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Original Article

Comparison of coronal sealing of flowable composite, resin-modified glass ionomer, and mineral trioxide aggregate in endodontically treated teeth: An *in-vitro* study

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ABSTRACT

Background: Coronal seal is one of the essential factors that affects the success of endodontic treatment and reinforces the apical seal. The intra-orifice barrier is an efficient alternative approach to decrease coronal leakage in endodontically treated teeth and various materials have been used for this purpose. This study aimed to compare the coronal sealing of flowable composite, resin-modified glass ionomer (RMGI), and mineral trioxide aggregate (MTA) in endodontically treated teeth.

Materials and Methods: In this *in vitro* study, 35 single-canal canine teeth were divided into five groups, including flowable composite, RMGI, MTA, positive control, and negative control groups. The teeth were filled with restorative materials according to the factory's instructions. Afterward, the samples were immersed in 2% methylene blue dye solution for 1 week at 37°C and 100% humidity condition. Finally, the teeth were sectioned longitudinally and dye penetration was measured using a stereomicroscope with ×10. Data were analyzed with Kolmogorov–Smirnov and Kruskal–Wallis tests ($\alpha = 0.05$).

Results: The positive control group showed the highest amount of dye penetration compared to other groups (12.34 ± 0.46). Dye penetration in the MTA group was significantly lower (4.25 ± 0.31) compared to the RMGI group (5.94 ± 0.24) ($P = 0.02$). Moreover, while the dye penetration in the MTA group was lower than in the flowable composite group (5.65 ± 0.26), the difference was not statistically significant ($P = 0.12$).

Conclusion: MTA reduces the coronal leakage and provides an acceptable coronal seal in endodontically treated teeth, especially compared to RMGI, and therefore, using MTA as an intra-orifice barrier increases the endodontic treatment success rate.

Key Words: Composite resins, dental leakage, dental materials, root canal therapy

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INTRODUCTION

Microorganisms and their products are the major causes of periapical inflammation, and therefore, the main purposes of endodontic treatments are decontaminating microorganisms from teeth's root

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canal system and preventing reinfection.[1,2] For reinfection prevention and increasing the success rate of endodontics treatment, in addition to the emphasis on the apical seal, the importance of the coronal seal is also highlighted. Since all root canal fillings have leakage and no type of sealer or filling technique can prevent leakage, an appropriate coronal seal is more effective in preventing periapical inflammation than the apical seal.[3] Therefore, achieving the coronal seal to prevent microleakages into the root canal system is essential. Improper coronal restoration after root canal treatment leads to the penetration of microorganisms and their products along the root canal system or spaces inside the root filling and then into the periapical tissues, resulting in treatment failure twice as high as cases with proper coronal seals.[4,5]

The intra-orifice barrier is one of the effective approaches to reduce coronal microleakage in endodontically treated teeth, which involves implementing materials on the orifice of the canal immediately after removing the coronal part of the gutta-percha and sealer.[6] Various materials have been utilized for creating the coronal barrier to prevent microleakage, including amalgam, mineral trioxide aggregate (MTA), composite, intermediate restorative material, and calcium-enriched mixture (CEM) cement.[6-8]

MTA is a biomaterial and a combination of tricalcium silicate, dicalcium silicate, tricalcium aluminate, tetra-calcium aluminoferrite, and bismuth oxide MTA which was developed in the early 1990s.[9] MTA has been used for varied clinical applications, including pulp capping, pulpotomy, internal root resorption treatment, root-end fillings, and repair of furcation perforations. However, MTA has disadvantages such as long setting time and high cost.[7] Another material that has been used for achieving a coronal seal is the flowable composite. Flowable composites have been used for minimal invasive occlusal restorations, pit and fissure sealants, class II restorations with minimal extension, and noncarious cervical lesions.[10] While flowable composites have advantages such as their ability to form thin layers, the lack of air entrapment between layers, and high flexibility, having a high shrinkage rate is a disadvantage.[11] Moreover, resin-modified glass ionomer (RMGI) cement is used for coronal sealing and has a high bond strength to dentin, as well as significant fluoride release.[12,13] However, using RMGI is limited by the curing depth, especially when multiple layers are used.[14]

Previous studies have evaluated the coronal microleakage for various materials such as MTA, flowable composite, and RMGI. Yavari *et al.*'s study compared the microleakage of four restorative materials (MTA, composite resin, amalgam, and CEM cement) as intra-orifice barriers in endodontically treated teeth and showed that the MTA and CEM cement are more effective in preventing microleakage compared to amalgam and composite resin.[7] In addition, Ramezanali *et al.* compared the coronal sealing MTA, Biodentine, and CEM cement as intra-orifice barriers. The results showed that among the study groups, the MTA had the highest amount of microleakage, followed by Biodentine and CEM Cement; however, the differences were not significant.[15]

Due to the importance of coronal seal in endodontics treatment success rate, the various characteristics of MTA, RMGI, and flowable composite, and a lack of previous studies about comparing the microleakage in these three materials, this study aimed to compare coronal sealing of flowable composite, RMGI, and MTA in endodontically treated teeth.

MATERIALS AND METHODS

In this *in vitro* study, 35 extracted canine teeth, which were extracted due to orthodontic or periapical problems from September 2021 to May 2022, were selected. The inclusion criteria were single-canal teeth, which were determined by radiography, the absence of caries, cracks, or anomalies in the crown and root, and the absence of a calcified canal. Based on the sample size calculation mentioned below, the sample size of this study was calculated as a minimum number of 35 teeth.

$$n = \frac{\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2 (\sigma_1^2 + \sigma_2^2)}{d^2}$$

$\alpha = 0.05 \rightarrow Z_{1-\frac{\alpha}{2}} = 1.96$, $1-\beta = 0.80 \rightarrow Z_{1-\beta} = 0.84$, $\sigma = 0.67$, $d = 0.44$

Performed procedures were following the ethical standards of the Declaration of Helsinki, "Ethical Principles for Medical Research Involving 'Human Subjects," adopted by the 18th World Medical Assembly, Helsinki, Finland, June 1964, and as amended most recently by the 64th World Medical Assembly, Fortaleza, Brazil, October 2013. All procedures performed in the present study were approved by the Ethical Committee of Islamic Azad University Tehran (IR.IAU.DENTAL.REC.1400.038).

Access cavities were prepared with a high-speed handpiece. Then, the working length of the canal was determined using a stainless-steel K file size 15 (Mani Inc, Tochigi, Japan). The file was inserted into the canal, and by observing the tip of the file in the apex region, the length was measured and recorded by subtracting 0.5 from the length. The canal was prepared up to file size 35 using the step-back technique, followed by flaring up to size 80. After each filing, the canals were irrigated with 5.2% hypochlorite solution (Hypoendox, Morvabon, Iran). Then, the canals were obturated using lateral condensation technique with gutta-percha (DiaDent, Burnaby, Canada) and AH26 sealer (Dentsply Sirona, Charlotte, NC, USA). Finally, 3 mm of gutta-percha was removed from the coronal portion with a hot plugger.

After root canal treatment, the teeth were fixed in acrylic blocks and randomly divided into five groups as follows:

1. Flowable composite group: The access cavities were acid-etched using Ultra-Etch 37% phosphoric acid (UtlraDent, UT, USA) for 15 s, washed for 15 s, and then two layers of bonding agent (Single Bond, 3M ESPE, MN, USA) were applied and cured for 20 s. Then, they were filled with 3 mm of flowable composite (Opus Bulk Fill Flow, FGM Dental Group, Joinville, Brazil) and cured for 40 s with a blue phase light cure device (Ivoclar Vivadent, Schaan, Liechtenstein) at 1000 mW/cm², 400 nm wavelength, and 2 mm depth of cure
2. RMGI group: The access cavities were filled with 3 mm of glass-ionomer cement (Fuji II LC, GC, Tokyo, Japan), which was mixed according to the manufacturer's instructions, and cured for 20 s
3. MTA group: The access cavities were filled with 3 mm of MTA (Angelus MTA, Angelus Dental, Londrina, Brazil), which was mixed according to the manufacturer's instructions, and then a moist cotton was placed adjacent to the MTA for 2 h
4. Positive control group: The access cavities were sealed completely with nail polish
5. Negative control group: The access cavities were left unfilled.

While in all study groups, all tooth surfaces (crown and root) except for the incisal surface (for allowing the dye to penetrate through coronal access) were covered with two layers of nail polish, in the negative control group, all tooth surfaces, including the incisal surface, were covered with nail polish. After filling the access cavities, all specimens were kept at 37°C and 100% humidity for 24 h.

Finally, all specimens were immersed in 2% methylene blue solution (Himedia Laboratories, Maharashtra, India) at neutral pH and 37°C and 100% humidity in an incubator for 7 days. Afterward, the specimens were washed under tap water for 5 min and dried with compressed air. To evaluate the dye penetration into the specimens, after removing the nail varnish completely from the tooth surfaces by cotton soaked in acetone, all teeth were longitudinally sectioned into 2 halves with a diamond disc at the mesial and distal surfaces in the middle of the crown and root [Figure 1]. Finally, the extent of dye penetration from the crown toward the apex was measured using a stereomicroscope (SMZ 1000, Nikon, Tokyo, Japan) with ×10.

The performed procedures are summarized in Figure 2.

Statistical analysis

Kolmogorov–Smirnov and Kruskal–Wallis with *post-hoc* Mann–Whitney *U*-tests were performed using IBM SPSS 26 (IBM, NY, USA) ($P < 0.05$ was considered statistically significant).

RESULTS

Coronal microleakage of 70 specimens was analyzed in this study. The MTA group had the lowest amount of dye penetration, while the glass ionomer resin group

Figure 1: Fixed tooth in acrylic blocks after being sectioned.

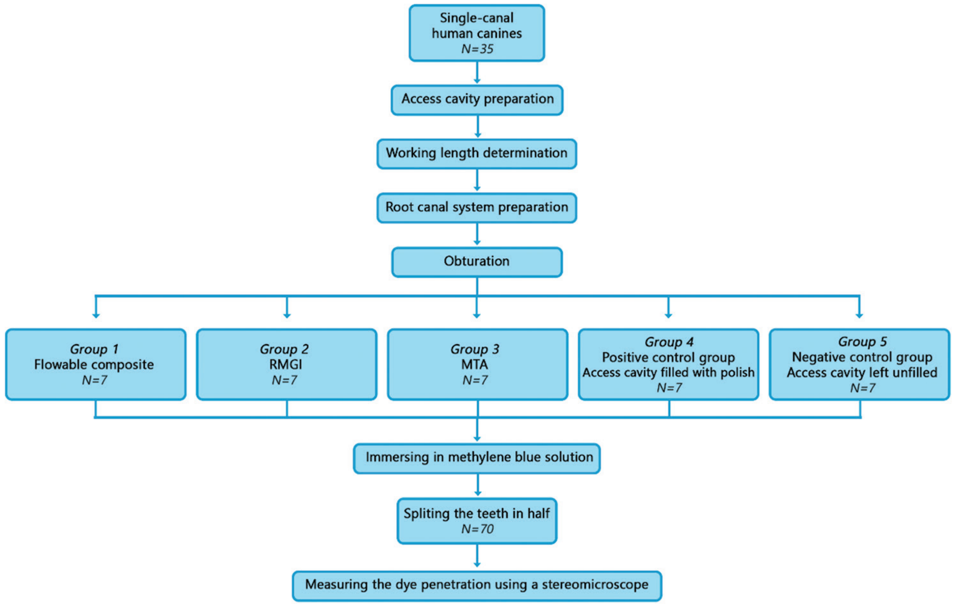

Figure 2: Diagram of performed procedures.

had the highest amount of dye penetration (excluding the positive and negative control groups). Table 1 shows further information about the amount of coronal microleakage in each group. According to the results of the Kolmogorov–Smirnov test, the variable did not have a normal distribution ($P < 0.05$). Therefore, nonparametric tests were performed.

According to the results of the Kruskal–Walli's test, there was a statistically significant difference in the amount of cervical microleakage among study groups ($P < 0.05$), and for pairwise comparison, the Mann–Whitney *U*-test was performed as a *post-hoc* analysis [Table 2]. The amount of coronal microleakage was significantly different in all pairwise comparisons except for the negative control and MTA groups ($P = 0.200$), the MTA and flowable composite groups ($P = 0.120$), flowable composite and glass ionomer groups ($P = 0.464$), and finally the glass ionomer and positive control groups ($P = 0.120$).

DISCUSSION

Based on the findings of this study, MTA, RMGI, and flowable composite groups showed microleakage. MTA had the lowest amount of coronal microleakage, while RMGI had the highest amount of coronal microleakage compared to MTA and Flowable composite. While the coronal microleakage in MTA was significantly higher than in the RMGI group, the differences between the flowable composite group and the other two groups were not significant. It is important to note that the final restoration of the cavity restores function and beauty to the tooth, and since the coronal seal is provided by materials such as glass ionomer, flowable composite, or MTA, the final restoration of the cavity does not affect the coronal

Table 1: Mean and standard deviation values of coronal microleakage among different study groups (µm)

Group	Mean±SD	Range
Flowable composite	5.6571±0.26992	5.3–6
RMGI	5.9429±0.24398	5.5–6.2
MTA	4.2571±0.31015	3.9–4.7
Negative control	12.3429±0.46496	11.5–12.8
Positive control	0.1857±0.24103	0–0.5

RMGI: Resin-modified glass ionomer; MTA: Mineral trioxide aggregate; SD: Standard deviation

Table 2: Pairwise comparison of coronal microleakage in different study groups

First group	Second group	*P*
Negative control	MTA	0.200
Negative control	Flowable composite	0.005*
Negative control	RMGI	0.000*
Negative control	Positive control	0.000*
MTA	Flowable composite	0.120
MTA	RMGI	0.022*
MTA	Positive control	0.000*
Flowable composite	RMGI	0.464
Flowable composite	Positive control	0.022*
RMGI	Positive control	0.120

*Statistically significant. RMGI: Resin-modified glass ionomer; MTA: Mineral trioxide aggregate seal. Therefore, the final restoration will not affect our results.

Although previous studies have supported the effectiveness of intra-orifice barriers for reducing coronal microleakage,[16] there is no consensus on the used materials for coronal sealing and conflicting results have been reported regarding the ability of different materials for coronal sealing.[10,12,17] As a result, the findings of this study can be lucrative for choosing the suitable material for achieving a more acceptable coronal seal.

Similar to the present study, Yavari *et al*.'s study in 2012 compared the coronal microleakage of amalgam, resin composite, MTA, and CEM Cement as the intra-orifice barrier in endodontically treated teeth. This study showed that MTA and CEM Cement were more effective in preventing microleakage in endodontically treated teeth as an intra-orifice barrier compared to amalgam and resin composite.[7] Furthermore, Tselnik *et al*.'s study in 2004 recommended MTA and glass ionomer as acceptable coronal sealing materials.[18] In addition, a study conducted by Roberts *et al*. in 2008 demonstrated that MTA can be a suitable intra-orifice barrier material.[17] MTA is a suitable material for achieving coronal seal due to its hydrophilic and antimicrobial properties, high pH, hydroxyapatite crystalline structure, and ease of placement.[17,18]

Kumar and Dengre's study in 2018 was conducted with the aim of comparing the effect of conventional glass ionomer cement, RMGI cement, and flowable composite in preventing marginal leakage. This study showed that flowable composite had the highest amount of microleakage followed by RMGI and conventional glass ionomer cement.[19] Kumar *et al*.'s[19] study mentioned that less amount of microleakage of glass ionomer cement is attributed to its ability to absorb water, directly attach to dentin, and release fluoride, which reduces marginal microbial leakage due to its antimicrobial properties. On the other, the present study demonstrated that the amount of microleakage of flowable composite is lower than RMGI cement. This discrepancy may be due to differences in methodology, as Kumar *et al.* used molar teeth while this study used canine teeth. Glass ionomer dentin bonding, especially to the pulp floor of molar teeth, can lead to less microleakage in molar teeth compared to canine teeth.[19]

Tselnik *et al*.'s study[18] used microbial leakage to evaluate the marginal seal; however, in the present study, dye penetration was utilized. Dye penetration is the most common method in studies of marginal leakage due to its affordability and ease of usage. Due to having a lower molecular weight, dye molecules have a higher depth of penetration compared to bacterial cells. Therefore, if a restorative material can resist dye penetration in *in vitro* conditions, it will likely perform better in clinical conditions against bacteria.[20]

Performing the procedures in an optimum *in vitro* condition was the limitation of this study. The authors suggest performing further prospective studies in an *in vivo* environment with a higher sample size.

CONCLUSION

MTA reduces the coronal leakage and provides an acceptable coronal seal in endodontically treated teeth, especially compared to RMGI, and therefore using MTA as an intra-orifice barrier increases the endodontic treatment success rate.

Ethical approval and consent to participate

Procedures followed were in accordance with the ethical standards of the Declaration of Helsinki "Ethical Principles for Medical Research Involving 'Human Subjects," adopted by the 18th World Medical Assembly, Helsinki, Finland, June 1964, and as amended most recently by the 64th World Medical Assembly, Fortaleza, Brazil, October 2013. All procedures performed in the present study was approved by the Ethical Committee of Islamic Azad University Tehran (IR.IAU.DENTAL.REC.1400.038).

Data availability

The datasets analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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