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The marginal adaptation of Cold Ceramic sealer, Endoseal MTA, and AH26: A scanning electron microscope study

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Abstract

Objective: The current study evaluated the marginal adaptation of different endodontic sealers based on epoxy resin, mineral trioxide aggregate (MTA), and cold ceramic (CC) to intraradicular dentin using scanning electron microscopy (SEM).

Methods: Forty-five extracted single-rooted teeth were obtained. After root canal instrumentation, the samples were obturated using the lateral condensation technique with gutta-percha and one of the following sealers (n=15 for each group): 1) An epoxy resin-based sealer (AH26), 2) an MTA-based sealer (Endoseal MTA), and 3) a cold ceramic-based sealer (CC sealer). A cross-section was prepared 3 mm from the apex of each tooth. Using scanning electron microscopy (SEM), we measured the average maximum distance between the root filling material and the canal walls in four sectors of the root cross-section. Data were analyzed using one-way ANOVA and post-hoc Tukey's test (α=0.05).

Results: The average linear distance between the sealer and dentinal wall significantly differed among the three groups (P=0.001). Pairwise comparisons revealed that the mean distance in the AH26 group (11.99 ± 4.31 µm) was significantly higher than that in the CC sealer (7.25 ± 1.94 µm; P<0.001) and Endoseal MTA group (8.86 ± 3.33 µm; P=0.014). The marginal gap between the CC sealer and Endoseal MTA group was statistically comparable (P = 0.735).

Conclusion: The CC sealer and Endoseal MTA exhibited similar marginal adaptation to root canal dentin, which was superior to the epoxy resin-based AH26 sealer. Endoseal MTA and cold ceramic sealers could be recommended for endodontic treatments to reduce the risk of reinfection.

Keywords: Bioceramics, Calcium Silicates, Marginal Adaptation, Mineral Trioxide Aggregate, Root Canal Filling Materials, Sealers

Introduction

The primary objective of root canal treatment (RCT) is to remove the infected pulp tissue and replace it with a biocompatible material that ensures proper sealing (1). Inadequate marginal adaptation of filling materials can form gaps, which allow microbial penetration and increase the risk of treatment failure (2). Endodontic sealers help prevent recurrent infections by filling the gaps between gutta-percha and dentin, as well as sealing the accessory canals (3).

Endodontic sealers are classified based on their composition and setting reactions. Epoxy resin-based sealers, set through an addition-polymerization reaction. These sealers have been widely used due to their strong bonding properties. AH-26 (Dentsply Maillefer, Ballaigues, Switzerland) is a widely used epoxy resin-based sealer. Its major disadvantages include shrinkage and the release of formaldehyde after polymerization, which is toxic (4, 5).

Bioceramics are specialized ceramic materials developed for medical and dental usage. They contain alumina, zirconia, bioactive glass, glass ceramics, hydroxyapatite, and calcium phosphates (6). Bioceramic sealers form a crystalline structure similar to hydroxyapatite, which bonds effectively to root dentin (7, 8). Their sealing ability in root canals with both oval and round cross-sections is comparable to gold standard sealers like AH Plus (9-11). Some of the bioceramic materials include Mineral Trioxide Aggregate (MTA), biodentine, Portland cement, and cold ceramic (CC) (12).

Endoseal MTA sealer (E. MTA; Maruchi, Wonju, Korea) is an MTA-based bioceramic sealer that comes in a premixed, pre-loaded format within an airtight syringe. This allows for direct application to root canals (13). Its composition includes calcium silicates, calcium aluminates, calcium aluminoferrite, and calcium

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sulfates. Previous studies have reported its biocompatibility, antibacterial properties, and sealing efficacy (2, 14). However, Endoseal MTA has several limitations, such as discoloration, a long setting time, a short working time, and insufficient compressive strength. Additionally, the lack of a solvent for MTA makes it challenging to remove it from the root canal if endodontic retreatment is necessary (13).

Cold ceramic (CC) is a bioceramic cement primarily composed of four key compounds: calcium oxide, silicon oxide, barium oxide, and sulfur oxide, constituting approximately 93% of its chemical composition (15). This material has been used in repairing root perforation, apical plug formation, and vital pulp therapy (VPT). CC exhibits an initial setting time of 15 minutes and achieves a complete setting within 24 hours in the presence of moisture (16). It demonstrates superior sealing ability compared to MTA, glass ionomer, and amalgam in blood-contaminated areas (17). However, its sealing capacity is similar to MTA under dry and saliva-contaminated conditions (17).

The viscosity of CC is not suitable for obturating the root canals. To address this issue, a new CC-based sealer has been developed (Samin, Iran). This sealer features a powder composition similar to that of CC, while its liquid component primarily consists of a type of heavy alcohol. Research on this novel sealer is still limited. A study by Mahdavisefat et al. (18) found that both CC sealer and AH-26 produced similar tissue reactions in rats, suggesting that CC sealer is a biocompatible material. However, the marginal adaptation of this new sealer has yet to be investigated. Therefore, this study aimed to evaluate and compare the marginal adaptation of an epoxy resin-based sealer (AH26), an MTA-based sealer (Endoseal MTA), and a cold ceramic-based sealer (CC sealer) using scanning electron microscopy (SEM).

Materials and methods

The study protocol was reviewed and approved by the ethics committee of Shahid Sadoughi University of Medical Sciences, Yazd, Iran (IR.SSU.DENTISTRY.REC.1402.150).

Sample preparation

The required sample size was calculated based on previous research (19), with $\alpha=0.05$ and $\beta=0.8$, resulting in 15 samples per group. A total of 45 intact, single-rooted human teeth with mature apices and straight canals were collected. Teeth used in this study were extracted for reasons unrelated to the research, such as periodontal disease and irreparable coronal caries. Informed consent was obtained from all subjects for using their teeth in further research. Teeth with root canal calcification were excluded. After removing surface debris, the samples were immersed in a 5.25% sodium hypochlorite solution (Morvabon, Iran) for 10 minutes for disinfection.

The samples were decoronated at the cemento-enamel junction (CEJ). A size 10 file was inserted into the canal until the tip was visible at the apical foramen. The working length was set at 1 mm from the apical foramen. The coronal one-third of each canal was enlarged using Gates-Glidden drills (sizes 1–3, MANI, Japan). Next, root canal instrumentation and debridement were performed using a step-back technique with K-files up to size #40. The root canals were irrigated with 5.25% sodium hypochlorite and 0.9% normal saline. Finally, the prepared canals were thoroughly dried using paper points (META, Korea).

Sample allocation

The samples were obturated using the lateral compaction technique with gutta-percha cones (Meta Biomed, South Korea) and one of the following root canal sealers (n=15):

1) An epoxy resin-based sealer (AH26; Dentsply, Tulsa, OK, USA): The sealer was prepared according to the manufacturer’s instructions, with a powder-to-liquid ratio of 2:1. A coated gutta-percha with the sealer was inserted up to the working length. Additional gutta-percha cones were compacted laterally. The extended cones were removed at the orifice level.
2) An MTA-based sealer (Endoseal MTA; Maruchi, Wonju, South Korea): This premixed sealer was dispensed directly into the middle third of the canal using a syringe with a disposable canal tip, following the manufacturer's instructions. The injection was continued until the sealer was visible at the root canal orifice. A master gutta-percha cone was slowly placed into the canal with 2–3 pumping motions. Additional gutta-percha cones were inserted, and the cones were removed at the orifice level.
3) A cold ceramic-based sealer (CC sealer; Samin, Iran): The sealer was prepared following the manufacturer's instructions, with a powder-to-liquid ratio of 2:1. This mixed sealer was dispensed directly into the middle third of the canal using a lentulo spiral (MANI, Japan). A master gutta-percha cone was slowly placed into the canal with 2–3 pumping motions. Additional

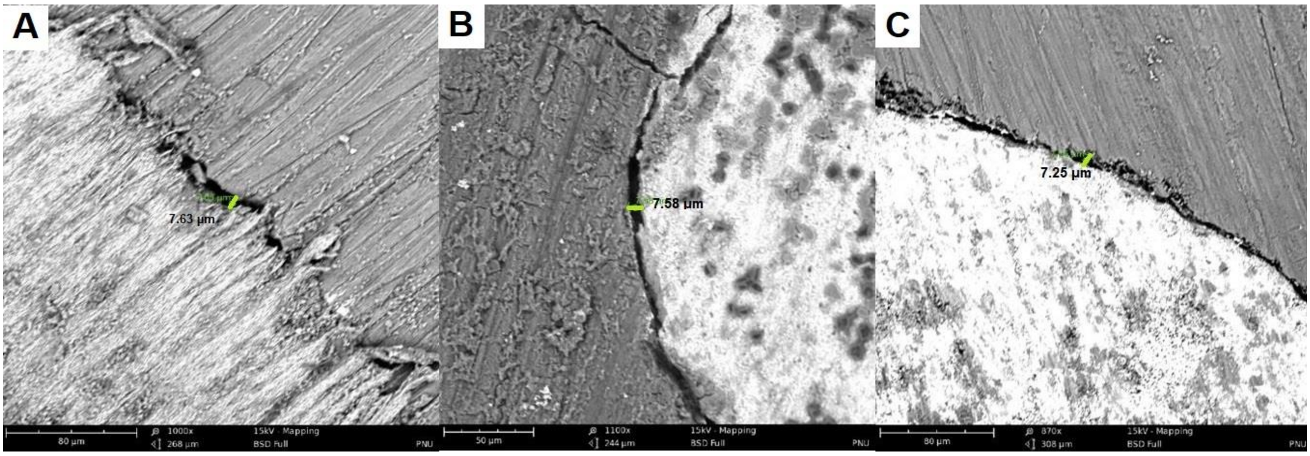

Figure 1. Microscopic images of A) AH26 sealer, B) EndoSeal MTA sealer, and C) CC sealer

gutta-percha cones were inserted, and the cones were removed at the orifice level.

Measuring the marginal adaptation

Following obturation, the samples were incubated in distilled water at 37°C for one week. A cross-section was prepared 3 mm from the apex of each tooth using a diamond disc under continuous water irrigation. Microscopic examination was conducted using an SEM (Phenom G2 Pro, Phenom World BV, The Netherlands). The apical section was examined, and the average maximum distance between the root-filling material and the canal wall was measured in four directions for each sample (19) (Figure 1). The SEM examination included observations at varying magnifications to ensure a detailed evaluation. The SEM device featured an auto-calibration system to enhance measurement precision. All SEM observations and measurements were supervised by an experienced specialist.

Statistical analysis

The normal distribution of the data was evaluated using the Kolmogorov-Smirnov test. Comparisons among the experimental groups were performed using one-way ANOVA, followed by the Tukey post hoc test for pairwise comparisons. Statistical analyses were conducted with SPSS version 26.0 (IBM Inc., NY, USA), and p-values lower than 0.05 were considered statistically significant.

Results

The results revealed gaps between the filling materials and root canal walls at 3 mm from the apex in all study groups. As observed in Table 1, the AH26 group exhibited the lowest marginal adaptation, with a mean gap of 11.99 ± 4.31 µm, while the CC sealer showed the highest marginal adaptation, with a mean gap of 7.25 ± 1 .94 µm.

ANOVA indicated a statistically significant difference in marginal adaptation among the three groups (P = 0.001; Table 1). Pairwise comparisons revealed significant differences between AH26 and CC sealer groups (P = 0.001), as well as between AH26 and Endoseal MTA groups (P = 0.014). However, the difference in marginal adaptation between Endoseal MTA and CC sealer was not statistically significant (P = 0.73).

Discussion

The present study evaluated the marginal adaptation of AH26, Endoseal MTA, and CC sealer to root canal walls using SEM analysis. Several methods have been introduced to assess the apical sealing ability of root canal filling materials, including dye penetration tests, liquid filtration, micro-CT, and direct observation via stereomicroscope or SEM. Micro-CT is the gold standard for evaluating root canal filling quality because it can precisely locate and quantify voids. However, since many sealers are opaque, micro-CT may fail to detect smaller voids within the root-filling material. Kim et al. (20) suggested that micro-CT may be less sensitive than sectioning methods when detecting small voids. SEM

Table 1. Mean± standard deviation of maximum marginal gap (µm) among the groups

Sealer	Mean
AH26	11.99±4.31[a]
Endoseal MTA	8.86±3.33[b]
CC sealer	7.25±1.94[b]
P value	0.001*

*Values less than 0.05 represent a significant difference between the groups according to one-way ANOVA.
Different lowercase letters represent a significant difference between groups according to Tuckey's test.

helps detect and measure the microscopic gaps and voids within the filling materials (19).

The primary finding of this study was that the bioceramic sealers, Endoseal MTA, and CC sealers exhibited significantly better marginal adaptation compared to the AH26 sealer. Furthermore, the marginal adaptation of Endoseal MTA and CC sealers was comparable. The superior performance of the bioceramic sealers in this study, compared to AH26, could be attributed to the susceptibility of epoxy resin sealers to shrinkage due to the presence of silicone oil in their composition (21). In contrast, bioceramic sealers are hydrophilic, which improves their adhesion to the dentin wall and promotes the precipitation of hydroxyapatite. Additionally, bioceramic sealers have smaller particle sizes, which facilitate better penetration into dentinal tubules and enhance their sealing capability (22-24).

The findings of the present study are consistent with previous SEM studies that demonstrated superior marginal adaptation for bioceramic sealers, including Bio-Ceramic BC sealer (25, 26), ProRoot MTA sealer (27), and Endoseal MTA sealer (28, 29), as compared to epoxy resin-based sealers. However, other studies reported no significant differences in marginal adaptation between epoxy resin sealers and Endosequence BC (30) or Endoseal MTA (31). These discrepancies may arise from variations in study design, including differences in microleakage testing, sample preparation, sealer formulations, or root canal preparation and cleaning protocols. For example, variations in the handling of the smear layer during canal preparation could influence the bonding properties of the sealer to dentin, thus affecting the marginal adaptation (24). The smear layer can interfere with the bonding of the sealer to dentin, but there is no consensus on whether it should be removed or left intact (32). Removing the smear layer allows for more thorough cleaning and disinfecting of root canal walls, which may improve the adaptation of root canal filling materials. However, the smear layer can also seal the dentinal tubules, reducing the penetration of bacteria and toxins into the dentin (32). The clinical relevance of the smear layer's presence on treatment outcomes remains uncertain (32). The smear layer was present in all samples in the present study, as EDTA was not used. This could have an impact on the bonding efficiency of the sealers used in this study.

Among the bioceramic sealers, CC sealer demonstrated the best marginal adaptation, although this difference was not statistically significant compared to Endoseal MTA. The powder composition of CC sealer is similar to that of CC cement, which has been used for over 20 years. CC cement has shown a superior sealing performance compared to gutta-percha-Endoseal MTA sealer (33) and comparable marginal adaptation to MTA (19). Additionally, in cases where blood contamination occurred, CC cement exhibited superior marginal adaptation compared to MTA Angelus (34).

CC sealer was introduced with a lower viscosity compared to CC cement. The favorable marginal adaptation of the CC sealer may be attributed to its capacity to release calcium ions, which react with phosphorus in the dentin to form hydroxyapatite crystals (18). Endoseal MTA also penetrates dentinal tubules and forms apatite crystals (35). These crystals help fill the microscopic gaps between the canal wall and the root-filling material and enhance the sealer’s ability to form a better seal.

A limitation of the current study is that it did not assess the marginal adaptation along the entire canal length. Only one section, located 3 mm from the apex, was evaluated due to insufficient resources. However, this specific region is particularly important for studying marginal adaptation due to the higher presence of the accessory canals (36). Future research should concentrate on assessing the long-term performance of the CC sealer. It is also advisable to investigate the efficacy of the CC sealer in filling teeth with anatomical variations using different obturation techniques.

Conclusions

Both the CC sealer and Endoseal MTA showed comparable marginal adaptation to root canal dentin and outperformed the epoxy resin-based AH26 sealer. These results highlight the superior sealing capability of bioceramic sealers over epoxy resin-based sealers, implying that they may reduce the risk of reinfection in endodontic treatments.

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Conflict of interest

The authors declare no competing interests.

Author contribution

F.M. and J.M. contributed to the study conceptualization, design, supervision, and critical revision of the manuscript. A.M. was responsible for data acquisition, analysis, interpretation, and drafting of the manuscript. All authors read and approved the final manuscript.

Ethics approval

The study protocol was approved by the ethics committee of Shahid Sadoughi University of Medical Sciences (IR.SSU.DENTISTRY.REC.1402.150). Informed consent was obtained from all subjects for using their teeth in further research.

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