Evaluation of the Apical Seal of Mineral Trioxide Aggregate in the Absence and Presence of Smear Layer

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ABSTRACT

Aim: The aim of this study was to in vitro evaluate the apical sealability of mineral trioxide aggregate (MTA) when used as an orthograde root filling material, and to evaluate whether smear layer removal has any influence on the apical seal of this material.

Materials and methods: Forty single-rooted human mandibular premolars were selected in this in vitro study. The selected teeth were randomly divided into two equal groups (n = 20) based on the irrigation type. Group 1 was irrigated using distilled water to keep the smear layer intact, and group 2 was irrigated using NaOCl 5.25% and ethylenediaminetetraacetic acid (EDTA) 17% to remove the smear layer. All teeth were instrumented using a step-back technique and obturated using white MTA. Microleakage of 0.2% rhodamine B solution at the tooth-material interface was evaluated to assess the apical seal of MTA. The data were analyzed statistically using Mann–Whitney test U-test (p = 0.05).

Results: When the smear layer was present, MTA revealed less leakage compared to the group of MTA without smear layer with statistically significant difference (p <0.05).

Conclusion: The apical seal produced by MTA when smear layer is left intact was better than the apical seal of MTA when smear layer is removed. It can be stated that MTA is a promising root canal filling material with good sealing ability in the presence of a smear layer.

Clinical significance: Using white MTA material for the obturation of root canals is a useful procedure. It could be done without complexity in irrigation during root canal treatment and cause no discoloration to the teeth.

Keywords: Microleakage, Mineral trioxide aggregate, Obturation, Smear layer.


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INTRODUCTION

The objectives of endodontic treatment are to clean and shape the root canal system and to seal this system with a permanent three dimensional (3D) filling that does not allow leakage. The criteria for an ideal root canal obturation material include excellent adaption to the walls of the preparation, nontoxicity, well tolerated by the periapical tissues, promoting healing, noncorrosive, dimensionally stable, radiopaque, nonabsorbable, and not be affected by the presence of moisture or blood. In addition, the obturation material should be sterilizable, nonstaining, and able to be placed and removed easily from the root canal system. However, the improvement of endodontic materials and treatment concepts has led to a considerable reexamination and reassessment of the aforementioned criteria. It might be contraindicated, for example, that the material used for obturation should be easily removed from the root canal system because ideal obturation requires a material that essentially provides a resistant and steady hermetic seal.

Among the different obturation materials, gutta-percha is still the dominant material for root canal obturation because of its advantages such as ease of use, handling properties, and biocompatibility. However, gutta-percha is characterized by inherent weakness
which makes it not the ideal material for root canal obturation. The ideal root canal obturation material has not yet been established.3

Mineral trioxide aggregate (MTA) was first introduced as a root-end filling material in 1993.4 The aggregate has special chemical and physical properties due to the hydrophilic particles (tricalcium silicate and tricalcium aluminate) in the composition of the powder of MTA in addition to the other fine trioxides (tricalcium oxide, silicate oxide, bismute oxide). This material set in the presence of moisture, and takes about 3–4 hours to set with a pH of 12.5.5 The biocompatibility of MTA and its antibacterial properties, marginal adaptation, sealing properties, and its hydrophilic nature make this material distinctive and different from other available obturation materials.6 This material showed excellent characteristics when used as a root-end filling material, pulp capping, pulpotomy, apical barrier formation in teeth with open apices, repair of root perforations, and root canal filling.6

MTA is available in two types based on the color known as gray and white MTA. Scanning electron microscopy (SEM) and electron probe microanalysis characterized the differences between GMTA and WMTA and found that the major difference between GMTA and WMTA is in the concentrations of Al₂O₃, MgO and FeO.7

It has been suggested to use MTA as an obturating material for the entire root canal system or as root canal sealer due to its good sealing ability and its property of setting with the presence of moisture.5,9 When MTA is used as root canal sealer and is compacted against dentin a dentin MTA interfacial layer forms in the presence of phosphate. This adherent interstitial layer resembles hydroxylapatite in composition and structure.10

Instrumentation of the root canal, using either manual or rotary techniques, during endodontic treatment creates a smear layer and smear plugs.11-13

The smear layer consists of inorganic particles of calcified tissue and organic elements such as pulp tissue debris, odontoblastic processes, microorganisms, and blood cells in dentinal tubules.14 It is not clear yet whether the smear layer should be removed or not before obturating the root canal. If the smear layer is left intact, it might interfere with the adaptation of the obturation materials to the root canal wall.15 In addition, it prevents irrigants, medicaments and filling materials from penetrating the dentinal tubules, and the presence of this layer is considered to be the cause of leakage between root canal walls and the obturation material.14 On the other side, it could be assumed that the smear layer can play a role in the protection from bacteriological diffusion and penetration into the dentinal tubules.16

This study aimed to in vitro assess the apical sealability of MTA when used as an orthograde root filling material, and to evaluate whether smear layer removal has any influence on the apical seal of this material.

MATERIALS AND METHODS

Forty single-rooted human mandibular premolars were selected in this in vitro study. The teeth were matched anatomically based on visual examination of buccolingual and mesio-distal radiographs. The inclusion criteria for the teeth were as follows: teeth exhibited one canal, confirmed by X-ray, had mature apices, no cracks, the roots were free from resorption, caries, and restorations, and were not dilacerated. The teeth were extracted due to periodontal or orthodontic considerations.

The teeth were randomly divided into two equal groups (n = 20) based on the irrigation type during root canal preparation. Group 1 was irrigated using distilled water to keep the smear layer intact and group 2 was irrigated using NaOCl 5.25% and EDTA 17% to remove the smear layer.

Teeth Preparation

Any adherent soft tissues, bone fragments or calculus were removed via scaling and polishing. The dental crowns were sectioned at the cementoenamel junction with a high-speed diamond bur (Komet, Gebr. Brasseler GmbH & Co. KG Germany) under continuous water spray to obtain access to the root canal. The canal lengths were visually established by placing a size 10 K file (Mani Inc., Tochigi-Ken, Japan) into each root canal until the tip of the file was visible at the tip of the apical foramen. The working length was established 1 mm short of the apex. The canal systems were instrumented to the working length with a size #40 K file by using a step-back technique.

In group 1, canals were irrigated with 1 mL of distilled water after each instrument using Max-I-Probe irrigation probes size 30 gauge (Dentsply Rinn, York, PA, USA) and finally flushed with 5 mL of distilled water.

In group 2, canals were irrigated with 1 mL of 5.25% NaOCl after each instrument using Max-I-Probe irrigation probes size 30 gauge then irrigated with 3 mL of 17% EDTA (MD Cleanser, META Biomed, South Korea) for 1 minute followed by 3 mL of 5.25% NaOCl in order to neutralize EDTA action in the root canal and finally flushed with 5 mL of distilled water. Root canals were then dried using sterile paper points (Diadent Group International, South Korea)

Obturation of the Root Canals

Root canals were obturated using WMTA (ProRoot-MTA; Tulsa Dental, Tulsa, OK) Powder and liquid were mixed according to the manufacturer’s instructions.
The mixture was applied to the canal using an amalgam carrier and then condensed vertically using hand pluggers (Dentsply/Maillefer, Ballaigues, Switzerland). Then, a moist cotton pellet was placed on top of the MTA mixture to allow complete setting.

The length and density of the root canal obturation and the absence of voids were confirmed radiographically. The access opening of all groups was sealed with an intermediate restorative material (IRM) (Dentsply DeTrey GmbH, Konstanz, Germany) and the teeth were kept in 100% humidity at 37°C for 7 days to allow the obturation materials to set.

**Dye Infiltration**

The teeth surfaces were coated with two layers of nail varnish leaving the apical foramen of the root exposed. To test the nail varnish sealability and the penetrability of the dye in the root canal, six additional teeth were used; three were obturated using gutta-percha points vertically condensed with zinc oxide-eugenol sealer and considered as a positive control group. In addition, three teeth were left without obturation as a negative control group. The negative control group was completely coated with two layers of nail varnish, including the apical foramen.

All teeth of the specimen and the two control groups were put into test-tubes containing 0.2% rhodamine B solution (SIGMA-ALDRICH, Co, USA) and centrifuged at 3000 rpm for 5 minutes.

Subsequently, the teeth were rinsed under running water and allowed to dry at room temperature for 24 hours. Then, the teeth were sectioned longitudinally in a buccolingual direction with a diamond disk (22 mm in diameter and 0.3 mm in thickness) using a low-speed handpiece with water coolant.

Afterward, the sections were examined under a stereomicroscope (Scope SC-S100, Germany) with (x20) magnification for evaluation of linear dye penetration at the tooth-material interface (Figs 1 and 2).

**Evaluation of Apical Leakage**

In this *in vitro* study Escobar et al.’s criteria were used to evaluate the infiltration proportions:

- **0**: Infiltration loss (dye penetration 0 ≤ 1.5 mm).
- **1**: Simple infiltration (dye penetration 1.5–3 mm).
- **2**: Medium infiltration (dye penetration > 3 mm).

The data were analyzed with descriptive statistical methods using Mann–Whitney U-test (*p* = 0.05) using statistical package for social sciences (SPSS version 13.0, SPSS, Chicago, IL, USA). The level of significance was set at 0.05.

**RESULTS**

Both groups demonstrated dye leakage. The scores for apical dye penetration evaluation by Escobar et al. criteria showed that group 2 (without smear layer) had a higher frequency of medium infiltration (N = 17) and lower frequency of infiltration loss (N = 0). The scores for apical dye penetration evaluation by Escobar et al. criteria are shown in Table 1.

On the contrary, the results revealed that the lowest mean of leakage (3.2175 mm) was recorded in group 1 (with smear layer) and the highest mean of leakage (6.8750 mm) was recorded in group 2 (without smear layer). The extent of dye penetration in millimeters, the means, and the standard deviations for each group are listed in Table 2.

In the positive control group the three roots showed dye penetration over the entire length of the root canal, whereas all three roots in the negative control group showed no evidence of dye penetration which proves that the conditions of the tests are correct.

Data for apical leakage which subjected to Mann–Whitney U-test revealed that there were statistically significant differences among the groups (0.05).
When the smear layer was present, MTA revealed less leakage compared to the group of MTA without smear layer with statistically significant difference ($p < 0.05$).

**DISCUSSION**

One of the main reasons of endodontic failure is the leakage, both apically and coronally, into and out of the canal space. There are several test methods used to evaluate the sealing quality produced by root canal obturation materials. The most famous method used is dye penetration because it is easy to handle and does not need complicated materials.

Methylene blue is commonly used in marginal sealing studies, but its incompatibility with alkaline substances may cause discoloration of the dye. Calcium hydroxide results from mixing calcium oxide, which is found in MTA, with water leading to a subsequent increase in pH. Thus, discoloration of the surfaces stained by methylene blue may occur. Therefore, using rhodamine B dye solution for assessing the sealing ability of MTA is more suitable.

When smear layer was removed, root canals were irrigated with 1 ml of daily prepared 5.25% NaOCl after each instrument using Max-I-Probe irrigation probes size 30 gauge and final irrigation with 3ml of 17% EDTA for 1 minute followed by 3 mL of 5.25% NaOCl. It was observed that 17% of EDTA has the potential for causing excessive peritubular and intertubular dentinal erosion if the application time exceeds 1 min. Thus in the present study, EDTA had application time which was limited to 1 minute.

It is known that EDTA alone does not completely remove the smear layer, and that the best results are achieved with EDTA combined with sodium hypochlorite solutions. Because using solutions such as EDTA and sodium hypochlorite leaves crystals on the canal walls, and it could be beneficial to make a final irrigation step with 5 ML distilled water.

The result of our study indicated that using MTA as a root canal filling material in free smear layer root canals causes more apical leakage than using MTA in positive smear layer root canals with statistically significant differences between the two groups ($p = 0.003$). It could be assumed that smear layer plays the role of a coupling agent that improves the bonding between MTA and the tubular dentin, and the fact that MTA is a hydrophilic material and sets in the presence of moisture could have a positive effect to improve the adaption between MTA and the walls of the root canal. This finding is supported by the studies of Yildirim et al., Yildirim et al., and de Souza et al., but is not in agreement with the study conduct by Li and Zhang which demonstrated that removal of the smear layer did not cause significantly less apical leakage than that when the smear layer was left intact.

The previous finding indicated that leakage significantly increases when using sodium hypochlorite with a mixture of tetracycline, an acid, and a detergent (MTAD) or EDTA before placing WMTA for perforation repair in comparison to using only NaOCl or no irrigation. Another study revealed that WMTA partially dissolves when it remains in contact with BioPure MTAD for 5 minutes.

The use of MTA as an obturating material was clinically supported, in some case reports. Complete or partial obturation of the root canal system by using MTA is a viable option for teeth that exhibit extensive internal root resorption, open apices, and selected cases that show anatomic variations that include dens evaginatus, C shaped canals, fusion, or gemination. On the other hand, some studies revealed the capacity of MTA to reinforce the immature teeth and increase their fracture resistance.

**CONCLUSION**

In conclusion, under the conditions of this in vitro study, the apical seal produced by MTA when the smear layer is left intact was better than the apical seal of MTA when the smear layer is removed. It can be stated that MTA is a promising root canal filling material with good sealing ability in the presence of a smear layer.

**Clinical Significance**

Using white MTA material for obturation of root canals is a useful procedure. It can be done without complexity in irrigation during root canal treatment and cause no discoloration to the teeth.

**Limitation of the Study**

The present study has some limitations that should be considered. This in vitro study was carried out on...
extracted teeth. However, laboratory conditions are not exactly similar to that of clinical conditions, and results obtained by in vivo studies may differ. In addition, there are no other studies for evaluation of the apical seal of MTA in the absence and presence of smear layer.

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