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Comparative In Vitro Assessment of Retro-MTA Cement and Endoseal MTA Sealer for Apical Perforation Sealing

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Featured Application

This study helps clinicians select the most effective material for sealing apical perforations, showing that Retro-MTA provides a more reliable apical seal than Endoseal MTA.

Abstract

Apical perforation is a possible complication during root canal treatment, often caused by instrumentation beyond the working length, and requires prompt, precise sealing. In immature teeth needing endodontic therapy, the same principles used for managing apical perforations apply. Despite the widespread use of calcium silicate cement (CSC)-based materials, there is limited evidence comparing the sealing performance of putty-type CSCs and injectable bioceramic sealers in apical perforations under standardized laboratory conditions. This study aimed to compare the sealing ability of Retro-MTA cement and Endoseal MTA sealer in standardized apical perforations using the fluid-filtration method. In this in vitro study, 34 extracted human maxillary central incisors were used and divided into two groups. In Group 1, apical perforations were sealed with Retro-MTA and obturated using warm vertical compaction. In Group 2, perforations were sealed with Endoseal MTA and obturated using the single-cone technique. Micro-leakage was assessed using the fluid-filtration method. Data were analyzed with an independent *t*-test ($\alpha = 0.05$). All samples exhibited leakage after two weeks. However, Retro-MTA demonstrated significantly lower micro-leakage than Endoseal MTA (0.265 vs. 0.473 $\mu L/min/cmH_2O$; $p < 0.001$), corresponding to approximately a 44% difference in leakage values between the two materials. The findings indicate that Retro-MTA provides a superior apical seal and lower leakage rates than Endoseal MTA. Therefore, Retro-MTA appears to be the more effective material for sealing apical perforations and managing open apices, potentially providing more stable apical seal under controlled laboratory conditions.

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1. Introduction

Dental caries and resorptions and receiving dental treatments could cause perforations. Perforations jeopardize the prognosis of treatments [1,2]. Perforations are pathways that link periodontium and inner canal space, and if they are contaminated with microorganisms, because of leakage, it would cause sinus track, bone loss, and infection [3]. Several factors affect the prognosis of teeth with perforation, such as perforation size and location, accessibility of perforation, the material used to seal it, the time between perforation occurrence, and management. Hence, if it is properly diagnosed and treated with optimal material it would not affect the long-term prognosis of the tooth [4].

Many materials have been proposed for sealing perforations, such as amalgam, interim restorative materials, resin, and zinc oxide eugenol [5]. Sealing perforations with these materials presented several disadvantages, including the inability to induce osteogenesis, poor performance in moist environments, difficult handling characteristics, and limited biocompatibility. After introducing MTA by Torabinejad, MTA is commonly used to seal perforations [6]. It is biocompatible and hydrophilic, with sealing ability in the presence of moisture, low solubility in tissue fluid, and low leakage against bacteria [7–9]. Retro-MTA (BioMTA, Seoul, Republic of Korea) is a putty-type calcium silicate cement (CSC) supplied as a fine hydrophilic powder that sets rapidly upon hydration. It has appropriate characteristics such as anti-bacterial properties, biocompatibility, low cytotoxicity, short setting time, lesser discoloration, and the property to be used as restoration in sealing a perforation [10]. Endoseal MTA (Maruchi, Gangwon-do, Republic of Korea) is a premixed injectable bioceramic sealer delivered in a syringe, composed of calcium silicate, calcium aluminate, calcium aluminoferrite, calcium sulfate, and radiopacifiers. It is reported to have good mechanical and biological properties, suitable setting time, biocompatibility, and bioactivity [11,12]. This sealer is used with gutta-percha as a core material, but it is claimed that it could repair the perforation during application. Using this sealer type of CSCs (Endoseal MTA) is much easier and less time-consuming than applying the putty type of CSCs (Retro-MTA) in the defects. However, evidence regarding its efficacy compared with the putty form of CSCs remains limited. Therefore, using it in clinical settings requires an experimental study of perforation's sealing and a comparison of this material with calcium silicate-based cement [12–14].

In addition to the known advantages of CSC-based materials, the clinical relevance of evaluating their sealing performance under controlled laboratory conditions lies in the fact that apical perforations often present with irregular defect geometry, moisture contamination, and limited visibility. These factors can compromise the adaptation of repair materials and increase the risk of persistent leakage. Therefore, a more detailed comparison between putty-type CSCs and injectable bioceramic sealers is essential to clarify whether simplified application techniques compromise sealing integrity. Although several studies have evaluated the sealing ability of calcium silicate cements and bioceramic sealers, most investigations have focused on furcal perforations, internal resorption defects, or bacterial leakage models rather than standardized apical perforations [15–18]. Furthermore, injectable bioceramic sealers such as Endoseal MTA have been proposed as simplified alternatives to putty-type CSCs, yet evidence directly comparing their sealing performance in apical perforations remains limited and inconsistent. Existing studies differ in defect location, evaluation methods, and material formulations, leaving uncertainty regarding whether injectable sealers can achieve a seal comparable to putty-type CSCs under con-

trolled similar conditions [19–21]. This gap underscores the need for a direct comparison between these two types of CSC sealers in standardized apical perforations. This study aimed to compare the sealing ability of Retro-MTA cement and Endosael MTA sealer in the treatment of teeth with apical perforations. The null hypothesis was that there would be no difference between Retro-MTA and Endoseal MTA in establishing an apical seal in standardized apical perforations.

2. Materials and Methods

2.1. Study Design

This in vitro study was approved by the local ethics committee (IR.MUI.RESEARCH.REC.1400.183) and reported according to the PRILE 2021 checklist.

2.2. Sample Size Calculation

Using the formula $n = (z^2 \times p \times (1 - p))/d^2$ and according to the 95% confidence limits and type 1 error, the rate of $Z = 1.96$ and $\alpha = 0.05$ and considering $p = 0.5$ and $d = 0.25$, the number of samples required in each group is 15. Therefore, for this study, 17 samples were considered in each group [22]. Finally, a total of 34 samples of human central incisors, extracted due to periodontal problems, were collected. The teeth included in this experiment were one-rooted and had no caries, resorption, fracture, crack, calcification, or root anomalies. During the experiment, if any fractures or other problems occurred, the tooth was excluded.

2.3. Specimen Preparation

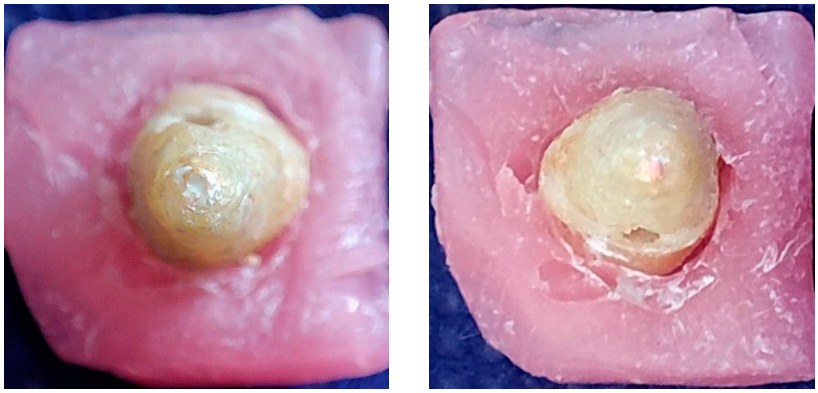
First, all calculus, bones, and debris were removed from root surfaces with a periodontal scaler (ultrasonic piezo scaler Uds-K, Woodpecker, Guilin, China) and rinsed with normal saline; then, they were put in 5.25% sodium hypochlorite (Nikdarman, Tehran, Iran) and were stored in normal saline. Teeth were cut with a crown cutter diamond disk DFS-Zircut (Dandal Company, Tehran, Iran) around the cementoenamel junction to retain 10 mm of root for the experiment. Roots were instrumented with ProTaper (Dentsply, Maillefer, Ballaigues, Switzerland) to size F3, with a crown-down technique. Canals were irrigated with 2.5% sodium hypochlorite and normal saline during the instrumentation, at the end 17% EDTA (Avant Dental Supply Company, Miami, FL, USA) for 1 to 3 min, and again normal saline for removing the smear layer. Roots were dried using multiple paper cones. In the next step, the apical region of the canals was instrumented with Gates Glidden #2 (Endostar, Warsaw, Poland) to create a perforation that was the same size and length as Gates Glidden cutting head; then, roots were mounted in gypsum and rinsed with normal saline and dried with paper points.

Roots were divided into two groups randomly, by a simple randomization technique (https://www.random.org/). In group A (n = 17) apical seal was achieved using Retro-MTA (BioMTA, Seoul, Republic of Korea), and in group B (n = 17) apical seal was achieved using Endoseal MTA (Maruchi, Gangwon-do, Republic of Korea). Table 1 summarizes the study groups, the tested materials, and their key compositional characteristics. In group A, the apical plug of Retro-MTA was placed into the canal with an MTA carrier (Micro Apical Placement System, Vevey, Switzerland), and then the coronal part was obturated using warm vertical compaction of gutta-percha (Fast Fill, Eighteeth, Changzhou, China) on 200 °C; a plugger #60 (DiaDent, Cheongju, Republic of Korea) was used to compact the material. In group B, the sealer was injected into the canal; then, a single cone of gutta-percha, size F3 ProTaper (Dentsply, Maillefer, Ballaigues, Switzerland), was soaked in the sealer and placed into the canal, seared off at the orifice level (Fast Pack, Eighteeth,

Changzhou, China). Figure 1 shows the apical preparation of selected teeth in each group. The specimens were temporarily sealed with cavisol (Golchai Co., Karaj, Iran).

Table 1. Study groups, tested materials, and their main compositional characteristics.

Groups	Material	Type	Delivery Form	Main Components (as Reported by Manufacturers)
A	Retro-MTA (BioMTA, Republic of Korea)	Putty-type calcium silicate cement	Powder + liquid	Calcium carbonate, silicon dioxide, aluminum oxide, calcium zirconia complex
B	Endoseal MTA (Maruchi, Republic of Korea)	Premixed injectable bioceramic sealer	Syringe: injectable paste	Zirconium dioxide, dimethyl sulfoxide, tricalcium silicate, water, bentonite clay, polyvinyl alcohol, polyvinyl pyrrolidone, lithium carbonate



(**a**) (**b**)

Figure 1. Apical view of teeth prepared with (**a**) Retro-MTA cement and (**b**) Endoseal MTA sealer.

2.4. Experimental Procedures

After ensuring the quality of canal filling using digital radiography, the teeth were placed in an incubator (Behdad Company, Tehran, Iran) at a temperature of 27 °C and 100% humidity for a week. After that, the samples of each group were completely covered with two layers of nail polish with two different colors. Then, the apical end of the roots was placed inside the latex tube and covered with cyanoacrylate glue (3 m Super Glue Gel, 3 m Company, Maplewood, MN, USA) to create a tight and impervious connection, and the free end of the tube was connected to the fluid-filtration device [23] and a pressure of 50 kPa was applied to the syringe connected to the device. The amount of leakage (μL/min/cmH_2O) in the groups was calculated by the bubble displacement, which is produced on the path of liquid movement. The longitudinal movement of the liquid column was converted into the volume of fluid passing from the samples, shown as μL/min/cm H_2O, after one week, by a researcher who was blinded by the experiment.

To enhance reproducibility, the fluid-filtration apparatus was calibrated before each measurement session using a standardized column displacement test to ensure consistent pressure delivery. All samples were examined for voids or defects in the obturation using two independent evaluators, and any specimen showing radiographic inconsistencies was replaced prior to testing. The operator performing the obturation procedures had more than five years of clinical endodontic experience, and all materials were manipulated strictly according to manufacturer instructions. Environmental conditions, including humidity, temperature, and storage medium, were standardized to minimize variability in material setting and hydration.

2.5. Statistical Analysis

Data were presented as mean (SD). Normality of leakage values was evaluated using the Shapiro–Wilk test, and the data met the assumptions for parametric analysis. Accordingly, an independent *t*-test was applied to compare leakage between groups, with the level of statistical significance set at $\alpha = 0.05$.

3. Results

Leakage data were normally distributed, and all specimens demonstrated measurable leakage, confirming that neither material produced a completely fluid-tight seal under the test conditions. However, an independent *t*-test confirmed a statistically significant difference between groups ($p < 0.001$). The mean (SD) of Endoseal MTA leakage was 0.473 (0.088) μL/min/cmH_2O, and Retro-MTA cement leakage was 0.265 (0.084) μL/min/cmH_2O (Table 2). Data showed that the mean amount of leakage measured among the Endoseal MTA sealer group was significantly higher than the Retro-MTA cement group ($p < 0.001$) (Figure 2). On average, Endoseal MTA leaked approximately 1.8 times more than Retro-MTA under identical testing conditions. The Retro-MTA samples clustered toward lower leakage values with a narrower range, whereas the Endoseal MTA group showed a broader spread and consistently higher readings. This pattern indicates that Retro-MTA not only produced lower mean leakage but also delivered more uniform sealing performance across specimens.

Table 2. Mean (SD) of Endoseal MTA sealer and Retro-MTA cement leakage (μL/min/cmH_2O).

Groups	Number	Mean (SD)	Minimum	Maximum
Endoseal MTA sealer	17	0.473 (0.088)	0.375	0.688
Retro-MTA cement	17	0.265 (0.084)	0.125	0.500

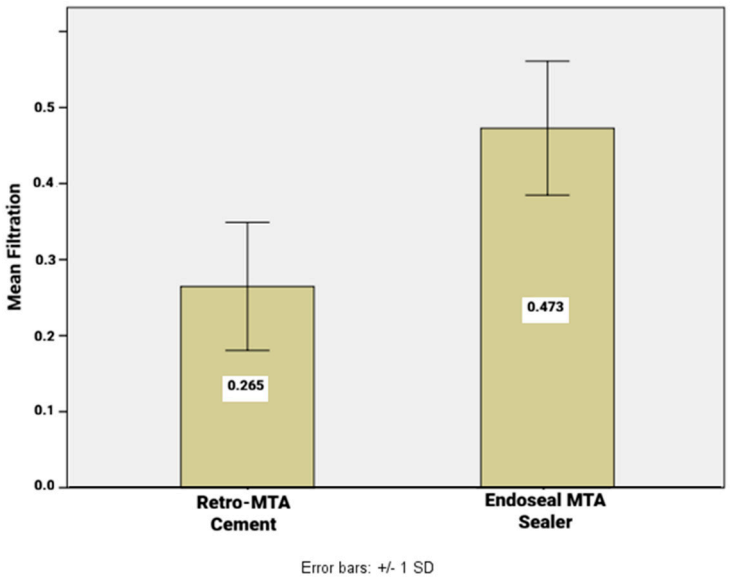


Figure 2. Retro-MTA cement and Endoseal MTA sealer mean leakage (μL/min/cmH_2O).

Comparison of minimum and maximum values further highlights the performance gap between the two materials. The lowest leakage recorded in the Retro-MTA group (0.125 μL/min/cmH_2O) was substantially below the minimum value observed in the Endoseal MTA group (0.375 μL/min/cmH_2O). Similarly, the highest leakage in the Endoseal MTA group exceeded that of Retro-MTA by nearly 0.19 μL/min/cmH_2O.

4. Discussion

The present study evaluated the sealing ability of Retro-MTA cement and Endoseal MTA sealer in standardized apical perforations using the fluid-filtration method. Based on the significantly lower micro-leakage values recorded for Retro-MTA across minimum, maximum, and mean measurements, the null hypothesis was rejected, indicating that the two materials did not perform equivalently under the tested conditions. Retro-MTA demonstrated markedly superior sealing performance, with mean leakage values nearly half those of Endoseal MTA (0.265 vs. 0.473 μL/min/cmH_2O), reflecting a more stable and effective apical barrier in this in vitro model. These findings highlight material-dependent differences in sealing behavior that may be relevant to the selection of repair materials, while remaining specific to the controlled laboratory conditions of the present study.

One of the important survival factors for perforated open apex roots is the sealing ability of restorative material. For repairing perforations, the best material that has been introduced is MTA, which has difficult manipulation [24]. Retro-MTA cement is one of the CSCs that has been used for perforation sealing. Recently, some bio-ceramic sealers such as Endoseal MTA have been introduced to repair perforations during obturation, which have fewer technical difficulties than putty forms of CSCs.

Endoseal MTA has been described in the literature as a calcium silicate-based injectable sealer with generally favorable biologic compatibility but variable physicochemical performance. Studies demonstrate that Endoseal MTA has favorable antibacterial characteristics, is well tolerated by connective tissues, eliciting only mild to moderate inflammation that subsides over time, with no evidence of necrosis, and even shows osteogenic potential through mineralized tissue formation in subcutaneous implantation models [25,26]. Physicochemically, Endoseal MTA shows acceptable radiopacity, high alkalinity, and extended setting times [12,27]. Its high dentinal tubule penetration has also been documented, and this penetration correlates positively with bond strength, suggesting that its flowable, hydrophilic nature may enhance interfacial adaptation [11].

Retro-MTA is a fast-setting hydraulic calcium silicate cement whose physicochemical and biologic behavior has been increasingly characterized in the recent literature. Radiographically, Retro-MTA demonstrates adequate radiopacity, meeting ANSI/ADA #57 requirements, largely due to its zirconium-based radiopacifier. Its alkaline pH profile is comparable to ProRoot MTA, with both materials showing a gradual decrease in pH over time [28]. Biologically, RetroMTA exhibits high biocompatibility, supporting cell viability in fibroblast assays and producing pulpal responses similar to ProRoot MTA, including continuous calcific barrier formation, minimal inflammation, and expression of odontogenic markers such as osteocalcin and dentin sialoprotein. Although some studies report slightly lower odontoblastic differentiation and angiogenic potential compared with ProRoot MTA, RetroMTA consistently demonstrates favorable tissue compatibility, rapid setting, and acceptable cytotoxicity profiles, supporting its use as a viable alternative CSC in vital pulp therapy and perforation repair [28–30].

Previous studies evaluating the sealing ability and performance of calcium silicate-based materials in perforation repair have reported heterogeneous results depending on the material tested, perforation location, and evaluation method. Adl et al. [22] found that ProRoot MTA and Biodentine exhibited significantly higher dislodgement resistance than Endoseal MTA in furcation perforations of mandibular molars, suggesting that injectable bioceramic sealers may provide inferior mechanical stability compared with putty-type CSCs. Although the study by Adl et al. evaluated dislodgement resistance rather than microleakage, their findings similarly demonstrated inferior performance of Endoseal MTA compared with putty-type CSCs such as ProRoot MTA and Biodentine. Despite the difference in evaluation methods, both their results and the present study point toward a

consistent trend in which Endoseal MTA, as an injectable sealer, exhibits weaker sealing-related behavior than putty-like calcium silicate cements when used for perforation repair. This convergence across distinct testing modalities reinforces the material-dependent differences observed in our investigation.

Makhlouf et al. [17] reported greater dye penetration for MTA Angelus compared with Biodentine, indicating material-dependent differences in sealing quality. In contrast, Dastorani et al. [31] observed no significant difference between Endoseal MTA and ProRoot MTA in bacterial microleakage in mid-root perforations, and Baralay et al. [32] likewise found no difference among MTA Angelus, Endoseal MTA, and Biodentine in furcation perforations using a bacterial leakage model. These inconsistencies across studies may reflect variations in perforation site, sample size, evaluation technique, and the inherent differences between mechanical, dye-based, and bacterial leakage assessments. In the present study, Retro-MTA demonstrated significantly lower micro-leakage than Endoseal MTA under standardized apical perforation conditions, aligning with studies that reported inferior sealing or retention performance for Endoseal MTA compared with putty-type CSCs. However, the divergence from studies showing no difference underscores the influence of methodological factors and highlights the need for further standardized comparative research across different defect types and testing modalities.

One of the limitations of this study is that in this experiment, samples were disinfected, but contamination of the defect in clinical situations is one of the concerns that should be considered. This study did not include additional material characterization techniques, nor did it assess biological properties such as biocompatibility, antibacterial activity, or regenerative potential, as they were evaluated in previous studies. The present investigation was specifically designed to evaluate their sealing performance in standardized apical perforations using the fluid-filtration method. It is recommended that in future studies, other types of perforation, material, and evaluation should be examined to get more accurate and practical results.

5. Conclusions

Within the limitations of this in vitro study, Retro-MTA cement demonstrated significantly lower micro-leakage compared with Endoseal MTA sealer (0.265 vs. 0.473 $\mu L/min/cmH_2O$; $p < 0.001$), indicating a markedly superior sealing performance under standardized apical perforation conditions. This difference was consistent across minimum and maximum leakage values, with Retro-MTA showing a narrower and more favorable leakage range. These findings reflect material behavior in a controlled experimental model and should not be directly extrapolated to clinical practice. Further clinical research is needed to determine whether these differences translate into improved clinical outcomes and whether the observed performance advantages persist across different defect types, clinical conditions, and long-term scenarios, as current evidence on the comparative behavior of putty-type CSCs and injectable bioceramic sealers remains limited.

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Institutional Review Board Statement: The study was approved by the Research Ethics Committee of Isfahan University of Medical Sciences (protocol code IR.MUI.RESEARCH.REC.1400.183 and date of approval 18 July 2021).

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding authors.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviation

The following abbreviation is used in this manuscript:

CSCs Calcium silicate cements

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