

SHEAR BOND STRENGTH OF RESTORATIVE PARTICULATE RESIN COMPOSITE WITH A SHORT FIBER-REINFORCED RESIN COMPOSITE SUBSTRUCTURE

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ABSTRACT

Objective: This study aimed to identify the shear bond strength of two different restorative particulate resin composites with a short fiber-reinforced resin composite (SFRC) substructure.

Methods: Two restorative particulate resin composites, G-aenial Posterior™ (Group A, 10 specimens) and Tetric N-Ceram™ (Group B, 10 specimens), were used as an upper layer of everX posterior™, an SFRC. A shear bond strength test was performed using a universal testing machine with a load of 100 kgf and a crosshead speed of 0.5 mm/min. The data were analyzed statistically using the independent samples t-test.

Results: The mean shear bond strength values were found to be 18.64±1.5 MPa (Group A) and 22.05±1.8 MPa (Group B). A significant difference in shear bond strength between the two groups was found.

Conclusion: The shear bond strength value is higher in the Tetric N-Ceram™ restorative particulate resin composite with SFRC as a substructure than the G-aenial Posterior™ restorative particulate resin composite.

Keywords: Fiber-reinforced resin composite, Restorative particulate resin composite, Substructure, Bond strength.

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INTRODUCTION

Recently, resin composite materials with fiber reinforcement have been developed to improve the mechanical properties of dental materials [1]. Fiber-reinforced resin composites (FRCs) are structural materials that have at least two different constituencies.

These types of composites consist of fibers that act as a reinforcement, providing strength, and stiffness; moreover, the matrix around the fibers supports and facilitates the dental work being done [2].

FRCs are used to manufacture fixed dentures, removable dentures, periodontal splints, and orthodontic retainers [3]. They can also be used in the field of restorative dentistry for posterior teeth restorations. FRCs are designed to replace dentin as substructures, and combined with a restorative particulate resin composite as an enamel replacement layer on top, employing a sandwich technique to achieve biomimetic restoration. In its application, the bond between the two resin composites (FRC combined with a restorative particulate resin composite) is very important to ensure that the material acts as a unit of a restoration [4]. Furthermore, the bond between the two resin composite materials must be considered to avoid delamination of the restoration [5].

FRCs are classified as anisotropic materials, and their strength depends on the direction of the fiber that is used [2]. An FRC product that contains short, randomly arranged fibers have previously been developed [4].

Garoushi *et al.* conducted a study that found that the use of short FRCs (SFRCs) can significantly improve fracture resistance and flexural strength in comparison to bulk-fill restorative particulate resin composites [6]. Tanner conducted a study using a short multidirectional FRC with some commercial restorative particulate resin composite products [7].

Their results indicate that the bonding properties of short multidirectional FRCs were equal to the bonding properties of the

commercial restorative particulate resin composite products they tested [7]. Garoushi *et al.* (2006) conducted a study on load-bearing capacity and the use of SFRC as a substructure for a restorative particulate resin composite [8]. They found that the load-bearing capacity significantly increased as the SFRC thickness increased [8].

However, these studies did not evaluate the bonding strength of SFRCs containing different restorative particulate resin composite products, so it necessary to study that effect.

METHODS

In the present research study, two types of everX posterior™ (GC Corp, Tokyo, Japan) SFRC products were used as a substructure. In Group A, the microfilled hybrid bisphenol glycidyl dimethacrylate free (Bis-GMA free) G-aenial Posterior™ (GC Corp, Tokyo, Japan) restorative particulate resin composite was used as the top layer. In Group B, the nanohybrid universal Bis-GMA Tetric N-Ceram™ (Ivoclar Vivadent AG, Schaan, Liechtenstein) restorative particulate resin composite was used. Both groups consisted of 10 specimens, for a total of 20 specimens.

The SFRCs were placed in an acrylic mold with a circular cavity (6 mm × 4 mm) and then cured with a light-emitting diode (LED) light curing unit (LEDMAX- Hilux) with light irradiation of 700 mW/cm² for 20 s, as recommended by the manufacturer. Restorative particulate resin composite was then added to the surface of the SFRC substructure using a circular cavity (4 mm × 2 mm) and then cured with a LED light curing unit with light irradiation of 700 mW/cm² for 20 s, as recommended by the manufacturer.

The specimens are stored in a container filled with distilled water in an incubator at 37°C for 24 h. Then, the bonding area measurements were taken using a digital caliper. The specimen was placed in a universal testing machine (Shimadzu Japan), with a blade positioned at the interface, and with a crosshead speed of 0.5 mm/min and a load of 100 kgf.

The results were recorded and entered into the shear bond strength formula. After the test was completed, the fracture surfaces were observed under a stereomicroscope with 10× and 20× magnification.

The independent samples t-test was used to analyze the significance of the differences in the shear bond strength value between the two groups. All data were subjected to a normality test and Levene's test of homogeneity of variance ($\alpha=0.05$) following the assumption of equal variances.

RESULTS

The shear bond strength test results are presented in Table 1 and shown graphically in Fig. 1. The shear bond strength test results of the microfilled hybrid Bis-GMA free (GC G-aenial Posterior™, Group A) showed a mean value of 18.64±1.5 MPa; the results for the nanohybrid universal Bis-GMA (Ivoclar Tetric N-Ceram™, Group B) showed a mean value of 22.05±1.8 MPa. The independent samples t-test result demonstrated a statistically significant difference in shear bond strength between the two groups. Schematics and stereomicroscope pictures of the fracture surface conditions are shown in Fig. 2-7 [9]. Of 20 specimens, eight had mixed cohesive fractures, six had cohesive fractures in the restorative particulate resin composite, three had cohesive fractures in the SFRC, and three had a fracture at the interface between the SFRC and the restorative particulate resin composite; cohesive fractures in the restorative particulate resin composite.

DISCUSSION

In the present study, a significant difference was found in the shear bond strength value between the SFRC and the specimens with both types of restorative particulate resin composites (Group A, microfilled hybrid Bis-GMA free; 18.64±1.5 MPa and Group B, nanohybrid universal

Bis-GMA; 22.05±1.8 MPa). The significant difference can be due to the differences in the composition of the restorative particulate resin composites.

The percentage of the filler content in the restorative particulate resin composite products used in this study was similar: 81% wt (GC G-aenial Posterior™) and 80.5% wt (Ivoclar Tetric N-Ceram™); therefore, it is possible that the filler content did not have any effect on the differences in the shear bond strength values for the two groups [10-12]. Nonetheless, both of the restorative particulate composite products used in the study contained different types of monomers. The monomer used in the GC G-aenial Posterior™ restorative particulate resin composite consists of urethane dimethacrylate (UDMA), and it does not contain Bis-GMA. The monomer used in the Ivoclar Tetric

Table 1: The shear bond strength test results

Groups	Mean shear bond strength test value (MPa)±SD
Microfilled hybrid Bis-GMA free (GC G-aenial Posterior™, Group A)	18.64±1.5
Nanohybrid universal Bis-GMA (Ivoclar Tetric N-Ceram™, Group B)	22.05±1.8

SD: Standard deviation

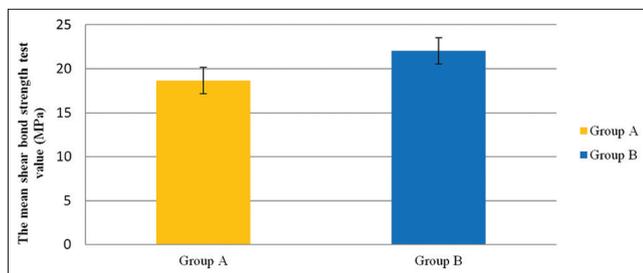


Fig. 1: The shear bond strength test results

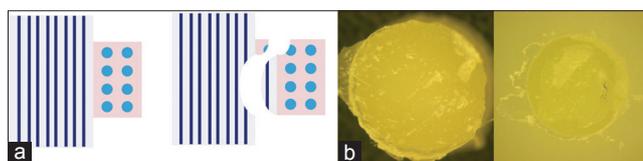


Fig. 2: (a) Schematics of the fractures, (b) stereomicroscope pictures of the fractures, Group A; cohesive fractures in the short fiber-reinforced resin composite and restorative particulate resin composite

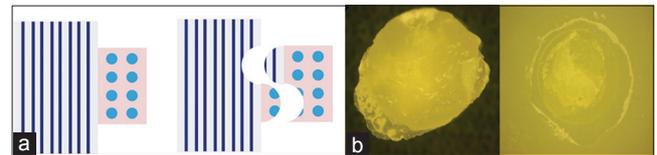


Fig. 3: (a) Schematics of the fractures, (b) stereomicroscope pictures of the fractures, Group A; cohesive fractures in the short fiber-reinforced resin composite and restorative particulate resin composite

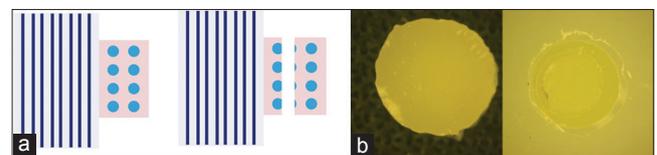


Fig. 4: (a) Schematics of the fractures, (b) stereomicroscope pictures of the fractures, Group A; cohesive fractures in the restorative particulate resin composite

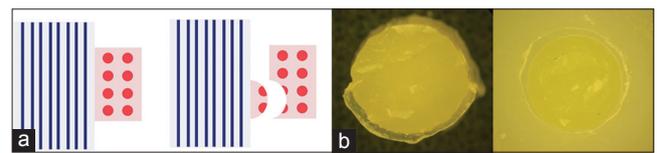


Fig. 5: (a) Schematics of the fracture, (b) stereomicroscope pictures of the fractures, Group B; fractures at the interface between the short fiber-reinforced resin composite and the restorative particulate resin composite; cohesive fractures in the restorative particulate resin composite

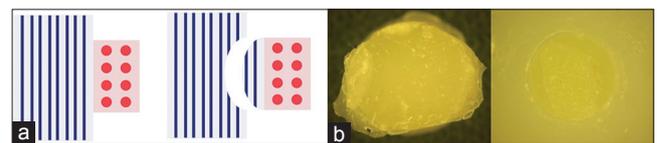


Fig. 6: (a) Schematics of the fractures, (b) stereomicroscope pictures of the fractures, Group B; cohesive fractures in the short fiber-reinforced resin composite

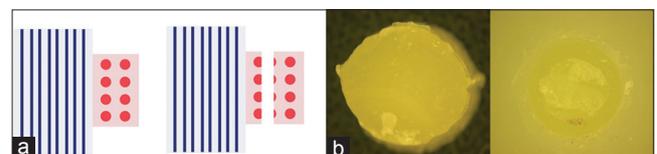


Figure 7: (a) Schematics of the fractures, (b) stereomicroscope pictures of the fractures, Group B; cohesive fractures in the restorative particulate resin composite

N-Ceram consists of Bis-GMA, ethoxylated Bis-EMA, and UDMA [11,12]. The Bis-GMA monomer is formed from the reaction between bisphenol A and glycidyl methacrylate with hydroxyl groups, which allows intramolecular hydrogen bonding [13]. Resin composite material can have covalent bonds or hydrogen bonds. The covalent bond between SFRC and the restorative particulate resin composite occurs through the use of electrons, in this case carbon (C=C). The hydrogen bond is a secondary bond that can occur only if the monomers that are used have a hydroxyl group (OH) [14]. Covalent and hydrogen bonds can occur in a restorative particulate resin composite with a Bis-GMA monomer, while in a restorative particulate resin composite that does not contain a Bis-GMA monomer, a carbon covalent bond can occur. In the present study, this could have possibly caused the significant difference in the shear bond strength value between the two groups. The group (Group B) that contained the Bis-GMA monomer had a stronger bond, resulting in a higher shear bond strength value. The SFRC used in the study contains a linear, poly (methyl methacrylate) polymer and a bifunctional monomer (Bis-GMA and triethylene glycol dimethacrylate), which form semi-interpenetrating polymer network chains [15]. This allows the monomers in the restorative particulate resin composite to diffuse into the linear polymer matrix of the SFRC. The interdiffusion of monomers occurs when the solubility parameter of the monomer in the particulate resin composite approaches the solubility parameter of the linear polymer of the SFRC. The numerical values of the solubility parameter describe the amount of energy needed to separate the molecules. Two materials with similar solubility parameter values have enough energy to permit mixing [2]. The solubility parameter of the restorative particulate resin composites used in this study is not yet known; however, it can be assumed that the significant difference in shear bond strength value is probably caused by the differences in the solubility parameters. The group (Group B) with the higher shear bond strength value is likely to have a solubility parameter that is more suitable to the linear polymer of SFRC, allowing for interdiffusion of the monomers that strengthen the bond. Therefore, it is necessary to further analyze the specimens using confocal laser scanning microscopy to determine the differences in the interdiffusion of the monomers between SFRC and the restorative particulate resin composites [16].

Moreover, the bond between the SFRC and the restorative particulate resin composite can be reinforced by the micromechanical retention of the fiber surface and the presence of an oxygen-inhibited layer [2]. In the study procedures, the particulate-filled resin composite was applied to the top of the SFRC immediately after the SFRC curing process was completed. When polymerization occurs, the presence of oxygen can lead to the formation of an unreacted layer because oxygen has two unpaired electrons; thus, it binds with free radicals more easily than the molecules on the composite [17]. Although a Mylar strip was used in the study, when the SFRC curing process was completed, the strip was immediately removed. This was followed by the application of the particulate-filled resin composite. Polymerization of the resin composite continued for 24 h, so it can be assumed that there might be an unreacted layer on the surface of the resin composite that can form a covalent bond between the SFRC and the particulate-filled resin composite. Polacek and Jancar also reported that there might be an unreacted layer that can support the bond between the FRCs and the particulate-filled resin composite [18]. Bijelic-Donova *et al.* (2014) studied the effect of treatment on the surface of an FRCs and a particulate-filled resin composite to determine the thickness of an oxygen-inhibited layer [19]. They found that although the surface of the FRCs and the particulate-filled resin composite were treated with a spray of water and ethanol, an oxygen-inhibited layer was found, as observed with a stereomicroscope [19]. After the testing, the condition of the fracture varied widely, i.e. They were cohesive on the SFRC and the particulate resin composite, while the cohesiveness of the fractures was mixed on some parts of the SFRC and some parts of the particulate resin composite. It can be assumed that the bond between the materials is adequate because a complete

separation of the materials was not observed in any of the fracture conditions, even though no interlayer was seen, which would have ensured that a bond had occurred between the materials.

CONCLUSION

The study's results can be summarized as follows:

- The shear bond strength value of the nanohybrid universal Bis-GMA Ivoclar Tetric N-Ceram restorative particulate resin composite with SFRC as a substructure is higher than the shear bond strength value of the microfilled hybrid Bis-GMA free GC G-aenial Posterior restorative particulate resin composite.
- The fracture conditions observed after the test was completed varied widely. Cohesive fractures in the SFRC and the restorative particulate resin composite were the types of fractures most often found.

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