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Research Report

The effect of silanated and impregnated fiber on the tensile strength of e-glass fiber reinforced composite retainer

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ABSTRACT

Background: *Fiber reinforced composite (FRC) is can be used in dentistry as an orthodontic retainer. FRC still has a limitations because of to a weak bonding between fibers and matrix.* ***Purpose:*** *This research was aimed to evaluate the effect of silane as coupling agent and fiber impregnation on the tensile strength of E-glass FRC.* ***Methods:*** *The samples of this research were classified into two groups each of which consisted of three subgroups, namely the impregnated fiber group (original, 1x addition of silane, 2x addition of silane) and the non-impregnated fiber group (original, 1x addition of silane, 2x addition of silane). The tensile strength was measured by a universal testing machine. The averages of the tensile strength in all groups then were compared by using Kruskal Wallis and Mann Whitney post hoc tests.* ***Results:*** *The averages of the tensile strength (MPa) in the impregnated fiber group can be known as follow; original impregnated fiber (26.60±0.51), 1x addition of silane (43.38±4.42), and 2x addition of silane (36.22±7.23). The averages of tensile strength (MPa) in the non-impregnated fiber group can also be known as follow; original non-impregnated fiber (29.38±1.08), 1x addition of silane (29.38±1.08), 2x addition of silane (12.48±2.37). Kruskal Wallis test showed that there was a significant difference between the impregnated fiber group and the non-impregnated fiber group ($p<0.05$). Based on the results of post hoc test, it is also known that the addition of silane in the impregnated fiber group had a significant effect on the increasing of the tensile strength of E-glass FRC ($p<0.05$), while the addition of silane in the non-impregnated fiber group had a significant effect on the decreasing of the tensile strength of E-glass FRC.* ***Conclusion:*** *It can be concluded that the addition of silane in the non-silanated fiber group can increase the tensile strength of E-glass FRC, but the addition of silane in the silanated fiber group can decrease the tensile strength of E-glass FRC. It is also known that the impregnation of fiber can increase the tensile strength of E-glass FRC.*

Keywords: *Silane; impregnation; tensile strength; fiber reinforced composite.*

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INTRODUCTION

The need for orthodontic treatment in various countries including in Indonesia has continued to increase. Many people are interested in orthodontic treatment to improve the condition of teeth.[1] After the orthodontic treatment is completed, a retainer is necessary needed to maintain the results of orthodontic treatment. This is because the teeth will have a tendency to return to their original position, and they also require a relatively long time to remain in the same position.[2] The main material usually used to make the retainer is metal. However, metal still has limitations, such as high rigidity level hindering stabilization process of teeth during retention period,[3] has poor esthetic,[4] and allergens.[5] Therefore, a new material with better properties than metal is necessary to be considered, especially for patients who require high aesthetics and have allergy to metals.

Fiber reinforced composite (FRC) is a composite with fiber reinforcement widely used in dentistry. The use of FRC for orthodontic retainer actually has been developed, either using polyethylene fiber[6] or using fiber glass.[3,7] E-glass FRC retainer even can be an alternative retainer with several advantages, such as having high aesthetics, easy to be used, and easy to be made (only needs one visit).[8] Nevertheless, E-glass FRC retainer can cause fracture due to weak bond between resin matrix composite and fiber glass. It can be seen on how fibers are released from the FRC after tested mechanically.[9] The addition of silane as coupling agent is expected to bind fiber and matrix chemically to improve the adhesion between the fiber and the matrix resin. Furthermore, impregnation process that can unify E-glass fiber bundles in a single FRC system will improve adhesion system and increase the strength of the material.

Tensile strength test can be used to test the bond between two materials including the bond between the fiber and the matrix in the FRC. Tensile strength is one of important indicators to ensure whether the retainer was able to stabilize teeth in a relative long period.[10,11] Therefore, this research is aimed to examine the effect of the addition of silane and the impregnation of fiber on the tensile strength of E-glass FRC.

MATERIALS AND METHODS

Materials used in this research were E-glass fiber, impregnated fiber (everStick®ORTHO, Stick Tech Ltd, Finland), non-impregnated fiber (Ahlstrom Fiberglass R338-2400/ V/ P®, Finland), flowable composite (Tetric Flow Chroma, Ivoclar Vivadent, Liechtenstein), and silane (Monobond-S, Ivoclar Vivadent, Liechtenstein). Samples in this research were classified into two groups, each of which consisted of three subgroups based on the type of fiber and the frequency of silane provision, namely subgroup I: FRC with original impregnated fiber; subgroup II: FRC with impregnated fiber and 1x addition of silane; subgroup III: FRC with impregnated fiber and 2x addition of silane; subgroup IV: FRC with original non-impregnated fiber; subgroup V: FRC with non-impregnated fiber and 1x addition of silane; and subgroup VI: FRC with non-impregnated fiber and 2x addition of silane.

Samples were made using acrylic molds (60 x 40 x 6 mm) with a modified cavity in the central (30 x 5 x 2 mm) and a narrowing area (12 x 3 x 2 mm). Those acrylic molds were marked on their edges as a marker for setting resin and fiber. Composite resin was injected up to 0.5 mm to the bottom of the molds. Both impregnated fiber and non-impregnated fiber were cut to a length of 30 mm. Silane was applied using microbrush on impregnated fiber in subgroup II and III and on non-impregnated fiber in subgroup V and VI. Those fibers were allowed to stand for 60 seconds, and then dried with an air spray for 5 seconds. Those fibers were placed on the molds, which have been filled by flowable composite. Flowable composite was added again until the molds were fully filled.

The surface of FRCs was then covered using a celluloid strip followed by irradiation with light curing unit perpendicular, 1 mm distance to the samples. FRCs were released from the molds. A tensile strength test was conducted using universal testing machine with a speed of 1 mm/ min. The tensile strength of each group was calculated by dividing the load by the cross sectional area of the material after the fracture. The data were then analyzed statistically with Kruskal Wallis test and post hoc Mean Whitney test.

RESULTS

The results showed the comparison of the averages of the tensile strength among the groups. It is known that the tensile strength in the group with 1x addition of silane and the group with 2x addition of silane was decreased about 13% and 50%/. The average of the tensile strength and the standard deviation values for all groups can be seen in Figure 1.

Based on the results of Kolmogorov-Smirnov test, it was known that the distribution of the data obtained was normal. Based on the results of Lavene homogeneity test, it is also known that the data obtained were not homogeneous. Thus, non-parametric Kruskal-Wallis test was required to analyze the difference of the average of the tensile strength among all groups.

Based on the results of Kruskal Wallis test, it is known that the addition of silane did not affect the tensile strength of FRC, while the type of fiber affected the tensile strength of FRC. Therefore, it can be said that the fiber impregnation significantly affects the increasing of the tensile strength of FRC.

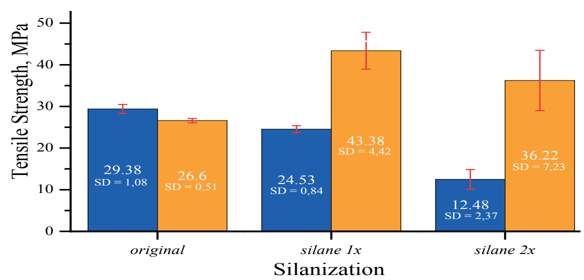

Figure 1. The average and standard deviation of tensile strength (MPa) of E-glass FRC.

Table 1. The results of post hoc test on the tensile strength of E-glass FRC 19.

Group	Interaction		Z	Sig
Impregnated fiber	Original	*Silane* 1x	-2.31	0.02*
		Silane 2x	-1.73	0.08
	Silane 1x	*Silane* 2x	-1.15	0.24
Non-impregnated fiber	Original	*Silane* 1x	-2.31	0.02*
		Silane 2x	-2.31	0.02*
	Silane 1x	*Silane* 2x	-2.31	0.02*

Note: *= significance (p<0.05)

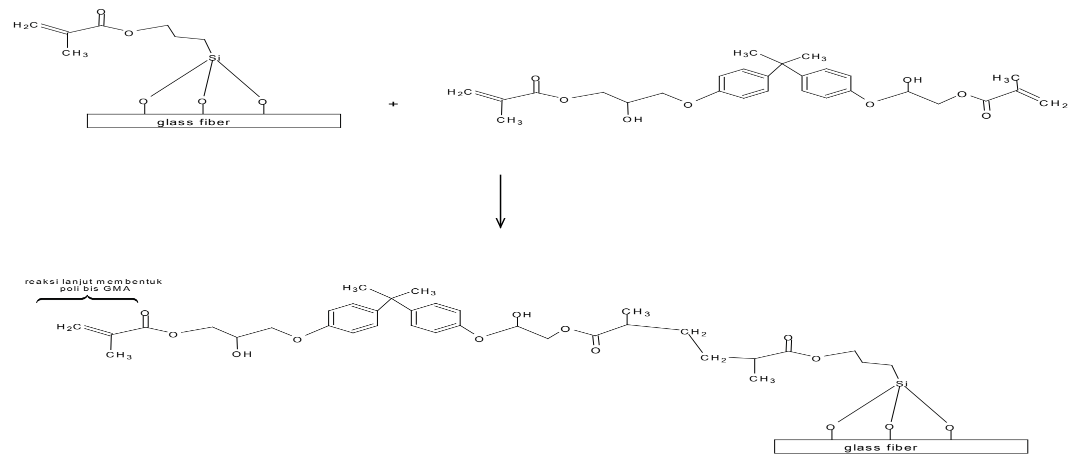

Figure 2. The bond between Bis-GMA, silane, and fiber.

The results of post hoc Mann Whitney test (Table 1) showed that in the group with impregnated fiber, the addition of silane significantly increased the tensile strength of e-glass FRC. Meanwhile, in the group with non-impregnated fiber, the addition of silane significantly reduced the tensile strength of E-Glass FRC.

DISCUSSION

The results showed that the type of fiber significantly has affected the increasing of the tensile strength of FRC. It is because impregnated fiber used in the research has already been coated with Bis-GMA and PMMA matrix in its production process.[12] As a result, Bis-GMA and PMMA will form the semi structure of Interpenetrating Polymer Network (IPN) bringing fibers together into a single bundle and increasing the bond of the fibers to the other materials.[13] It means that the process of coating with polymer matrix by the manufacturer guarantees the perfect impregnation of each fiber to produce fibers that easily bonded to the other materials and to increase the mechanical strength of FRC.

In the impregnated fiber group, it is known that the 1x addition of silane significantly increased the tensile strength, while the 2x addition of silane slightly lowered the tensile strength of FRC. Silane is a material that support and enhance the chemical bonding between inorganic materials (fiber) and organic material (composite matrix). Thus, alkoxy silane hydrolyzed will react with the surface of the hydroxyl group of the fiber, and then form cross bonding. The functional group of silane will bond with the functional group of Bis-GMA resin composite, >C=C<. The combination of cross bonding with the functional group of silane will improve the bond and hydrolytic stability of siloxane coating (Si-O-Si) between the composite resin and fiber glass so that the tensile strength of FRC will be increased.[14] The bonding that occurs between Bis-GMA, silane, and fiber are shown in Figure 2.

Addition of silane in fiber during post endodontic treatment can improve the tensile strength of the FRC significantly.[15] However, the tensile strength can be decreased after the 2x addition of silane on the FRC (16% compared to the 1x addition of silane). It means that the excessive use of silane can decrease the strength of FRC. This is because the excess silane molecules will form polysilane which is a covalent bond among silane molecules.[16] The presence of polysilane will weaken the bond between the fibers and the resin with an indication of decline in the flexural strength of the composite as the increasing number of polysilane.[17]

It is known that the tensile strength of non-impregnated fiber which had not given with silane was slightly higher than the tensile strength of impregnated fiber which had not given with silane. The non-impregnated fiber used in this research was unidirectional fiber that had given with saline by the manufacturer. The surface of the non-impregnated fiber coated with silane became one of the factors causing the increasing of the tensile strength of the fiber since silane can improve the chemical bonding between the fiber and the matrix.[14]

In the non-impregnated fiber, the addition of silane caused the decreasing of the strength of the FRC. This condition is due to the formation of silsesquioxane weakening the bond between the fibers and the resin.[19] The formation of silsesquioxane may occur between the beginning of the provision of saline and the 1x addition of silane since there are solvent and water resulted from the process. The solvent and water can cause the hydrolysis of silane and help to form a condensation polymerization process of silsesquioxane.[17]

The use of silanated fiber can make unperfect bonding, because fiber has a little functional group, so it is less reactive to silane solution applied. As a result, there will be no chemical bond between the composite resin and the fiber so that the mechanical strength becomes weak. Fiber-containing epoxy silane is also less reactive to silane, so it cannot act as a coupling agent between the fiber and the composite matrix.[18] The surface of fiber, however, will be more reactive after micromechanical modification on the surface, such as hydrogen peroxide before silane is given.[19] Similarly, a research conducted by Perdigao *et al.*,[18] showed that the addition of silane would not affect the increasing of the shear and tensile strength between the matrix composites and the fiber which have been given with silane by the manufacturer.

It can be concluded that the addition of silane in non-silanated fiber can increase the tensile strength of E-glass FRC, while the addition of silane in silanated fiber can lower the tensile strength of E-glass FRC. In other words, it can be said that fiber impregnation can increase the tensile strength of E-glass FRC.

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