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Shear Bond Strength of an Endodontic Tricalcium Silicate-Based Putty to Different Adhesive Systems at Different Time Intervals

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ABSTRACT

Introduction: New bioceramic products continue to be released into the market, with slight differences in formulation, manipulation, and manufacturer's instructions. NeoPUTTY is a new fast setting bioceramic putty that is easy to manipulate, and final restoration can be placed immediately.

Aim: This study aimed to evaluate the shear bond strength of resin-modified glass ionomer cement (RMGIC) and self-adhering flowable composite (SAFC) to the NeoPUTTY placed immediately or after 24 h.

Materials and Methods: A total of 80 Teflon blocks with a central hole (4 mm in diameter and 2 mm in depth) were prepared and filled with NeoPUTTY. The blocks were then assigned to two groups (n=40) based on the restorative materials used (SAFC or RMGIC). Each group was subdivided into two subgroups (n=20) based on the evaluation intervals (immediately and 24 h after placing the NeoPUTTY. After the bonding procedures, the shear bond strengths of the samples were measured in MPa at a strain rate of 0.5 mm/min. Data were analysed using one-way ANOVA, post hoc test, and t-test (P<0.05).

Results: A significant difference was found between all the groups, with the highest value obtained with SAFC placed after 24 h, whereas the lowest values were obtained with RMGIC when placed immediately.

Conclusion: The bond strengths of SAFC immediately or 24 h after placing NeoPUTTY were significantly higher than those of RMGIC. Thus, SAFC is recommended for use with NeoPUTTY instead of RMGIC.

Key words: NeoPUTTY, Self-adhering composite, Shear bond strenrth, Tricalcium silicate putty

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INTRODUCTION

Calcium silicate-based cements (CSCs) are a group of biomaterials that have been introduced into the market as an alternative to calcium hydroxide [1]. They are currently the material of choice for regeneration and repair treatments in endodontics due to their biocompatibility, bioactivity, sealing properties, and ability to induce reparative hard tissue formation [2].

The original tricalcium silicate-based product, known as mineral trioxide aggregate (MTA), was introduced to dentistry in 1993 by Torbinejad, et al. [3]. However, MTA has different limitations, such as discoloration of tooth structure, difficult handling, premixing, and long working time, which might require several appointments to complete treatment [4,5]. Therefore, several CSCs were introduced into the market, such as premixed tricalcium silicate-based putties, which were introduced in 2010 to overcome these limitations of MTA [6,7].

Premixed tricalcium silicate-based putties have the advantages of being easy to handle, premixed, hydrophilic, and offer immediate placement of the final restoration [8].

With CSCs a leakage-free restoration should be used to ensure a successful treatment [9,10]. Therefore, several studies have been conducted to evaluate the bonding of CSCs with different restorative materials (composite, glass ionomer, and amalgam) [9-12].

Kayahan et al. [11] evaluated the effect of acid etching on the compressive strength and surface microhardness of ProRoot MTA and recommended delaying the final restoration when acid etching is required for at least 4 days after mixing the MTA. In addition, the use of an intermediate material or liner, such as flowable composite or resin-modified glass ionomer, has also been suggested to avoid condensation forces [12].

A new composite known as self-adhering flowable composite (SAFC) has been introduced to the market by combining an all-in-one bonding system and flowable composite resin [13]. It has the advantage of fewer application steps where etching and bonding are eliminated to simplify the adhesive procedure [13]. Oz et al. [14] compared the long-term clinical performance of SAFC and flowable composite in Class I cavity restoration and concluded that SAFC exhibited a clinical performance like the conventional flowable applied with an etch-and-rinse adhesive.

NeoPUTTY (NuSmile, Houston, TX, USA) is a new fast-setting pre-mixed hydraulic calcium silicate putty that has been introduced to the market. The adhesion of restorative materials to NeoPUTTY has not been extensively studied. To date, no published papers have evaluated the shear bond strength of NeoPUTTY with SAFC or RMGIC. Therefore, this in vitro study aimed to test the shear bond strength of two different restorative materials, SAFC (Vertise™ Flow, Kerr, Orange, CA, USA) and RMGIC (GC Fuji II LC®, GC, Japan), with NeoPUTTY and to assess whether the proper time to perform the restorative procedure is immediately or 24 h after the placement of NeoPUTTY.

MATERIALS AND METHODS

This study was conducted after obtaining approval from the College of Dentistry Research Centre, Deanship of Scientific Research, King Saud University (No. FR-0604). A total of 80 polytetrafluoroethylene (Teflon) molds were prepared with a central hole measuring 4 mm in diameter and 2 mm in depth, fully filled with NeoPUTTY (NeoPUTTYTM, NuSmile, Houston, TX, USA), and the surface was smoothed using a spatula.

The samples were then randomly assigned to two groups based on the restorative material used: self-adhering flowable composite (SAFC) (Vertise™ Flow, Kerr, Orange, CA, USA) or resin-modified glass ionomer cement (RMGIC) (GC Fuji II LC®, GC, Japan). The samples in each group were then subdivided into two sub-groups (n=20) based on the setting procedure duration: immediately and after 24 h as follows:

- Group 1: SAFC, immediately.
- Group 2: RMGIC, immediately.
- Group 3: SAFC, after 24 h.
- Group 4: RMGIC, after 24 h.

In groups 1 and 2, the bonding procedures were carried out immediately after placing the Neo PUTTY, while groups 3 and 4 were incubated at 37°C and 100% humidity for 24 h after placing them vertically in a plastic container with wet gauze and secured tightly with a lid.

For the bonding procedure, a customized silicone mold with a thickness of 2 mm was fabricated for use in the bonding procedure. A 3-mm circular hole was made in the centre of the mold. The mold was placed at the centre of the Neo PUTTY.

In groups 1 and 3, the SAFC was bonded to NeoPUTTY following the manufacturer's instructions. In groups 2 and 4, the RMGIC was bonded to the Neo PUTTY after applying the cavity conditioner (GC cavity conditioner, GC, Japan). All samples were light-cured using a previously calibrated LED light-curing device (Bluephase G2; Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's instructions. After removing the mold, the samples were cured again for 20 s and incubated at 37°C and 100% humidity for 24 h before the shear bond strength test. All materials used are listed in Table 1.

Table 1: Materials, compositions, and instructions for use.

Material	Composition	Instructions for use
NeoPUTTYTM (NuSmile, Houston, TX, USA)	Tricalcium and dicalcium silicate and aluminate, tantalite, proprietary organic liquid and stabilizers	apply NeoPUTTY material with a minimum thickness of 1.5 mm.
Vertise Flow (Kerr, USA)	Matrix: GPDM adhesive monomer, UDMA, BisGMA, and other methacrylate comonomers, photoinitiators.	1. apply a thin layer and brush it with a microbrush (<0.5 mm)
	Fillers: 70% by weight. Ytterbium Fluoride, barium aluminosilicate glass, prepolymerized fillers, and colloidal silica	2. Light-cure for 15-20 s
		3. Place additional increments of Vertise Flow in 2 mm or less
		4. Light-cure for 20 s
GC Cavity Conditioner (GC Corporation, Tokyo, Japan)	20% polyacrylic acid, 77% distilled water, 3% aluminum chloride hydrate, 0.1% food additive blue No. 1.	1. Apply for 10 s
		2. Rinse with water for 10 s
		3. Gently air dry for 5 s, leaving a moist surface
Fuji II LC in caps (GC Corporation, Tokyo, Japan)	2-hydroxyethyl methacrylate (HEMA), Urethane Dimethacrylate (UDMA), Polyacrylic acid, Fluoro alumino-silicate glass, Distilled water	1. Automatically mix capsules for 10 s
		2. Apply to enamel and dentin surfaces
		3. Light cure for 20 s

Finally, the shear bond strength of the samples was determined in MPa using a universal testing machine (Instron5965, Instron, England) with a knife-edged rod at a crosshead speed of 0.5 mm/min.

To determine the fracture pattern the samples were examined using a stereomicroscope (Nikon Stereomicroscope 100 m Microscope, SMZ 1000, SMZ800, Swift, CA, USA) with a digital camera (Nikon digital cameraDXM1200F). The failure modes were categorized as follows:

- Adhesive failure: failure between NeoPUTTY and restorative materials.
- Cohesive failure: cohesive failure within the NeoPUTTY.
- Cohesive failure: cohesive failure within the restorative materials.
- Mixed failure: both adhesive and cohesive.

All data were processed using the Statistical Package for the Social Sciences software (version 21.0; SPSS Inc., Chicago, IL, USA). Comparisons between groups were analyzed using a one-way analysis of variance (ANOVA) and the post-hoc test. Statistical significance was set at P<0.05.

RESULTS

The mean, standard deviations, and minimum and maximum values of shear bond strengths (MPa) of SAFC and RMGIC to NeoPUTTY are listed in Table 2.

Table 2: Descriptive statistics of the shear bond strength of the four experimental groups.

Groups	No.	Mean	Std. Deviation	Minimum	Maximum
1	20	1.61107	0.515096	0.24649	2.79254
2	20	0.68541	0.162125	0.41837	0.96143
3	20	4.056668	0.853373	2.71431	5.56709
4	20	2.888581	0.581874	1.83173	4.09987
Total	80	2.310432	1.405586	0.24649	5.56709

Table 3 shows comparison of the four groups with respect to shear bond strength by using one-way ANOVA test, which revealed a statistically significant difference between all the groups (p=0.000).

Table 3: Comparison of the four experimental groups with respect to shear bond strength by one-way ANOVA.

	Sum of Squares	Dff	Mean Square	F-value	p-value
Between Groups	130.268	3	43.423	127.861	0
Within Groups	25.81	76	0.34		
Total	156.078	79			

The post hoc test was used to evaluate the differences between groups (Table 4). The results showed that the SAFC after 24 h (p=0.0000) had the highest bond strength values compared to the other groups. This was followed by the RMGIC after 24 h (p=0.000). The lowest shear bond strength values were obtained by the immediate placement of RMGIC (p=0.000).

Table 4: Post hoc comparison of shear bond strength between the four experimental groups.

Groups		Mean Difference (I-J)	Std. Error	p-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	0.92566000*	0.18428443	0	0.5586257	1.2926943
	Group 3	-2.44559800*	0.18428443	0	-2.8126323	-2.0785637
	Group 4	-1.27751150*	0.18428443	0	-1.6445458	-0.9104772
Group 2	Group 1	-0.92566000*	0.18428443	0	-1.2926943	-0.5586257
	Group 3	-3.37125800*	0.18428443	0	-3.7382923	-3.0042237
	Group 4	-2.20317150*	0.18428443	0	-2.5702058	-1.8361372
Group 3	Group 1	2.44559800*	0.18428443	0	2.0785637	2.8126323
	Group 2	3.37125800*	0.18428443	0	3.0042237	3.7382923
	Group 4	1.16808650*	0.18428443	0	0.8010522	1.5351208
Group 4	Group 1	1.27751150*	0.18428443	0	0.9104772	1.6445458

	Group 2	2.20317150*	0.18428443	0	1.8361372	2.5702058
	Group 3	-1.16808650*	0.18428443	0	-1.5351208	-0.8010522

*The mean difference is statistically significant (p-value<0.05)

The percentages of samples exhibiting the four failure modes in each group are shown in Figure 1. Mixed and cohesive failure within the NeoPUTTY were the predominant modes among all the groups.

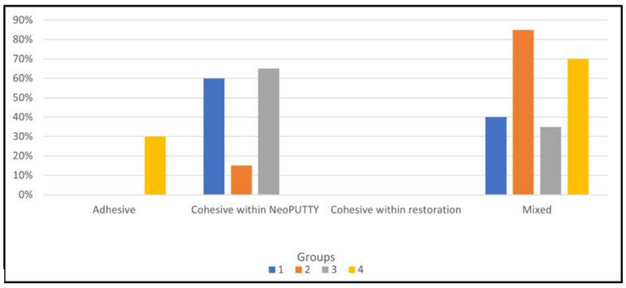

Figure 1: The percentages of samples exhibiting the four failure modes in each group.

DISCUSSION

Shear bond strength is a measure of the strength between two materials and estimates the local stress that the bonding layer can withstand. A higher shear bond strength means better bonding between the two interfaces and increases retention, which results in lesser microleakage [15]. Therefore, the shear bond strength was used in this study to evaluate the adhesive properties of SAFC and RMGIC with NeoPUTTY.

NeoPUTTY had the advantage of immediate placement of the final restoration. Therefore, in this study we select to place the material either immediately or after 24 h to check if there will be a difference in the values with time, since the initial setting time of NeoPUTTY is approximately 4 h at 37°C [16].

The results of the present study revealed a significantly higher mean shear bond strength with the SAFC than with the RMGIC when comparing the groups at the same time intervals. These results confirmed the previous report obtained by Doozaneh et al. [17] when they compared the shear bond strength of SAFC and RMGIC with MTA and a calcium-enriched mixture.

In the present study, the highest bond value was obtained with SAFC after 24 h. This could be explained by the presence of a phosphate functional monomer (GPDM), which may interact with the calcium ions in the NeoPUTTY and create a chemical bond between the SAFC and NeoPUTTY, resulting in a higher bond strength than RMGIC [18,19].

Ajami et al. [20] evaluated the shear bond strength of composite resin and giomer with MTA at different time intervals. In the composite resin groups, the shear bond strength values increased with time, whereas they decreased with the giomer. However, in the present study the value of shear bond strength increased with time in both materials, which might suggest further investigation to compare RMGIC versus the giomer bond with CSC.

When using the RMGIC, the manufacturer recommends conditioning the surface with a GC cavity conditioner before placing the restoration. Gulati et al. [15] evaluated the effect of using a conditioner on the shear bond strength between RMGIC with MTA and dentin and recommended that conditioning increases the bond strength between RMGIC and dentin with no significant effect on the RMGIC to the MTA shear bond strength value. Therefore, a cavity conditioner was used.

In this study, after testing the shear bond strength, all specimens were evaluated under a microscope to determine the mode of failure. Most failures observed were predominately cohesive within NeoPUTTY or the mixed failures. This finding is consistent with a previous study by Hursh et al. [21]. This mode of failure may indicate a failure in the material before adhesion or could be due to the smaller and uniformly sized particles in the fast-set putty [22].

The results of this study provide information that can aid clinicians in selecting the best material used in clinical practice. Based on our findings, using SAFC with NeoPUTTY is preferred over RMGIC. In addition, delayed adhesion of the final restoration was recommended.

The most important limitation of this study is that bonding was performed only between the two materials. In the clinical setting, a bonding interface between restoration and dentin and that between CSC and dentin are also present. Therefore, bonding to dentin should be considered and evaluated.

CONCLUSION

Within the limitations of the study, the shear bond strength was significantly higher at placement after 24 h than immediately with both materials. The bond strength of SAFC is higher than that of RMGIC. Thus, SAFC is recommended for use with NeoPUTTY instead of RMGIC.

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