for each sample.

Data were entered and analyzed using SPSS version 25. Descriptive statistics were calculated as mean and standard deviation for dye penetration values in each group. The three moisture groups were compared using one-way analysis of variance. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 60 extracted single-rooted human teeth were included and allocated equally into three experimental groups according to intracanal moisture condition before obturation: dry canal, slightly moist canal, and wet canal. Each group contained 20 specimens. Apical dye penetration was measured in millimeters after immersion in 2% methylene blue dye for 48 hours and examination under 20× stereomicroscopic magnification.

The lowest mean dye penetration was observed in the slightly moist canal group, followed by the dry canal group and the wet canal group. Mean apical dye penetration was 0.75 ± 0.19 mm in the slightly moist group, 1.16 ± 0.24 mm in the dry canal group, and 1.59 ± 0.25 mm in the wet canal group. The distribution of leakage values across groups is summarized in Table 1.

Table 1. Mean Apical Dye Penetration According to Intracanal Moisture Condition

Group	Sample Size, n	Mean Dye Penetration (mm)	Standard Deviation
Dry canal condition	20	1.16	0.24
Slightly moist canal condition	20	0.75	0.19
Wet canal condition	20	1.59	0.25

The slightly moist canal group showed the lowest recorded mean leakage value, while the wet canal group showed the highest mean leakage value. The dry canal group showed an intermediate mean dye penetration value between the other two groups.

A one-way analysis of variance was applied to compare mean dye penetration among the three moisture groups. The analysis showed a statistically significant difference among the groups, with an F value of 12.63 and a reported p value < 0.05. The ANOVA findings are presented in Table 2.

Table 2. One-Way ANOVA Comparison of Apical Dye Penetration Among Groups

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value	p Value
Between groups	7.48	2	3.74	12.63	<0.05
Within groups	16.86	57	0.29	—	—
Total	24.34	59	—	—	—

The comparison demonstrated that intracanal moisture condition was associated with a statistically significant difference in mean apical dye penetration among the three experimental groups.

For clearer presentation of the main numerical pattern, the experimental groups has also be ranked according to mean leakage values. The ranking is shown in Table 3.

Table 3. Ranking of Moisture Conditions by Mean Apical Dye Penetration

Rank by Leakage	Moisture Condition	Mean Dye Penetration (mm)	Relative Position
1	Slightly moist canal	0.75	Lowest leakage
2	Dry canal	1.16	Intermediate leakage
3	Wet canal	1.59	Highest leakage

The difference in mean dye penetration between the wet canal and slightly moist canal groups was 0.84 mm. The dry canal group showed 0.41 mm greater mean dye penetration than the slightly moist canal group, while the wet canal group showed 0.43 mm greater mean dye penetration than the dry canal group.

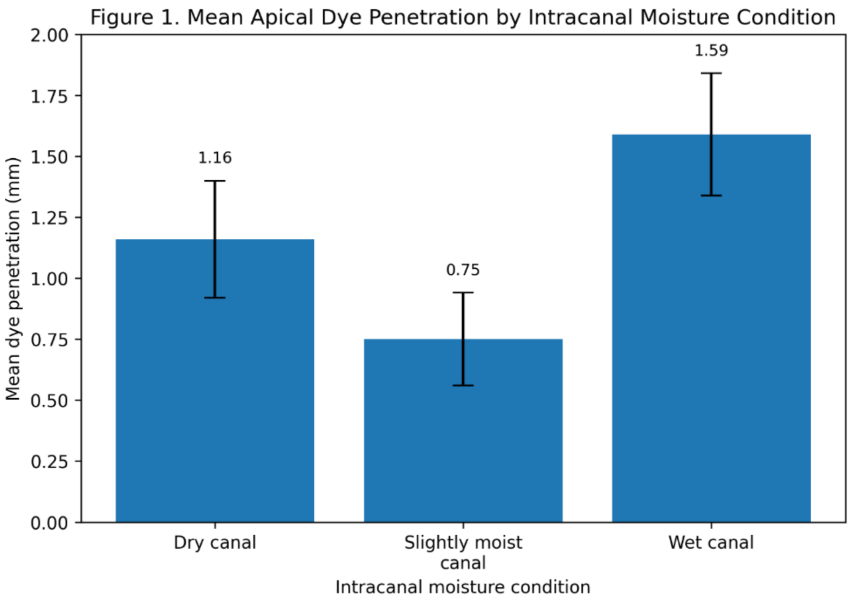

Figure 1. Mean Apical Dye Penetration by Intracanal Moisture Condition

Figure 1 shows the mean apical dye penetration values recorded in the three experimental groups: dry canal, slightly moist canal, and wet canal. The slightly moist canal group demonstrated the lowest mean dye penetration, indicating the least apical microleakage among the tested conditions. The dry canal group showed an intermediate level of dye penetration, while the wet canal group showed the highest mean dye penetration. This pattern indicates that controlled residual moisture was associated with better sealing performance, whereas excessive moisture was associated with increased leakage.

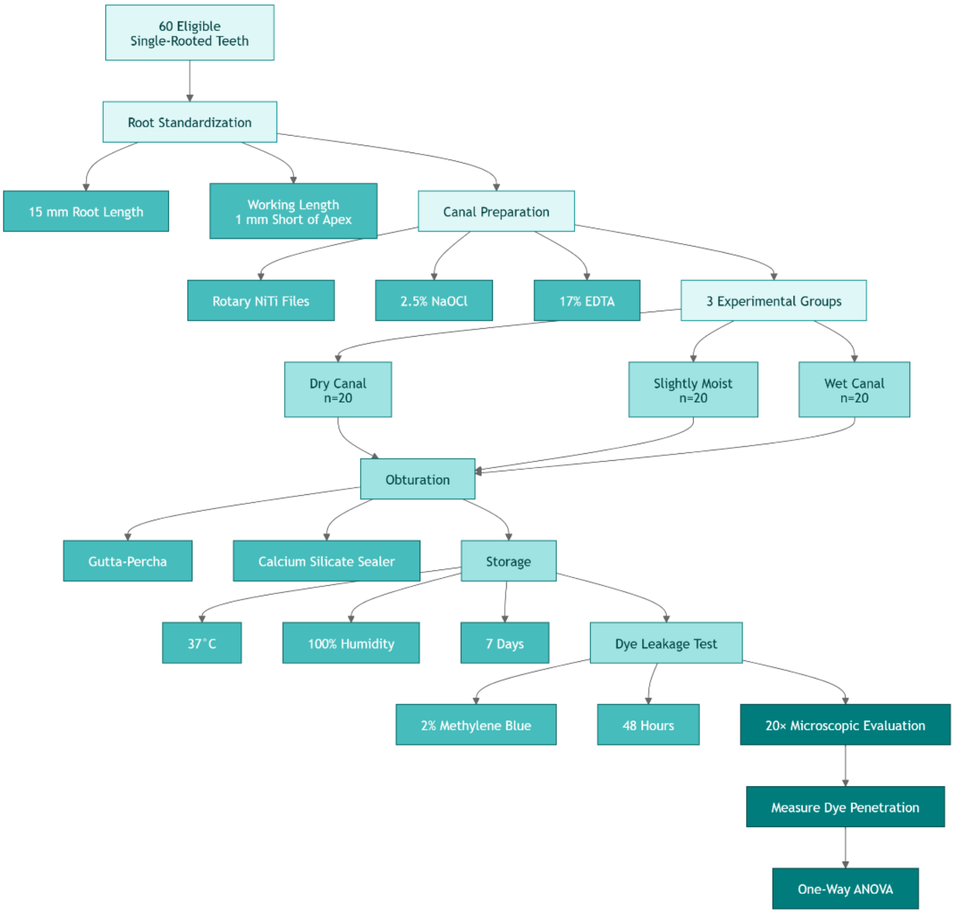

Figure 2. Experimental Workflow of the In-Vitro Study

This workflow summarizes the experimental protocol used to evaluate the sealing ability of a calcium silicate–based sealer under different intracanal moisture conditions. Sixty standardized single-rooted teeth underwent canal preparation and irrigation before random allocation into dry, slightly moist, and wet canal groups (n=20 each). Following obturation with gutta-percha and calcium silicate sealer, samples were stored at 37°C and 100% humidity for seven days, followed by dye leakage assessment using 2% methylene blue and stereomicroscopic evaluation at 20× magnification before statistical analysis using one-way ANOVA.

DISCUSSION

The present in-vitro study evaluated the effect of different intracanal moisture conditions on the apical sealing ability of a calcium silicate–based root canal sealer. The principal finding was that the slightly moist canal condition produced the lowest mean dye penetration, while the wet canal condition produced the highest leakage. The dry canal group showed intermediate values. These findings indicate that the amount of residual moisture present inside the root canal before obturation can influence the sealing performance of calcium silicate–based sealers.

The superior performance observed in the slightly moist canal group may be related to the hydraulic nature of calcium silicate–based sealers. These materials require moisture to initiate and continue their hydration reaction. A limited amount of residual moisture on the canal walls may therefore support sealer setting, improve flow along dentinal surfaces, and enhance adaptation to canal irregularities. In this study, the slightly moist condition showed the lowest mean apical dye penetration, suggesting that controlled moisture may create a more favorable environment for sealing than complete dryness or excessive wetness.

The dry canal group demonstrated greater dye penetration than the slightly moist group. This finding suggests that complete drying may not provide the most favorable condition for calcium silicate–based sealers. Unlike resin-based sealers, which generally require a dry field for optimal performance, calcium silicate–based materials depend on moisture for hydration. Excessive drying may reduce the availability of moisture required for proper setting and may limit the interaction between the sealer and dentinal walls (12,13). As a result, the sealer may not adapt as effectively to the canal surface, which could explain the intermediate leakage values observed in the dry canal group.

In contrast, the wet canal group showed the highest mean dye penetration. This indicates that although calcium silicate–based sealers require moisture, the presence of excessive fluid inside the canal may compromise their sealing ability. Excess moisture may dilute the sealer, alter its consistency, interfere with placement, or prevent close adaptation between the sealer and dentin (14). It may also contribute to the formation of voids or interfacial gaps, allowing greater dye penetration from the apical region. Therefore, the results support the concept that these sealers perform best in a controlled moist environment rather than in visibly wet canals.

The findings are clinically relevant because complete canal dryness is often difficult to achieve during endodontic treatment. Dentinal tubules naturally contain fluid, and irrigants used during cleaning and shaping may remain inside the canal despite paper-point drying. The present results suggest that, when using calcium silicate–based sealers, clinicians should aim to remove visible excess fluid while avoiding complete desiccation of canal walls (15). A slightly moist canal environment may allow better sealer performance, whereas leaving the canal overly wet may increase the risk of microleakage.

These findings also reinforce the importance of adapting drying protocols to the type of sealer being used. Traditional obturation protocols often emphasize complete canal dryness, particularly for materials that are sensitive to moisture contamination (16,17). However, this approach may not be ideal for hydraulic calcium silicate–based sealers. For these materials, the goal should be controlled moisture management: the canal should be free of pooled irrigant or visible wetness but should not be excessively dried.

The results of this study are consistent with the known properties of calcium silicate–based sealers, including hydrophilicity, moisture-dependent setting, and potential interaction with dentin. Their ability to release calcium ions and form mineralized interfacial deposits has been suggested as a possible contributor to improved sealing (18,19). However, the present study assessed sealing ability through dye penetration only; it did not directly evaluate hydration products, dentinal tubule penetration, chemical bonding, or hydroxyapatite formation. Therefore, these mechanisms should be interpreted as possible explanations rather than directly demonstrated findings.

The use of extracted human teeth and standardized canal preparation strengthens the experimental design by allowing comparison under controlled laboratory conditions. The division of samples into equal groups and the use of a single obturation technique also helped reduce procedural variation. Dye penetration testing provided a simple quantitative method for comparing apical leakage among groups. However, dye leakage methods have limitations because dye molecules are smaller than bacteria and may not fully represent clinical microbial leakage. Therefore, the findings should be interpreted within the limitations of an in-vitro microleakage model.

Several additional limitations should be considered. First, the study was performed under laboratory conditions and cannot fully reproduce the oral environment, where factors such as tissue fluids, blood contamination, canal anatomy, occlusal forces, and long-term functional stresses may influence sealer behavior. Second, only one calcium silicate–based sealer was tested, so the findings may not apply equally to all commercially available bioceramic sealers, which may differ in composition, particle size, flow, solubility, and setting characteristics. Third, the moisture conditions were categorized as dry, slightly moist, and wet, but these conditions were not quantified by volume of residual fluid. More precise standardization of moisture levels could improve reproducibility in future research.

Future studies should compare different calcium silicate–based sealers under standardized moisture conditions and use additional assessment methods such as micro-computed tomography, scanning electron microscopy, fluid filtration, or bacterial leakage models. Long-term evaluation after aging, thermocycling, or simulated clinical stress would also provide useful information about the durability of the seal. Further research may also examine how different irrigation protocols, final rinse solutions, and drying techniques affect sealer adaptation and microleakage.

Overall, this study demonstrates that intracanal moisture condition has a significant influence on the sealing ability of calcium silicate–based root canal sealers. A slightly moist canal condition produced the most favorable sealing result, while excessive wetness increased apical leakage. These findings support the use of controlled canal drying before obturation with hydraulic calcium silicate–based sealers and suggest that maintaining slight residual moisture may improve apical sealing performance.

CONCLUSION

Within the limitations of this in-vitro study, intracanal moisture significantly influenced the sealing ability of the calcium silicate–based root canal sealer. The slightly moist canal condition showed the lowest mean dye penetration, indicating better apical sealing, whereas the wet canal condition showed the highest leakage. These findings suggest that controlled residual moisture may provide a more favorable environment for calcium silicate–based sealers than either complete dryness or excessive wetness during obturation.

REFERENCES

1. Camilleri J. Hydraulic calcium silicate cements in endodontics. Int Endod J. 2015. doi:10.1111/iej.12380
2. Donnermeyer D, et al. Calcium silicate-based sealers: a review of properties and clinical implications. Materials. 2021. doi:10.3390/ma14143965
3. Khalil I, et al. Physicochemical properties of AH Plus bioceramic sealer and Bio-C sealer. Head Face Med. 2024. doi:10.1186/s13005-023-00403-z
4. Zhang W, et al. Solubility and sealing characteristics of iRoot SP root canal sealer. Acta Odontol Scand. 2011. doi:10.3109/00016357.2011.572291
5. Siboni F, et al. Push-out bond strength of calcium silicate-based sealers. J Endod. 2017. doi:10.1016/j.joen.2016.10.018
6. Loushine BA, et al. Setting properties and sealing ability of bioceramic sealers. J Endod. 2011. doi:10.1016/j.joen.2010.11.021
7. Han L, Okiji T. Bioactivity evaluation of calcium silicate-based root canal sealers. Int Endod J. 2013. doi:10.1111/iej.12022
8. De-Long C, He J. Materials science in endodontics. Dent Clin North Am. 2007. doi:10.1016/j.cden.2007.01.002
9. Grossman LI. Physical properties of root canal sealers. J Endod. 1976. doi:10.1016/S0099-2399(76)80123-1
10. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive review. J Endod. 2010. doi:10.1016/j.joen.2009.09.009

11. Zhang H, Shen Y, et al. Antibacterial activity of calcium silicate-based sealers. J Dent. 2009. doi:10.1016/j.jdent.2008.11.004

12. Candeiro GTM, et al. Cytotoxicity of calcium silicate sealers. J Appl Oral Sci. 2016. doi:10.1590/1678-775720150412

13. Viapiana R, et al. Chemical characterization of bioceramic root canal sealers. J Endod. 2014. doi:10.1016/j.joen.2013.10.019

14. Gandolfi MG, et al. Calcium silicate materials: properties and clinical applications. Clin Oral Investig. 2015. doi:10.1007/s00784-015-1506-7

15. Reyes-Carmona JF, et al. Biomineralization ability of bioceramic sealers. J Endod. 2009. doi:10.1016/j.joen.2009.04.024

16. Shokouhinejad N, et al. Bond strength of bioceramic sealer to dentin. J Endod. 2013. doi:10.1016/j.joen.2013.04.003

17. Zhou HM, et al. Physical properties of calcium silicate sealers. J Endod. 2013. doi:10.1016/j.joen.2013.04.012

18. Nagas E, et al. Dentinal tubule penetration of bioceramic sealers. Int Endod J. 2014. doi:10.1111/iej.12119

19. Camilleri J. Sealability of bioceramic materials. Dent Mater. 2015. doi:10.1016/j.dental.2015.03.003