

Evaluation of Sealing Effect and Working Time of Root Canal Filling MTA Materials

Hyojin Kim, Youngjin Kim, Soonhyeun Nam, Kwon Taeyub, Hyunjung Kim

Department of Pediatric Dentistry, School of Dentistry, Kyungpook National University

Abstract

The purpose of this study is to examine the sealing effect and efficiency of root canal filling MTA (Endoseal, Endoseal MTA).

A total of 106 extracted single rooted teeth were used and classified with group AH (AH-26), group PR (ProRoot MTA), group ES (Endoseal) and group EM (Endoseal MTA) depending on filled sealers. Time was measured in each group when sealers were filled. The groups were divided into subgroup A and subgroup B. The sealing of root canal walls and penetration of sealer in the dentinal tubule were evaluated, respectively.

According to the results, the sealing of root canal walls and dentinal tubule penetration of root canal filling MTA were inferior to AH-26 ($p < 0.05$). When compared with ProRoot MTA, however, there was no significant difference in sealing of root canal walls ($p > 0.05$), but dentinal tubule penetration was high ($p < 0.05$). Working time was shorter in root canal filling MTA than ProRoot MTA and AH-26 ($p < 0.05$).

In conclusion, root canal filling MTA has lower root canal sealing effect than resin-based sealer, however, when in MTA needed root canal filling, it could be an effective alternative.

Key words : Mineral trioxide aggregate, Dye leakage, Sealer penetration, Time

I. Introduction

Complete sealing of the root canal is an important requirement for successful root canal treatment. Root canal lesions do not occur in dental pulp exposed to a sterile environment, but do occur in dental pulp exposed to bacteria¹. Therefore, if the root canal is not sealed properly, re-infection occurs via micro-leakage, which leads to treatment failure².

The most commonly used root canal filling material is the combination of a gutta percha (GP) cone and resin-based sealer. Bowman³ first introduced the GP cone in 1867, and it has since been used as the standard filling material because of its stable volume, adhesion, thermo-

plasticity, antibiotic effects, and radio-opacity. The resin sealer is also radio-opaque, easy to mix, non-soluble in body fluids, and has excellent bonding capacity. However, it causes tissue irritation until it hardens and it is difficult to use with a perforation or open apex^{4,5}.

Mineral trioxide aggregate (MTA) was first used in 1993⁶. Given its stable volume, adhesion, thermoplasticity, antibiotic effects, and radio-opacity, MTA is used widely in apical barrier formation, pulp capping, pulpotomy, and sealing perforated dental roots with an open apex⁷⁻⁹. However, it is difficult to handle, making it complicated to fill a narrow root canal with the material. This problem can be partially overcome with the lentulo spiral, MTA carrier, and other methods, but it is still

Corresponding author : Hyunjung Kim

Department of Pediatric Dentistry, School of Dentistry, Kyungpook National University, 2177 Dalgubeol-daero, Jung-gu, 41904, Korea

Tel: +82-53-600-7211 / Fax: +82-53-426-6608 / E-mail: jungkim@knu.ac.kr

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difficult to apply MTA to a narrow root apex. It is also difficult to remove MTA after it hardens, which makes retreatment difficult. These characteristics have limited the use of MTA as a direct filling material within the root canal¹⁰.

Recently, two new silicate-based sealers (Endoseal and Endoseal MTA) have been developed and used as a root filling material because of their ease of use, removability after hardening, and penetration into narrow root canals^{11,12}. The two have the same basic ingredient, silicate, although Endoseal is a powder and Endoseal MTA is pre-mixed. With both products, the root canal is filled using a new method: sonic vibration.

Many studies have examined the functions of MTA in apical barrier formation, pulp capping, pulpotomy, and sealing perforated dental roots and have demonstrated its stable volume, bioaffinity, antibiotic effects, and hard tissue formation¹³⁻¹⁵. However, only a few studies have examined MTA for filling root canals.

A root canal filler must not only seal all root canals in three dimensions but also block the re-entry of bacteria by penetrating the dentinal tubules^{16,17}. Various MTAs are currently being tested for filling root canals because of their material characteristics. Clinically, however, it is only possible to check the seal of the root canal using periapical radiographs, which are not precise enough to evaluate micro-leakage and can observe only two-dimensional filling. Consequently, more research is needed to check if these MTAs are suitable for filling root canals.

Therefore, this study evaluated the suitability of MTA as root canal filler by comparing the sealing of root canal walls and penetration into the dentinal tubule of various MTAs (ProRoot MTA, Endoseal, and Endoseal MTA) with a proven epoxy resin-based sealer (AH-26).

II . Materials and Methods

The study used 106 single-root teeth kept in physiological saline after extraction. Organic debris on the

tooth surface was removed by immersion in 1% NaOCl solution for 4 days. The crown of the tooth was removed to the cement-enamel junction with a high-speed fissure bur. Then, the dental pulp was removed using a #10 K-file (MANI, Tochigi, Japan) and the working length was measured by pulling it 1 mm out of the root apex.

The root canal was enlarged to #40/0.04 taper with the Crown Down method using Profile (Dentsply, Ballaigues, Switzerland). In this process, the root canal was disinfected with 5.25% NaOCl before moving on to the next larger profile. After the root canal was shaped, 18% ethylenediaminetetraacetic acid (EDTA) was applied for 3 minutes and then the canal was irrigated again with 5.25% NaOCl. Moisture was removed with paper points and patency was confirmed by passing #10 K-file. The teeth were divided randomly into four groups of 25 according to the filling material used (Table 1).

In group AH, the root canal was filled using lateral condensation with an epoxy-resin-based sealer (AH-26, DeTrey/Dentsply, Germany) and a #40/0.04 taper GP cone as the master cone. Then, the upper GP cone was removed with B&L- α (B&L Biotech, Ansan, Korea) and the cavity entrance was sealed with Cavit (3M ESPE, Seefeld, Germany). In group PR, the root canal was filled using ProRoot MTA (Dentsply, Switzerland). A variety of methods were attempted because the manufacturer does not specify a method for filling a root canal. After mixing 1 g ProRoot MTA powder and 0.35 g Repair Material Water, MTA carrier (Dentsply, Swiss) was applied to the apical 1/3 of the root and compressed using a plugger. Then, the cavity entrance was sealed with Cavit. In group ES, the filling materials were Endoseal (Maruchi, Wonju, Korea) and a #30/0.04 taper GP cone. After mixing 300 mg powder and 0.14 mL distilled water, the mixture was put in the cap and Endoseal was applied to the root canal using a centrix gun (Shinwoo Dental, Korea). Then, the Endoseal was induced to penetrate the canal by rotating a #15 K-file. Insertion was carried out to the root canal using the GP

Table 1. Materials used for the experiment

Group	Product name	Main composition	Manufacturing company/Nation
AH	AH-26	Epoxy resin, Bismuth oxide, Methenamine, Silver, Titanium dioxide	Dentsply/Germany
PR	ProRoot MTA	Calcium silicates, Calcium aluminates, Calcium sulfate, Bismuth oxide	Dentsply/Switzerland
ES	Endoseal	Calcium silicates, Calcium aluminates, Calcium sulfate, Zirconium oxide, Phyllosilicates	Maruchi/Korea
EM	Endoseal MTA	Calcium silicates, Calcium aluminates, Calcium aluminoferrite, Calcium sulfates	Maruchi/Korea

cone and then ultrasonic vibration was applied to the master cone for 5 seconds using a pincette. After removing the upper GP cone with B&L- α , the cavity entrance was sealed with Cavit. In group EM, the filling materials were Endoseal MTA (Maruchi, Wonju, Korea) and a #30/0.04 taper GP cone. As per the manufacturer's instructions, using a 23 gauge needle, the Endoseal MTA was injected until it tightly filled the root apex. Then, a #30/0.04 taper GP cone was inserted and pumped lightly. Ultrasonic vibration was applied to the master cone for 5 seconds using a pincette. Then, the upper GP cone was removed with B&L- α and the cavity entrance was sealed with Cavit. The roots of all group were then stored at 37°C and 100% humidity for 48 hours.

The time spent on each filling procedure until the Cavit was used was recorded and the filling shape was evaluated with periapical radiographs. All of the filling processes and time measurements were performed by one clinician.

Within each group, the samples were randomly divided into subgroups A and B. Subgroup A was used to evaluate the root apex seal based on the penetration of a dye. Three positive and negative controls were also tested. In the positive controls, only a #40 GP cone was inserted into the root canal and all of the outer surfaces of the teeth were covered with two layers of nail varnish except a 1 mm region at the root tip. In the negative controls, the entire outer surfaces of the teeth, including the root tip, were covered with two layers of nail varnish. In the experimental group, which comprised 60 samples, 15 from each group, the outer surfaces of the teeth except a 1 mm region at the root tip were coated with two layers of nail varnish and stored at room temperature for 24 hours. Then, after confirming that the nail varnish had hardened, they were immersed in 1% methylene blue solution for 72 hours. Finally, the dental root was washed with running tap water, dried for 24 hours, and cut into longitudinal sections with diamond disk under sprinkled water.

To quantify dye leakage, the maximum distance that the dye moved from the anatomical apex toward the crown was measured under an illuminated microscope (SZ61, Olympus, Tokyo, Japan) at X 12 magnification with an objective micrometer (Union, Tokyo, Japan).

Subgroup B was used to check the degree of penetration of the sealer within the dentinal tubules using scanning electron microscopy (SEM). In the experimental group, which comprised 40 samples, 10 from each group,

the samples were cut with a diamond disk under sprinkled water, leaving the lower 6 mm of the cervical area, and a groove was cut in the lower part using a fissure bur. Then, the specimen was dehydrated for 10 minutes each in a series of solutions with ethanol concentrations increasing from 50% to 100% in 10% increments and dried for 24 hours at room temperature in a closed container containing silica gel. Cross-sections were cut using a chisel and hammer in the upper notch and these were coated with Pt via ion sputtering (E-1030, Hitachi High Technologies, Tokyo, Japan).

Using SEM (SU-8220, Hitachi High Technologies, Tokyo, Japan), images of the 4 mm of root apex were obtained at $\times 500$, $\times 1000$, and $\times 1500$ magnification depending on the degree of sealer penetration. In the images, the maximum penetration of the sealer was measured using Adobe Photoshop 7.0. The data were analyzed using one-way analysis of variance (ANOVA) and Dunnett's T3 *post hoc* test. The confidence level was $p < 0.05$.

III. Results

1. Dye penetration assay

In the three positive controls, the dye penetrated all of the root canals, while in the three negative controls, no dye penetration was observed. Except for two samples in group AH, dye penetration was observed in all of the experimental samples.

Table 2 summarizes the micro-leakage in the experimental groups. The micro-leakage was the lowest in group AH, followed in order by groups ES, EM, and PR. The differences between group AH and the other experimental groups were significant ($p < 0.05$) in one-way ANOVA and Dunnett's T3, while there were no significant differences ($p > 0.05$) among groups ES, EM, and PR.

Table 2. Extent of apical dye penetration (mm)

Group	Minimum	Maximum	Mean \pm SD	<i>p</i> -value
AH	0.00	6.42	2.06 ^a \pm 1.59	.000
PR	1.59	9.00	4.98 ^b \pm 2.68	
ES	1.25	9.00	5.35 ^b \pm 2.17	
EM	3.58	9.00	5.79 ^b \pm 2.00	

SD indicates standard deviation

One-way ANOVA test followed by Dunnett's T3 *post hoc* analysis

a,b: Dunnett's T3 grouping, which means the same letter are not significantly different

2. Depth of sealer penetration in dentinal tubules

Table 3 shows the penetration depth of the sealer within the dentinal tubules. In group AH and the controls, penetration to the maximum depth was observed at $\times 500$ magnification in all samples. In the experimental groups, the maximum penetration was in the order group EM, ES, and PR (Fig. 1). There were significant differences among all of the groups ($p < 0.05$).

Table 3. Sealer penetration depth into dentinal tubules at the apical section (μm)

Group	Minimum	Maximum	Mean \pm SD	<i>p</i> -value
AH	329.27	636.36	483.57 \pm 108.12	.000
PR	0.00	37.81	16.20 \pm 13.16	
ES	21.37	62.05	35.18 \pm 14.03	
EM	44.38	76.44	66.99 \pm 8.88	

SD indicates standard deviation

One-way ANOVA test followed by Dunnett's T3 *post hoc* analysis

There are significant differences among all of the groups

3. Time required for root canal filling

Table 4 summarizes the time spent filling the canals in each group when canal enlargement was completed with a #40/0.04 taper. group EM required the least time (44.70 seconds), followed by groups ES (74.97 seconds), PR (280.39 seconds), and AH (328.32 seconds). All of the differences were significant ($p < 0.05$) and the time differences between groups EM and ES and groups PR and GP were particularly large.

Table 4. Time required for root canal filling (second)

Group	Minimum	Maximum	Mean \pm SD	<i>p</i> -value
AH	293.58	395.91	328.32 \pm 28.98	.000
PR	245.36	300.52	280.39 \pm 16.06	
ES	64.36	91.47	74.97 \pm 8.19	
EM	35.46	53.82	44.70 \pm 5.49	

SD indicates standard deviation

One-way ANOVA test followed by Dunnett's T3 *post hoc* analysis

There are significant differences among all of the groups

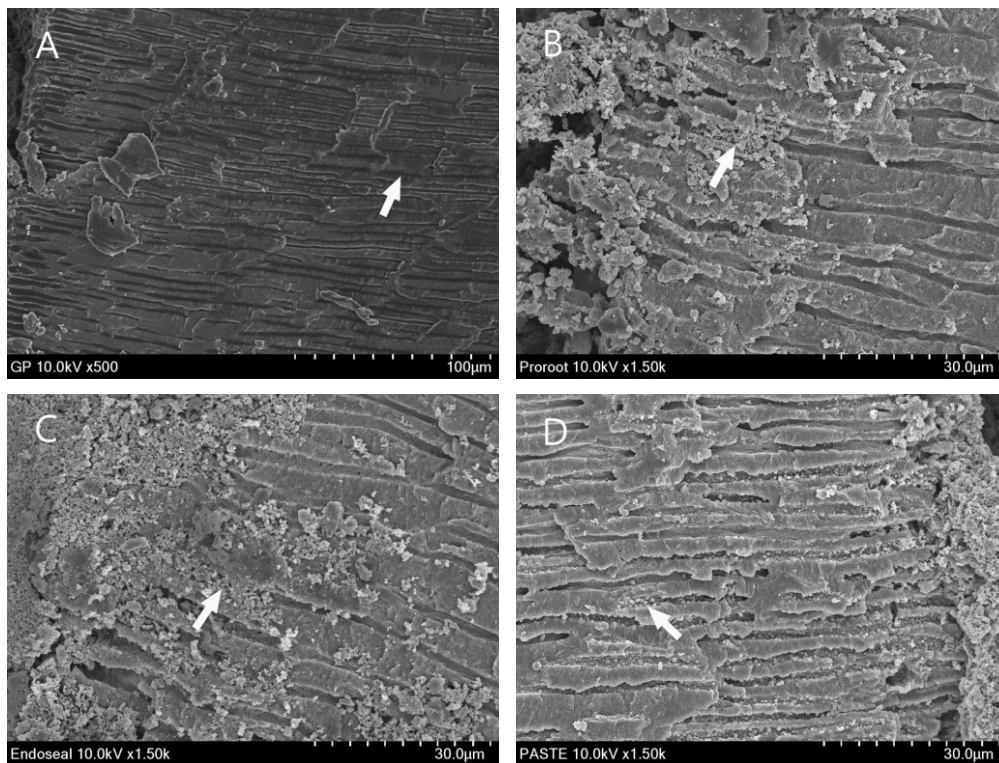


Fig. 1. Longitudinal view of specimens. (A) Group AH. All dentinal tubules are filled with AH-26 (magnification: $\times 500$). (B) Group PR. Dentinal tubules nearby are empty (magnification: $\times 1500$). (C) Group ES. Partial dentinal tubules are filled with Endoseal (magnification: $\times 1500$). (D) Group EM. Most dentinal tubules are filled with Endoseal MTA (magnification: $\times 1500$).

IV. Discussion

This study evaluated whether MTA can be used as a root canal filling material. In this *in vitro* study, the MTA groups took less time than AH-26, both sealing of the root canal walls and penetration within the dentinal tubules were inferior with MTA. Comparing ProRoot MTA, Endoseal, and Endoseal MTA within the MTA groups, there were no significant differences in sealing the root canal walls, but Endoseal MTA had the best results in terms of dentinal tubule penetration and working time.

Following root canal sealing, leakage occurs mainly between the filling material and root wall. The degree of leakage can be reduced using root filling materials that fit within the canal snugly^{20,21}. Several methods have been used to evaluate the seal between these filling materials and the root wall, such as dye penetration, bacterial penetration and fluid filtration. The methylene blue penetration method we used is relatively inexpensive, safe and results in high penetration because the dye is a very small molecule^{22,23}. Therefore, if the methylene blue molecules do not pass the filling material, the micro-leakage of bacteria and their byproducts should also be prevented²⁴.

In this study, the extracted teeth were immersed in methylene blue solution for 3 days to ensure full penetration. A vacuum device was not used because it has been reported that the amount of micro-leakage can be over-evaluated *in vivo* using such a device²⁵.

The root sealing effect of AH-26 was significantly better than that of the MTA groups. For a sealer to penetrate the narrow root canal, its flowability should be good. However, the flowability of MTA made from powder is inevitably inferior to that of the paste type AH-26. MTA expands while hardening and moisture is required for hardening. There may be insufficient moisture in the prepared root canal for complete hardening of the MTA.

The penetration of the sealer within dentinal tubule improves the sealing ability by increasing the contact surface between the filling material and dentin^{18,19}. Chemical bonding between the sealer and dentin does not occur, except with GI sealer, but the mechanical bonding increases the retention of the filling material in the root canal²⁶⁻²⁸. MTA sealers with antibiotics are more effective at preventing bacteria from penetrating the dentinal tubules^{18,29}.

Many factors affect dentinal tubule penetration by a

sealer, such as the presence or absence of a smear layer, the clinician's technique, the diameter of the dentinal tubule, the sealer application method, and the physical and chemical characteristics of the sealer³⁰⁻³². After root canal preparation, we immersed the samples in 17% EDTA for 3 minutes to remove the smear layer. To reduce the variability in dentinal tubule diameter, we studied only single-rooted tooth and examined only the apical 4 mm. In addition, because one clinician performed all of these procedures, interobserver errors were eliminated. Therefore, the significant differences seen in the dentinal tubule penetration of each sealer in this study resulted from the physical and chemical characteristics of the sealers.

For a sealer to penetrate the dentinal tubules, it should have sufficient flowability and low surface activity³³. There was a clear difference between AH-26 and the MTA groups: AH-26 is a liquid sealer, while the MTA groups are particle types, as seen in the SEM images. This difference affects the flowability and surface activity of each sealer. Within the MTA groups, the Endoseal MTA particles were the smallest and ProRoot MTA particles were the largest. This was reflected in the differences in penetration of the dentinal tubules. Therefore, both the type of material and size of particles affect the dentinal tubule penetration depth.

Compared to the resin-based sealer, the working times were faster for the MTA groups. Endoseal and Endoseal MTA were faster to use than ProRoot MTA because the latter must be applied in layers in the root canal using MTA carrier after mixing. This process is time-consuming and working with the plugger increases hand fatigue. In comparison, Endoseal and Endoseal MTA are injected into the root canal, which is filled using sonic vibration. As Endoseal MTA is pre-mixed, the time required is reduced further.

Studies that have compared root canal filling with a variety of MTA products have concluded that MTA is an effective root apex filling material^{11,34,35}, which is the opposite to our conclusion. Nevertheless, we found that Endoseal and Endoseal MTA were better than ProRoot MTA. Therefore, when treating root canals that are difficult to fill with AH-26, such as an open apex or dental root perforation, Endoseal or Endoseal MTA might be useful. However, when filling the root canals of mature permanent teeth, we recommend using a GP cone and epoxy resin-based sealer.

The results in an actual oral environment might differ

from our *in vitro* findings. Although the sealing effect of a sealer should last for a long time, we did not consider changes in the physical properties of the sealers over time. Therefore, long-term studies should analyze the root canal filling effect of MTA *in vivo*.

V. Conclusion

In our study, Endoseal and Endoseal MTA, new MTA products, were faster to use than AH-26, but did not seal the root canal walls or penetrate the dentinal tubules as well. However, both were better than ProRoot MTA as root canal filling materials, with better dentinal tubule penetration and shorter times required. Therefore, AH-26 and GP cones are recommended as root canal filling material for mature permanent teeth, while Endoseal and Endoseal MTA may be useful when treating the root canals with an open.

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국문초록

근관 충전용 MTA의 밀폐 효과와 작업 시간 평가

김효진 · 김영진 · 남순현 · 권태엽 · 김현정

경북대학교 치의학전문대학원 소아치과학교실

본 연구의 목적은 근관 충전재로서 MTA(Endoseal, Endoseal MTA)의 밀폐 효과와 효율을 평가하는 것이다.

총 106개의 발거된 단근치가 사용되었으며, 충전된 실러에 따라 AH군(AH-26), PR군(ProRoot MTA), ES군(Endoseal), EM군(Endoseal MTA)으로 나누어졌고, 모든 충전시 소요 시간이 측정되었다. 그 군들은 다시 A 하위군, B 하위군으로 나누어 근관벽과의 밀폐성과 상아세관내 실러의 침투도를 각각 평가하였다.

결과는 근관 충전용 MTA는 AH-26에 비해 근관벽과의 밀폐성과 상아세관 침투도는 떨어졌으며, ProRoot MTA와 비교 시 근관벽과의 밀폐성은 차이가 없었지만, 상아세관 침투도는 높았다. 작업 시간은 근관 충전용 MTA가 ProRoot MTA와 AH-26에 비해 짧았다.

결론적으로 근관 충전용 MTA는 레진계 실러보다 근관 밀폐 효과는 떨어지지만 MTA가 필요한 근관 충전시 효과적인 대안이 될 수 있다.

주요어: MTA, 염료 누출, 실러 침투, 시간