Coronal Seal Microleakage Effect of the Four Different Types of Restorative Materials on Endodontically Treated Lower Premolar

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ABSTRACT

Aim and objective: The aim and objective of this study was to compare the quality of the coronal seal of four different types of restorative material on the endodontically treated teeth.

Materials and methods: A total of 112 extracted permanent lower premolars were endodontically prepared and divided into four groups ($n = 28$). Each group received different types of coronal restoration. Group I, glass ionomer cement Fuji IX (GC International, Japan), Group II, nano-hydroxyapatite-silica glass ionomer cement (Hospital Universiti Sains Malaysia), Group III, Smart Dentin Replacement (SDR™) (Dentsply, Konstanz, Germany), and Group IV, Zmack microhybrid universal resin composite (Zhermack SpA, Italy). Twenty-six samples from each group were then covered with two layers of nail varnish except at the restoration site, while two control samples were totally covered, including the restoration site. The samples were further divided into 2 groups of 13 samples and 1 control, each. They were immersed in the 2% methylene blue dye solution for 7 and 30 days, respectively. All samples were sectioned in a vertical direction, and dye penetration depth was measured. Data analysis was carried out using one-way analysis of variance.

Results: A significant difference in sealing ability was observed ($p < 0.05$) with Group IV demonstrating the best sealing ability followed by Group III, Group II, and lastly Group I in dye penetration tests. The gap width between the dentin wall and restorative material in Groups III and IV was minimal compared to Groups I and II.

Conclusion: Group IV (Zmack universal composite) demonstrated better coronal seal compared to silicate glass powder-based restorative materials.

Clinical significance: The use of Zmack universal composite in the endodontically treated tooth can be superior in providing better coronal seal and closest adaption to the access cavity wall.

Keywords: Coronal seal, Fuji IX GIC, Nano-hydroxyapatite-silica glass ionomer cement, Smart dentin replacement composite, Zmack universal composite.

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INTRODUCTION

Endodontic treatment is used to eliminate pulp tissue infection as well as to protect the disinfected root canal from future microbial invasion. However, the reinfection can occur in endodontically treated tooth and there is still a 20–30% failure rate in a well-sealed disinfected root canal.¹ Most of the studies suggested that coronal leakage is far more likely to be the major determinant of clinical success or failure than apical leakage in endodontically treated teeth.² Saliva and microorganisms from the oral cavity may rapidly migrate alongside poorly adapted coronal restorations and even root fillings.³ There are many debates in choosing the most appropriate coronal restorative material in endodontic treatment. Over the years, mineral trioxide aggregate, amalgam, composite resin, glass ionomer cement (GIC), bioceramic-based materials, and nano-hydroxyapatite (nano-HA)-based materials have been chosen as a permanent restoration for coronal seal. The biggest challenges among all these types of materials are their ability to achieve a tight and adequate coronal seal to prevent any possibility for reinfection. The purpose of this *in vitro* study is to evaluate four different types of restorative materials and their coronal-sealing ability on endodontically treated teeth using dye penetration test and to compare the adaptation of different restorative materials on the access cavity wall of endodontically treated tooth under scanning electron microscope (SEM).

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MATERIALS AND METHODS

This was an *in vitro* experimental study on 112 human single-rooted mature and caries free of human lower permanent premolars recently extracted due to orthodontic purposes. Radiographic examination

under digital radiograph (Planmeca Romexis®, Helsinki, Finland) was performed to ensure that only a lower premolar with a single canal was selected. Scaling was performed to remove calculus and debris. Then, the teeth were immersed for 48 hours in 2.5% sodium hypochlorite (NaOCl) solution for disinfection. This study was based on Cardoso et al., where the single canal was chosen for an assessment of single direction of the dye penetration from coronal into the most apical site of the canal. Whereas, the lower premolars were selected because of their usefulness in the dental arch and supplement the grinding of the molars during mastication.^{4,5} Therefore, the teeth required a strong coronal restoration to withstand the mastication load in order to avoid fracture and further leakage.

The access cavities were prepared using high-speed endodontic cutting access burs No. 75A (Reco-Dent, Sweden) with water coolant to create a standardized access cavity volume with dimensions of $2 \times 2 \times 6$ mm. To ensure approximately 6 mm of cavity depth was attained, the periodontal probe was used to measure the depth of each cavity.⁶ The access cavity diameter measured with caliper.⁷ Crown down technique was then performed using Protaper rotary (Dentsply Maillefer, USA), the final preparation was with the F2 file. During root canal therapy, irrigation using 2.5% NaOCl solution (Hospital Universiti Sains Malaysia) and a final rinse with 17% EDTA solution (Meta Biomed, South Korea) were performed to remove smear layers. F2 gutta-percha (Dentsply Maillefer, USA) and Endo Rez sealer (Ultradent Inc., South Jordan, USA) were used for obturation. Along with the procedures, the teeth were handled in moist gauze in order to minimize dehydration.

The obturated teeth were divided into four groups ($n = 28$ for each group). Access cavities were restored with one of the four tested materials:

- Group I: Access cavity restored with conventional GIC FUJI IX (GC International, Japan).
- Group II: Access cavity restored with nano-HA-silica GIC (Hospital Universiti Sains Malaysia).
- Group III: Access cavity restoration with Smart Dentin Replacement (SDR™) (Dentsply, Konstanz, Germany).
- Group IV: Access cavity restored with Zmack microhybrid universal resin composite (Zhermack SpA, Italy).

The materials were placed into the cavity access according to the manufacturer's instructions. The samples were kept in incubator at 37°C, 100% humidity for 72 hours, and 500 cycles of thermocycling process using a thermocycling machine (TS Series Liquid, Weiss Technik, North America) in sequential water baths of 5°C, 37°C, and 55°C to mimic human oral cavity and allow the sealers to set.

Dye Penetration Test

Twenty-six samples from each group were then covered with two layers of nail varnish (SuperNails, London, United Kingdom) except at the restoration site, while two control samples were totally covered, including the restoration site. Then, the samples were further divided into 2 groups of 13 samples and 1 control, each. One group was immersed in the 2% methylene blue dye solution (MKCD3437, Sigma Aldrich, USA) for 7 days, while another group was immersed for 30 days. After 7 and 30 days, respectively, nail varnish was applied on the uncovered area before all the specimens went for cleaning under running water for 2 hours. The samples were dried for 12 hours at room temperature and sectioned in a mesiodistally along their longitudinal axis using hard tissue cutter

(EXAKT 312, EXAKT Technologies, Inc., Oklahoma City, USA). The prepared samples were observed under Leica microscope (Leica Micro-system Imaging Solutions, Cambridge, UK) at magnification of $\times 20$ where the reading for the depth of dye penetration from coronal to most apex was measured by Image J software (License: Public Domain, BSD-2) in millimeters (mm) and assessed, according to Cardoso et al.⁸

Marginal Adaptation Test

One experimental sample was randomly selected from each group, both 7 and 30 days immersion, respectively. The sample was observed under the SEM (FEI Quanta 450, Oregon, USA) using a high accelerating voltage of 15.0 kV at different magnifications ranging from $\times 25$ to $\times 2000$ and microphotographs were taken at $\times 2000$ magnification for both 7 and 30 days (Fig. 1). Largest value of the width of the gap between the restorative material and dentinal wall of cavity access was assessed and recorded in micrometers (μm) (Table 1).

Statistical Analysis

All the data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 24.0 software (Chicago, Illinois, USA).

The Kolmogorov–Smirnov test was used for the normality of dye penetration data distribution and Levene's test for homogeneity of variances. Since the data were normally distributed, they were analyzed using parametric test. The dye penetration test between all restorative groups was compared using independent t test. The significance different was assessed by one-way analysis of variance (ANOVA) test, followed by the *post hoc* Tukey test for multiple comparison. Analysis of variance and pairwise comparison tests were conducted to compare the mean of the dye penetration test among the groups. The level of significance of the test was set at $p < 0.05$.

RESULTS

For the 7 days of the dye penetration test, Zmack universal composite (Group IV) (Figs 2A and B) showed the lowest depth of the dye penetration compared to other groups (Table 2). There was a significant difference ($p < 0.05$) in the depth of the dye penetration of Zmack universal composite (Group IV) compared to the conventional GIC (Group I) (Figs 2G and H) and nano-HA-silica GIC (Group II) (Figs 2E and F). However, no significant difference was observed between Zmack universal composite (Group IV) and SDR composite (Group III) (Figs 2C and D and Table 3).

For the 30 days of the dye penetration test, Zmack universal composite (Group IV) consistently showed the lowest depth of the dye penetration compared to other groups (Table 4). There was a significant difference ($p < 0.05$) in the depth of the dye penetration of Zmack universal composite (Group IV) compared to all other groups (Table 5). The result showed that Zmack universal composite (Group IV) has an acceptable sealing ability compared to other type of restorative materials.

DISCUSSION

Endodontic failure has always been associated with poor quality of the coronal seal. The long-term outcome of thermal changes in the oral cavity can cause elastic deformation and physical alterations of both tooth structures and restoration materials which results in

Figs 1A to H: Microphotographs (x2000) of the width of the gap between the different restorative material and dentinal wall of cavity access after 7 and 30 days of tooth immersion in the dye

Table 1: Maximum gap width (μm) of different coronal restorative materials to the dentine wall

Tooth sample	Maximum gap width (μm)	
Group I (conventional GIC)	7 days	88.16
	30 days	107.66
Group II (nano-HA-silica GIC)	7 days	52.36
	30 days	104.96
Group III (SDR resin composite)	7 days	6.40
	30 days	25.70
Group IV (Zmack universal composite)	7 days	6.03
	30 days	8.06

microleakage. Studies have shown that coronal leakage is far more likely a determinant for the failure of a well-obtured root canal and therefore a sound coronal seal is of paramount importance to the successful outcome of the root canal treatment.⁹ Somani described microleakage as the movement of oral fluids between the tooth and restoration interface.¹⁰ The fluid may contain bacteria and other noxious substances that may cause failure of the restorative treatment. Saliva and microorganisms from the oral cavity may rapidly migrate alongside poorly adapted coronal restorations and even root fillings.^{3,11} The results of the present study show none of the investigated restorative material could eliminate the microleakage.

All the tested coronal restorative materials showing a smaller marginal gap and better quality of coronal seal after 7 days of

immersion compared to the 30 days of immersion in marginal adaptation test. When compared between groups, the gap width between the dentin wall and restorative material in Groups III and IV was minimal compared to Groups I and II. Group IV which shows the smallest value of the interfacial gap demonstrating the best quality of the coronal seal.

All the study groups showed microleakage of varying degrees. The results agree with the observation of Somani,¹⁰ Mali,¹² and Poggio.¹³ Although resin composite is widely used as a permanent restorative material, marginal microleakage is still one of its biggest drawbacks. This can be a result of polymerization shrinkage, fatigue cycling, and thermal changes in the oral environment.¹⁴ However, when compared to the resin composite with other materials, such as silicate glass powder-based restorative materials, the marginal microleakage is significantly minimal. Therefore, resin composite is more acceptable to be used as the permanent restoration on the endodontically treated tooth, whereas GIC and nano-HA-silica GIC are better to be used as provisional restoration. Glass ionomer cement improved its physical properties, such as hardness, compressive strength, diametral tensile strength, and flexural strength, when it was incorporated with nano-HA materials.^{15,16} Smaller particle size of nano-HA makes the gravity cohesion lower and thus increases its intermolecular physical bonding (Van der Waals forces) and creates a higher surface activity between the material and tooth. Thus, nano-HA material is expected to have a better coronal seal ability than conventional GIC.¹⁶ However, from the study, the coronal-sealing ability of GIC and nano-HA-silica GIC are almost

Figs 2A to H: Comparison of the depth of dye penetration under different coronal restorative materials after 7 and 30 days of immersion in 2% methylene blue solution

Table 2: Mean (standard deviation) of the depth of the dye penetration after 7 days of immersion in methylene blue solution (2%)

Type of restoration	Mean (SD)	F statistic (df)	p value
Conventional GIC	4251.70 mm	43.845	$p < 0.05$
Nano-HA-silica GIC	4185.79 mm		
SDR composite	848.87 mm		
Zmack universal composite	817.28 mm		

One-way ANOVA

similar. This could be due to long-standing exposure to the fluid and thermal which contributed to the modification or changes of their structures. Therefore, more research and clinical trials on the materials itself need to be conducted to provide more detail and valid outcomes. Intraoral thermal changes may be resulted by routine activity, such as eating, drinking, and breathing.¹⁷ This thermal changes may cause the gap volumes dimension changes between dental materials and tooth structure and will induce pump pathogenic oral fluids in and out of the gaps. Thermal cycling is an *in vivo* laboratory simulation of clinical service which

Table 3: Post hoc analysis multiple comparison after 7 days of immersion in methylene blue solution (2%)

Type of restoration	p value	95% Confidence interval	
		Lower bound	Upper bound
Zmack universal composite vs SDR composite	0.379	-2431.41226	597.76059
Zmack universal composite vs conventional GIC	0.000	-6105.24726	-3076.07441
Zmack universal composite vs nano-HA-silica GIC	0.000	-7196.66781	-4019.64452
SDR composite vs conventional GIC	0.000	-5188.42143	-2159.24857
SDR composite vs nano-HA-silica GIC	0.000	-6279.84198	-3102.81869
Conventional GIC vs nano-HA-silica GIC	0.330	-2606.00698	571.01631

Statistically significant different at $p < 0.05$

Table 4: Mean (standard deviation) of the depth of the dye penetration after 30 days of immersion in methylene blue solution (2%)

Type of restoration	Mean (SD) mm	F statistic (df)	p value
Conventional GIC	4627.80	8.115	$p < 0.05$
Nano-HA-silica GIC	4616.32		
SDR composite	3667.61		
Zmack universal composite	1973.04		

One-way ANOVA

Table 5: Post hoc analysis multiple comparison after 30 days of immersion in methylene blue solution (2%)

Type of restoration	p value	95% Confidence interval	
		Lower bound	Upper bound
Zmack universal composite vs SDR composite	0.026	-3231.50136	-157.63576
Zmack universal composite vs conventional GIC	0.002	-3848.65253	-708.67474
Zmack universal composite vs nano-HA-silica GIC	0.000	-4180.21219	-1106.34660
SDR composite vs conventional GIC	0.741	-2121.02787	952.83772
SDR composite vs nano-HA-silica GIC	0.342	-554.43910	2451.86076
Conventional GIC vs nano-HA-silica GIC	0.920	-1901.54856	1172.31704

*statistically significant different at $p < 0.05$

represents the oral thermal changes. The process simulated an oral condition, where the stress from the thermocycling process will be exaggerated directly affecting the marginal seal.¹⁸ They suggested that the sequence of temperature 35°C, 15°C, 35°C, and then 45°C with a corresponding dwell sequence of 28, 2, 28, and 2 seconds to be sufficiently clinically relevant and therefore recommended as a suitable discriminatory challenge. In our study, the samples were subjected to 500 cycles of thermocyclic process, represented for almost a month of clinical service. This was carried out in sequential water baths of 5°C, 37°C, and 55°C with a dwelling time of 30 seconds and transfer time of 10 seconds to mimic the human oral cavity and allow the sealers to set. Based on the recent findings, the results obtained *in vitro* studies cannot be directly extrapolated to the clinical situations, but somehow do provide some comparison. Therefore, *in vivo* and clinical trials need to be performed to provide more reliable and valid outcomes.

CONCLUSION

Zmack universal composite demonstrated the better coronal-sealing ability on endodontically treated tooth, followed by SDR composite, nano-HA-silica GIC, and lastly conventional GIC. Zmack universal composite also shown to have closest adaptation on access cavity wall of endodontically treated tooth compared to SDR composite and silicate glass powder-based restorative materials.

CLINICAL SIGNIFICANCE

The use of Zmack universal composite in the endodontically treated tooth can be superior in providing better coronal seal and closest adaption to the access cavity wall when compared with SDR composite followed by nano-HA and conventional silicate glass powder-based restoration materials.

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REFERENCES

- Machtou P. Apical seal vs coronal seal. *Endo Pract* 2006;9(2):19.
- Sriharan A. Discuss that the coronal seal is more important than the apical seal for endodontic success. *Aust Endod J* 2002;28(3):112–115. DOI: 10.1111/j.1747-4477.2002.tb00404.x.
- Vârlan C, Dimitriu B, Vârlan V, et al. Current opinions concerning the restoration of endodontically treated teeth: basic principles. *J Med Life* 2009;2(2):165.
- Hashii K, Tomida M, Yamashita S. Influence of changing the chewing region on mandibular movement. *Aust Dent J* 2009;54(1):38–44. DOI: 10.1111/j.1834-7819.2008.01086.x.
- Zhang Q, Witter DJ, Bronkhorst EM, et al. The relationship between masticatory ability, age, and dental and prosthodontic status in an institutionalized elderly dentate population in Qingdao, China. *Clinical Oral Investig* 2019;23(2):633–640. DOI: 10.1007/s00784-018-2477-z.
- Cruz E, Shigetani Y, Ishikawa K, et al. A laboratory study of coronal microleakage using four temporary restorative materials. *Int Endod J* 2002;35(4):315–320. DOI: 10.1046/j.1365-2591.2002.00446.x.
- Özyürek T, Ülker Ö, Demiryürek EÖ, et al. The effects of endodontic access cavity preparation design on the fracture strength of endodontically treated teeth: traditional vs conservative preparation. *J Endod* 2018;44(5):800–805. DOI: 10.1016/j.joen.2018.01.020.
- Cardoso AS, Silva NC, Silva JM, et al. Assessment of coronal leakage of a new temporary light-curing filling material in endodontically treated teeth. *Indian J Dent Res* 2014;25(3):321. DOI: 10.4103/0970-9290.138329.
- Siqueira Jr JF, Rôças IN, Favieri A, et al. Bacterial leakage in coronally unsealed root canals obturated with 3 different techniques. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000;90(5):647–650. DOI: 10.1067/moe.2000.110412.
- Somani R, Jaidka S, Jawa D, et al. Comparative evaluation of microleakage in conventional glass ionomer cements and triclosan incorporated glass ionomer cements. *Contemp Clin Dent* 2014;5(1):85. DOI: 10.4103/0976-237X.128675.
- Greabu M, Battino M, Mohora M, et al. Current opinions concerning the restoration of endodontically treated teeth: basic principles. *J Med Life* 2009;2(2):124.
- Mali P, Deshpande S, Singh A. Microleakage of restorative materials: an *in vitro* study. *J Indian Soc Pedod Prev Dent* 2006;24(1):15. DOI: 10.4103/0970-4388.22828.
- Poggio C, Chiesa M, Scribante A, et al. Microleakage in class II composite restorations with margins below the CEJ: *in vitro* evaluation of different restorative techniques. *Med Oral Patol Oral Cir Bucal* 2013;18(5):e793. DOI: 10.4317/medoral.18344.
- Kubo S, Yokota H, Sata Y, et al. The effect of flexural load cycling on the microleakage of cervical resin composites. *Oper Dent* 2001;26(5):451.
- Arita K, Lucas ME, Nishino M. The effect of adding hydroxyapatite on the flexural strength of glass ionomer cement. *Dent Mater J* 2003;22(2):126–136. DOI: 10.4012/dmj.22.126.

16. Moshaverinia A, Ansari S, Movasaghi Z, et al. Modification of conventional glass-ionomer cements with *N*-vinylpyrrolidone containing polyacids, nano-hydroxy and fluoroapatite to improve mechanical properties. *Dent Mater* 2008;24(10):1381–1390. DOI: 10.1016/j.dental.2008.03.008.
17. Palmer D, Barco M, Billy E. Temperature extremes produced orally by hot and cold liquids. *J Prosthet Dent* 1992;67(3):325–327. DOI: 10.1016/0022-3913(92)90239-7.
18. Powers JM, Sakaguchi RL, Craig RG. Craig's restorative dental materials. In: Sakaguchi RL, Powers JM, ed., Philadelphia, PA: Elsevier/Mosby; 2012.