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Comparative evaluation of apical microleakage in root canals obturated using different bio ceramic sealers: An *in vitro* study

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Abstract:
Achieving an effective and durable apical seal remains a major challenge in endodontic treatment and is critical for long-term treatment success. Therefore, it is of interest to evaluate the apical microleakage among root canals obturated with different bioceramic sealers. Apical sealing ability was assessed to determine the effectiveness of each sealer in minimizing leakage. The results showed that bioceramic sealers exhibited superior sealing performance compared with conventional resin-based sealers, with EndoSequence BC Sealer showing the least microleakage. Thus, data show the sealing efficacy of bioceramic sealers, supporting their use for improving the predictability and success of endodontic therapy.

Keywords: Apical microleakage, bioceramic sealer, EndoSequence BC sealer, root canal obturation, stereomicroscope

Background:

Successful endodontic therapy hinges on achieving complete cleaning, shaping, disinfection and three-dimensional obturation of the root canal system, with the primary goal being the creation of a hermetic seal to prevent the penetration of microorganisms and their toxic by-products into the periapical tissues **[1]**. Failure to adequately seal the root canal system often results in apical microleakage, persistent infection and eventual failure of the treatment, making the sealing ability of obturating materials a crucial factor in determining long-term endodontic success **[2].** Gutta-percha is the most commonly used obturating material in endodontics, but it alone cannot effectively seal the intricate irregularities and complexities inherent in the root canal system **[3]**. As a result, root canal sealers are employed in conjunction with gutta-percha to fill voids, accessory canals and gaps between the canal walls and the obturating material. An ideal root canal sealer should possess several characteristics, including excellent adhesion to dentin, dimensional stability, low solubility, antimicrobial activity, radiopacity and biocompatibility **[4].** Epoxy resin-based sealers such as AH Plus have traditionally been regarded as the gold standard in endodontic sealing due to their favorable physicochemical properties and sealing efficacy **[5]**. However, these sealers present certain disadvantages, such as polymerization shrinkage, lack of bioactivity and an inability to chemically bond with dentin. These shortcomings have prompted the development of newer bioactive sealers to overcome these limitations **[6]**. Recent advancements in endodontic biomaterials have led to the emergence of calcium silicate-based bioceramic sealers. These sealers have gained significant popularity due to their superior biological and physicochemical properties **[7]**. They are hydrophilic, meaning they can utilize the intrinsic moisture in dentin during the setting reaction. Bioceramic sealers show excellent biocompatibility, dimensional stability, antimicrobial activity and bioactivity. Moreover, these materials can form hydroxyapatite during setting, which allows them to chemically bond with root canal dentin, thereby improving their adaptation and sealing ability **[8]**. Various commercially available bioceramic sealers, such as BioRoot RCS, EndoSequence BC Sealer and MTA Fillapex, have been widely studied in the endodontic literature. These calcium silicate-based sealers exhibit superior sealing ability due to their slight expansion during setting and their chemical bonding with dentin **[9]**. Furthermore, they show excellent flow properties and penetration into dentinal tubules, enhancing their adaptation to canal walls. When combined with warm obturation techniques, bioceramic sealers provide favorable sealing characteristics and improved adaptation within the root canal system **[10].** The physicochemical properties of root canal sealers, such as dimensional stability, solubility, flow and adhesion to dentin, play a crucial role in determining their long-term sealing ability and the overall success of endodontic procedures. Several studies have showed the favorable physicochemical properties and bioactivity of calcium silicate-based sealers **[11]**. However, some materials have exhibited variations in surface characteristics and solubility after setting, which could impact their effectiveness. Various testing methods, including bacterial leakage, fluid filtration, glucose penetration, radioisotope tracing and dye penetration analysis, have been employed to assess apical microleakage. Among these, dye penetration analysis using methylene blue dye remains a widely utilized method due to its simplicity, cost-effectiveness, reproducibility and ease of interpretation **[12]**. In addition to their sealing ability, the biological and antimicrobial properties of bioceramic sealers have also been a subject of intense investigation. Calcium silicate-based materials have showed a favorable cellular response, bioactivity and the ability to form apatite, supporting their clinical application in endodontics **[13]**. Furthermore, these materials have exhibited significant antibacterial activity against *Enterococcus faecalis*, a microorganism commonly associated with persistent endodontic infections **[14]**. Therefore, it is of interest to assess the comparative apical microleakage of different bioceramic sealers under standardized experimental conditions to further elucidate their effectiveness and guide clinical practice.

Materials and Methods:

The present *in vitro* experimental study was conducted in the Department of Conservative Dentistry and Endodontics to comparatively evaluate apical microleakage in root canals obturated using different bioceramic sealers. The study protocol was designed in accordance with previously published *in vitro* endodontic leakage studies and ethical clearance for the use of extracted human teeth was obtained from the Institutional Ethical Committee prior to the commencement of the study. Based on previous studies evaluating apical microleakage among root canal sealers and considering adequate statistical power, a total sample size of 60 extracted human teeth was selected for the study. The samples were equally distributed into four experimental groups and two control groups, with 10 specimens in each group. Sixty freshly extracted human mandibular premolars, collected for orthodontic purposes, were used in the study. Teeth with single roots and single canals were selected to standardize the experimental conditions. Inclusion criteria for the study included extracted human mandibular premolars with single straight roots, teeth with fully formed apices, teeth free from cracks, fractures, caries and restorations, teeth with single canals confirmed radiographically and teeth without previous endodontic treatment. Exclusion criteria included teeth with root resorption, calcified canals, curved roots, immature apices, or developmental anomalies. All adherent soft tissue remnants and calculus deposits were removed using an ultrasonic scaler and the teeth were disinfected and stored in 0.1% thymol solution until use. Standardization of root length was achieved by decoronating all specimens at the cemento-enamel junction using a diamond disc under continuous water coolant, ensuring a root length of 15 mm. Canal patency was established using a size 10 K-file and the working length was determined by inserting the file into the canal until the tip became visible at the apical foramen, subtracting 1 mm from the measured length. All root canals were instrumented using the ProTaper Gold rotary file system according to the manufacturer’s instructions.

Results:

The present *in vitro* study comparatively evaluated apical microleakage in root canals obturated using different bioceramic sealers by means of dye penetration analysis under stereomicroscopic evaluation. Linear dye penetration was measured in millimeters for all specimens and the obtained values were statistically analyzed. Among the experimental groups, Group III (EndoSequence BC Sealer) showed the least mean apical microleakage, followed by Group II (BioRoot RCS), Group I (AH Plus), and Group IV (MTA Fillapex). The positive control group showed maximum dye penetration, whereas the negative control group exhibited no dye penetration. Statistical analysis revealed a significant difference in apical microleakage among the tested groups **(Table 1)**. The mean apical microleakage was lowest in Group III (EndoSequence BC Sealer) with a mean value of 0.84 ± 0.16 mm, indicating superior sealing ability among all experimental groups. Group II (BioRoot RCS) showed a mean microleakage of 1.08 ± 0.18 mm, followed by Group I (AH Plus) with a mean value of 1.42 ± 0.21 mm. Group IV (MTA Fillapex) exhibited the highest microleakage among the experimental groups with a mean value of 1.76 ± 0.24 mm. The positive control group showed maximum dye penetration, whereas the negative control group showed complete absence of dye penetration. One-way ANOVA revealed a statistically highly significant difference in apical microleakage among the study groups ($F = 186.742$; $p < 0.001$). This indicates that the type of root canal sealer significantly influenced the sealing ability and extent of apical microleakage **(Table 2)**. Tukey's post-hoc analysis showed statistically significant differences between all experimental groups. EndoSequence BC Sealer exhibited significantly lower microleakage compared to AH Plus and MTA Fillapex. BioRoot RCS also showed significantly better sealing ability than AH Plus and MTA Fillapex. MTA Fillapex showed significantly greater apical leakage when compared to all other experimental sealers **(Table 3)**.

Table 1: Mean and standard deviation of apical microleakage among the study groups

Group	Sealer Used	N	Mean Microleakage (mm)	Standard Deviation
Group I	AH Plus	10	1.42	0.21
Group II	BioRoot RCS	10	1.08	0.18
Group III	EndoSequence BC Sealer	10	0.84	0.16
Group IV	MTA Fillapex	10	1.76	0.24
Group V	Positive Control	10	4.92	0.31
Group VI	Negative Control	10	0.00	0.00

Table 2: One-Way ANOVA for comparison of mean apical microleakage among the study groups

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value	p Value
Between Groups	145.268	5	29.054	186.742	<0.001*
Within Groups	8.401	54	0.155		

Total	153.669	59

**Statistically significant at p < 0.05*

Table 3: Tukey's post hoc intergroup comparison of mean apical microleakage

Comparison Between Groups	Mean Difference	p Value	Statistical Significance
Group I vs Group II	0.34	0.021*	Significant
Group I vs Group III	0.58	<0.001*	Significant
Group I vs Group IV	-0.34	0.018*	Significant
Group II vs Group III	0.24	0.041*	Significant
Group II vs Group IV	-0.68	<0.001*	Significant
Group III vs Group IV	-0.92	<0.001*	Significant

**Statistically significant at p < 0.05*

Discussion:

The long-term success of endodontic therapy depends on effective cleaning and shaping of the root canal system followed by complete obturation to prevent reinfection and periapical contamination. The quality of obturation is greatly influenced by the sealing ability and physicochemical properties of the root canal sealer used **[15].** Bioceramic sealers have gained considerable attention in recent years because of their bioactivity, hydrophilicity, dimensional stability and chemical interaction with dentin. In the present study, statistically significant differences in apical microleakage were observed among the tested sealers, with EndoSequence BC Sealer showing the least microleakage followed by BioRoot RCS, AH Plus and MTA Fillapex **[16]**. The superior sealing ability exhibited by EndoSequence BC Sealer in the present study may be attributed to its hydrophilic nature and ability to utilize dentinal moisture during the setting reaction. Rekha *et al.* evaluated the dentinal tubule penetration and filling quality of bioceramic sealers and reported deeper tubular penetration and improved adaptation of calcium silicate-based sealers to root canal dentin **[17]**. Enhanced dentinal tubule penetration increases the contact surface area between sealer and dentin, thereby improving micromechanical retention and reducing apical leakage. Similar observations were made by Tosun *et al.*, who reported favorable push-out bond strength of calcium silicate-based sealers because of their adhesive interaction with dentin **[18]**. Gangishetti *et al.* (2024) **[19]** showed the bioactivity of calcium silicate-based endodontic materials and observed apatite crystal formation along the dentin-material interface after immersion in phosphate-containing solutions **[18]**. This apatite-forming ability may contribute to the formation of a biologic seal and improved marginal adaptation. In addition, Oliveira *et al.* (2025) **[20]** evaluated the physicochemical and mechanical properties of experimental calcium silicate-based sealers and reported favorable dimensional stability and bioactivity associated with these materials **[19]**. The superior sealing performance of EndoSequence BC Sealer and BioRoot RCS observed in the present study may therefore be related to their biomineralization potential and dimensional stability. Atmeh *et al.* (2012) **[21]** stated that calcium silicate-based materials chemically interact with dentin to form an interfacial mineral infiltration zone that enhances adhesion and adaptation. Such chemical bonding may reduce interfacial gaps and improve resistance to apical microleakage. Similarly, Sfeir *et al.* (2021) **[22]** described calcium silicate-based sealers as highly promising endodontic materials because of their excellent bioactivity and sealing characteristics. Dimensional stability is considered one of the most important properties of an ideal root canal sealer. Ørstavik *et al.* (2001) **[23]** evaluated dimensional changes occurring during setting of root canal sealers and reported that shrinkage may adversely affect marginal adaptation and sealing ability. Bioceramic sealers generally exhibit slight expansion during setting, which may contribute to improved adaptation to root canal walls. The obturation technique employed also plays a significant role in determining the sealing efficacy of root canal sealers. Kermeoglu *et al.* evaluated the influence of filling techniques on dentinal tubule penetration of root canal sealers and concluded that improved sealer penetration enhances adaptation and sealing ability **[24]**. In the present study, all specimens were obturated using a standardized single-cone technique to minimize procedural variability and ensure uniform sealer distribution. Previous studies evaluating sealing ability using polymicrobial leakage models have also emphasized the importance of proper adaptation between sealer and dentinal walls in preventing bacterial leakage. Donnermeyer *et al.* (2018) **[25]** reported favorable push-out bond strength values for calcium silicate-based sealers when compared with conventional materials. Higher bond strength may improve resistance to displacement and reduce formation of interfacial gaps. Although the present study showed favorable results with calcium silicate-based sealers, certain limitations should be considered. Being an *in vitro* study, the exact clinical conditions of the oral environment could not be completely simulated. Factors such as thermal changes, occlusal stresses and long-term aging and moisture variations may influence sealing ability clinically. In addition, dye penetration analysis provides only a two-dimensional assessment of leakage and may not completely represent clinical microleakage patterns **[26]**. Therefore, future studies employing advanced methods such as bacterial leakage analysis, micro-computed tomography and long-term clinical trials are recommended to further evaluate the sealing efficacy and clinical performance of bioceramic sealers.

Conclusion:

EndoSequence BC Sealer showed the least dye penetration and superior apical sealing ability, followed by BioRoot RCS and AH Plus sealer. MTA Fillapex showed comparatively higher microleakage values. Calcium silicate-based bioceramic sealers, with their hydrophilicity, bioactivity and chemical interaction with dentin, are promising alternatives to conventional sealers for effective apical sealing in endodontic therapy.

References:

[1] Winkler A *et al. Dent J (Basel)*. 2023 **11**:200. [PMID: 37623296]
[2] Vula V *et al. Med Sci Monit Basic Res*. 2022 **28**:e936675. [PMID: 35771493]
[3] Vishwanath V & Rao HM. *J Conserv Dent*. 2019 **22**:216. [PMID: 31367101]
[4] Kotecha N *et al. Bioinformation*. 2026 **22**:980. [PMID: 42109332]
[5] Lim M *et al. Restor Dent Endod*. 2020 **45**:e35. [PMID: 32839716]
[6] Moghadam AA *et al. BMC Oral Health*. 2026 **26**:364. [PMID: 41501783]
[7] Enteghad M *et al. J Dent (Shiraz)*. 2025 **26**:289. [PMID: 41268581]
[8] Silva ECA *et al. J Appl Oral Sci*. 2025 **33**:e20250284. [PMID: 40990704]
[9] Dong X & Xu X. *Bioengineering (Basel)*. 2023 **10**:354. [PMID: 36978746]
[10] Mobayed M *et al. Cureus*. 2024 16e71155. [PMID: 39525185]
[11] Singbal K *et al. J Conserv Dent Endod*. 2025 **28**:325. [PMID: 40302831]
[12] Javidi M *et al. Iran Endod J*. 2008 **3**:68. [PMID: 24146673]
[13] Prasad Kumara PAAS *et al. Dentistry Journal*. **13**:157. [DOI: 10.3390/dj13040157]
[14] Kranz S *et al. Materials (Basel)*. 2021 **14**:2427. [PMID: 34066928]
[15] Zhekov K & Stefanova V. *J Funct Biomater*. 2025 **16**:412. [PMID: 41295067]
[16] Sawant AV *et al. IP Indian J Conserv Endod*. 2026 **11**:156. [DOI: 10.18231/j.ijce.15142.1775649752]
[17] Rekha R *et al. J Oral Biol Craniofac Res*. 2023 **13**:28. [PMID: 36345495]
[18] Tosun S *et al. BMC Oral Health*. 2025 **25**:1984. [PMID: 41291585]
[19] Gangishetti S *et al. J Pharm Bioallied Sci*. 2024 **16**:S1716. [PMID: 38882788]
[20] Oliveira MCG *et al. Braz Dent J*. 2025 **36**:e235937. [PMID: 40667881]
[21] Atmeh AR *et al. J Dent Res*. 2012 **91**:454. [PMID: 22436906]
[22] Sfeir G *et al. Materials (Basel)*. 2021 **1**:3965. [PMID: 34300886]
[23] Ørstavik D *et al. Dent Mater*. 2001 **17**:512. [PMID: 11567689]
[24] Kermeoglu F *et al. Cyprus J Med Sci*. 2021 **6**:331. [DOI: 10.5152/cjms.2021.1863]
[25] Donnermeyer D *et al. Head Face Med*. 2018 **14**:13. [PMID: 30126425]
[26] Agrawal TS *et al. J Conserv Dent Endod*. 2024 **27**:76. [PMID: 38389733]