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RESEARCH ARTICLE

The effect of fiber type and position on the transverse strength of an fiber reinforced composite (FRC) bridge

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ABSTRACT

Fixed bridge made of porcelain fused to metal (PFM) is one of the widely used dentures. However, this type of denture is easily broken and cracked. As an alternative, a fixed bridge made of fiber-reinforced composite (FRC) is produced with more benefits since it is more efficient in terms of time and cost. The purpose of this research is to find out the effect of type and fiber position on the transverse strength of an FRC bridge. The experiment involved 35 rod of FRC with the dimensions of 25x2x2 mm^3. Subjects were divided into seven groups, each of which containing five subjects. Group I, II, III was reinforced with glass fiber on compression side, neutral side, and tension side. Group IV, V, VI were reinforced with polyethylene (PE) fiber on compression side, neutral side, and tension side. Group VII was not reinforced with any fiber. Rods were tested for transverse strength with universal testing machine and all data were analyzed with two way ANOVA at 95% confidence level. The results showed that type and position of fiber had a significant effect ($p<0.05$), while the interaction between type and position of fiber had no significant effect ($p>0.05$). Least significance different post hoc test showed significant difference ($p<0.05$) for all groups, except between compression and no fiber. The conclusion of this research was that addition of glass fibers on tension side in bridge FRC increased the transverse strength to be higher than that with PE fibers. Fiber placement on tension side might improve the transverse strength than that of the other side.

Keywords: fiber position; fiber reinforced composite; glass fiber; polyethylene fiber; transverse strength

INTRODUCTION

In 2018 the number of denture users in Indonesia amounted to 1.4% of the population, most of whom were citizens over the age of 65.[1] The most commonly used type of denture of the various types available is the conventional fixed denture made of porcelain fused to metal (PFM). However, this type of denture has many shortcomings since it is easily broken and cracked. Also, the metal alloy material used for the denture can suffer from corrosion.[2]

To overcome the shortcoming of metal alloy, there has been an attempt to widely develop the use of fiber in dentures. This is because fiber can improve physical and mechanical properties of denture since fiber can easily be formed, easily be set up, and has good aesthetic properties.[3] The most commonly used fibers in dentistry are glass fiber and polyethylene fiber.[4] Meanwhile, the type of fiber most commonly added to the denture is glass fiber.[2] Glass fiber material with a directional structure has twice the strength and flexibility of polyethylene fiber, but glass fiber has less rigidity and often shows cracks on the surface.[5]

The mechanical properties of FRC are influenced by the volumetric fraction, location, and direction of the fiber.[6] To obtain good mechanical strength, the FRC construction is placed in a position that experiences tension in the specimen, while to obtain higher strength in construction, fiber is placed vertically so that there will be many layers of fiber that will distribute the load.[7] In certain clinical conditions, fixed dentures will receive various forces during mastication, including compressive, tensile, and shear forces.[8] To analyze the type and position of fixed denture made of FRC, the researcher can perform a transverse strength test. The transversal strength

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test is still the most widely used mechanical properties test for fixed denture materials and the results of which can be helpful for developing and comparing clinically used products.[2]

MATERIALS AND METHODS

This research has received an ethical clearance from the research ethics committee Faculty of Dentistry, Universitas Gadjah Mada number 00690/KKE-P/FKG-UGM/EC/2016. The experiment involved 35 rod of FRC with the dimensions of 25x2x2 mm^3. Glass fiber was obtained from GrandTEC (VOCO, Germany) dan polyethylene fiber from CONSTRUCT (Kerr, USA). Subjects were divided in to 7 groups, each of which containing 5 subjects. Group I was reinforced with glass fiber on compression side, group II was reinforced with glass fiber on neutral side, group III was reinforced with glass fiber on tension side, group IV was reinforced with polyethylene fiber on compression side, group V was reinforced with polyethylene fiber on neutral side, group VI was reinforced with polyethylene fiber on tension side, while group VII was not reinforced with any fiber.

FRC samples was made with the addition of glass fiber on the compression side, firstly, the metal mold located on top of the glass slide was filled with composite resin. Then, each glass fiber piece was given 1 drop of silane on each side and was rinsed with a microbrush three times before being exposed to light for 10 seconds. Using tweezers, the fiber sheet was placed into the mold leaving a thickness of 0.5 mm as a place of composite resin.[9] The measurement of 0.5 mm thickness was conducted with a probe. Afterwards, a composite resin was applied at the top until it was as high as the mold, then it was covered with glass slide and irradiated with light curing unit. The irradiation was divided into 3 parts along the specimen, each for 40 seconds on both sides of the sample. The FRC plate was then polished with polishing discs and measured again with the calipers. The same method as sample preparation was applied to make FRC samples with the addition of glass fiber on the neutral side. The fiber was placed on the compression side. However, for the neutral side position, the fiber was placed 1 mm from the mold base by firstly applying composite resin to the mold as high as 1 mm. The same method as the sample preparation was also used to make FRC samples by adding glass fiber to the tension side, with the position of the fiber on the compression side or neutral side. However, for the tension side position, the fiber was placed as high as 0.5 mm from the mold base by firstly applying composite resin on the 0.5 mm high mold.

To make FRC samples by adding polyethylene fiber to the compression side, firstly, the metal mold located on top of the glass slide was filled with composite resin. Then, each piece of polyethylene fiber was given one drop of silane on each side, and swapped with a microbrush three times on each side before being irradiated for 10 seconds. Using tweezers, the fiber sheet was placed into the mold, leaving a thickness of 0.5 mm as a composite resin spot. The thickness of 0.5 mm was measured with a probe. After that, a composite resin was applied at the top until it was as high as the mold and covered with glass slide and irradiated with light curing unit. The irradiation was divided into 3 parts along with the specimen, each of which for 40 seconds on both sides of the sample. Furthermore the FRC plate was polished with polishing discs and measured again with the calipers. The same method as the sample preparation was applied to make FRC samples by adding polyethylene fiber to the tension side, with the position of the fiber on the compression side or neutral side. However, for the tension side position, the fiber was placed as high as 0.5 mm from the mold base by firstly applying composite resin on the 0.5 mm high mold.

For samples without fiber addition as a control group, the metal mold located on top of the glass slide was filled with composite resin until it was as high as the mold. Afterwards, it was covered with glass slide and irradiated with light curing unit. The irradiation was divided into 3 parts along the specimen, each of which for 40 seconds on both sides of the sample. The plate was then polished by polishing the disc and measured again with a caliper. Before the mechanical strength test was carried out, the sample was stored in an incubator by soaking it in an aquadest at 37 °C for 24 hours. This immersion process was aimed to obtain the same conditions with that of the oral conditions and equilibrium water sorption.[10]

Afterwards, it was proceeded with the transversal strength testing at the Laboratory of Mechanical Engineering and Industrial Materials, Faculty of Engineering, Universitas Gadjah Mada. Transversal strength testing of samples was conducted in the form of fiber reinforced composite rods of 25x2x2 mm size and various positions. Transversal strength tests were carried out by universal testing machine.

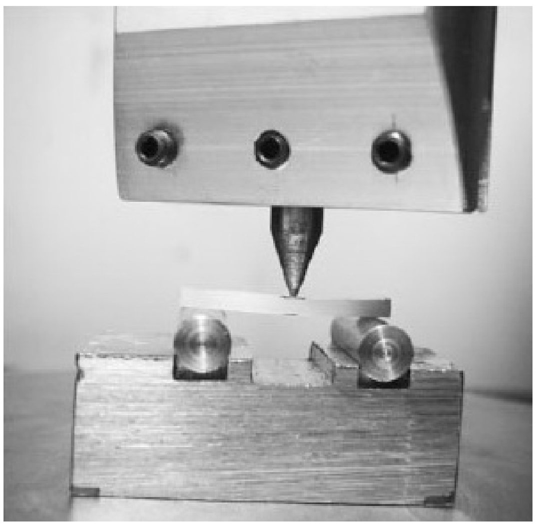

Figure 1. Placement of samples on universal testing machine[11]

RESULTS

In general, the mean of transverse strength in all groups of various types and positions showed an increasing tendency of the FRC transverse strength from the position of compression to tension, and the types of fiber ranging from polyethylene to glass fiber (Table 1).

The transversal strength normality test showed $p>0.05$ for all groups. Thus, it was concluded that the data for each group were normally distributed. The test of the transversal strength homogeneity showed $p>0.05$, which indicated the homogeneous distribution of data, therefore the data can be analyzed by two-way ANOVA test. The test was conducted to determine the variation in type and position of fiber. The F calculation for the type variable and the position variation showing significance ($p<0.05$). Variations in the type and position of fiber have a significant effect on the transversal strength. The interaction between type variables and fiber position showed no significant effect on transverse strength (Table 2).

The LSD analysis for type variations showed that there were significant differences between the mean of transverse strength in all groups ($p<0.05$) (Table 3). The group reinforced by glass fiber had higher transverse strength than polyethylene fiber group.

The results of the LSD analysis for position variations showed that there were significant differences between the mean transversal strength in all treatment groups ($p<0.05$), except that there were no significant differences between the compression and fiber-free positions ($p>0.05$) (Table 4).

DISCUSSION

Transversal strength is the ability of a material to resist transverse forces, namely a combination of tensile, compressive, and shear forces while functioning in the mouth both in the posterior and anterior regions. This study shows an increasing tendency of the mean transversal strength of the FRC group with fiber placed at the bottom of the specimen with either polyethylene or glass fiber. When a rod object is given a load, there will be a pressure distribution. Pressure on homogeneous material will be distributed evenly to all parts of the material.[12] It is possible to consider an FRC as a homogeneous material even though it may consist of different materials. An FRC with a homogeneous nature will have a different transverse strength when it has a different fiber position. Fiber placed on the surface of the FRC will have the lowest transverse strength. Fractures on FRC are easy to occur if the bottom of the FRC is supported with a larger composite matrix. Fiber plays a significant role in distributing pressure on FRC. The resultant

Table 1. Average and standard deviation of transverse strength (MPa) of GTC based on FRC with different positions and types of fiber

Group	n	Average	SD
Polyethylene fiber of compression position	5	61.99	10.51
Polyethylene fiber of neutral positon	5	77.09	17.48
Polyethylene fiber of tension position	5	159.34	89.14
Glass fiber of compression position	5	242.03	80.32
Glass fiber of neutral position	5	246.96	65.07
Glass fiber of tension position	5	350.74	99.71
Fiber Free	5	58.03	3.57

Table 2. Summary of the two-way ANOVA statistics on GTC transverse strength made of FRC between groups with variables (type and position)

Variables	df	F	p
Type	1	8.72*	0.004
Position	2	36.28*	0.000
Interaction between type of position	2	1.416*	0.224

*= significantly different (p<0.05)

Table 3. Summary of the transverse LSD test on GTC made of FRC with fiber type variables

Variables	Polyethylene	Glass	Fiber free
Polyethylene		66.188*	-97.064*
Glass			-164.252*
Fiber Free			

*= significantly different (p<0.05)

Table 4. Summary of the transverse LSD test of GTC made of FRC with fiber position variables

Variable	Compression	Neutral	Tension	Fiber free
Compression		130.133*	228.3*	-10.514
Neutral			97.167*	-141.646*
Tension				-238.814*
Fiber free				

*= significantly different (p<0.05)

force that is passed on braided (polyethylene) type fibers is smaller than that in unidirectional (glass) fibers. The fiber angle of the axis on the braided fiber plays a significant role in producing the smaller passed resultant force.[13]

Different types of fiber will lead to a significantly different result, and glass type fiber produces higher transverse strength in the FRC stem. Many studies reveal some factors affecting the strength of fiber reinforced composites, which include fiber length, fiber orientation, fiber shape, fiber adhesion in polymer matrices, and impregnation of fiber with resin.[14] This study used silane smeared glass fiber from the manufacturing factory. Modification of fiber surface using silane as found in glass fiber is known to increase the adhesion between fiber and composite matrix, which can increase the mechanical strength of fiber reinforced composite.[15] Glass fiber with silane content as a coupling agent can avoid fissures between fibers and composite matrix, thereby reducing the possibility for water absorption by resin.[16] The use of silane coupling agent results in glass fiber binding to the composite matrix.[17] The hydrolyzed group of silane will react with silica on the fiber surface and the organofunctional silane group will bind to the composite matrix to form strong covalent bonds. The alkoxy group is hydrolyzed into silanol and will form a cross bond with the surface of the hydroxyl group of glass material. The bond combination will increase the bonding and hydrolytic stability of the siloxane layer between composite resin and glass fiber.[18] The surface of polyethylene fiber used in this study has been modified in the form of plasma treatment. Plasma treatment can improve interfaces shear strength and energy absorption, thereby increasing the adhesion strength between fiber and resin.[19]

Placing glass fiber at the bottom of the FRC will increase the transverse strength of the FRC. In the transversal strength test, the bottom of the FRC will be drawn and results in a deflection. The fiber placed at the bottom of the FRC can distribute the pressure and produce a resultant force that is smaller than the composite matrix at the top of the FRC. The resultant force at the bottom of the FRC will never trigger a pull, which results in deflection. Small pressure on FRC will make FRC able to withstand deflection due to the transverse strength test. Most fractures occur because of the component of tensile pressure. Fiber placement on the pull side makes tensile pressure be distributed to FRC. On the other hand, fiber placed away from the side of the tension and closer to the surface of the specimen, which experiences a compression load, will decrease the transverse strength.[20]

The void of interaction between type and position of fiber in transverse strength, according to the previous research, showed that in the tension position there is no relationship between transverse strength and fiber type and volume because the type and volume of fiber has little effect on the transverse strength.[21] Fiber design such as fiber placement has more significant impact than fiber type.[6] The effect of fiber position is more dominant in influencing the mechanical properties of FRC. Thus, to optimize the effect of fiber, fiber addition must be placed on the tension side.[22]

CONCLUSION

The type of fiber type is proven to impact on the transverse strength of fiber reinforced composite bridge. Glass fiber can increase transverse strength to be higher than polyethylene fiber. The fiber position has an impact on the transverse strength of fiber reinforced composite bridge. Fiber with a tension position can increase the transverse strength of fiber reinforced composite bridge to be higher than the other positions.

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REFERENCES

1. Kementrian Kesehatan RI. Laporan Nasional RISKESDAS 2018. Jakarta: Lembaga Penerbit Badan Penelitian dan Pengembangan; 2019. 187-189
2. Agtini MD. Persentase Pengguna Protesa di Indonesia. Media Litbang Kesehatan. 2010; 10(2): 50-58.
3. Mohanty AK and Manjusri M. Fiber Technology for Fiber Reinforced Composite. Cambridge: Woodhead Publishing; 2017. 99-120.

4. Alla RK, Suresh S, Venkata RA, Kishore G, Nagaraj U. Influence of fiber reinforcement on the properties of denture base resins. Journal of Biomaterials and Nanobiotechnology. 2013; 4(1): 91-97. doi: 10.4236/jbnb.2013.41012
5. Tayab T, Akshay S, Kayalvizhi G. The Clinical applications of fiber reinforced composites in all specialties of dentistry an overview. International Journal of Composite Materials. 2015; 5(1): 18-24. doi: 10.5923/j.cmaterials.20150501.03
6. Van Heumen C. Fiber Reinforced Adhesive Bridges Clinical and Laboratory Performance. Thesis. Dutch: Radboud University Nijmegen. 2010. 11-50.
7. Niewczas A, Jolanta Z, Aneta K, Daniel P, Agata W, Grzegorz B. Influence of fibre reinforcement on selected mechanical proprties of dental composites. Acta Bioeng Biomech. 2017; 19(2): 3-10.
8. Nabilah VZ, Lusi H, and Agus S. Flexural strength of microhybrid composite resin with polyethylene fiber's layer addition. Proccedings Book FORKINAS VI FKG UNEJ. 2016: 276-284.
9. Spyrides SMM, Maira DP, Renata AS, Fernando LB. Effect of plasma position on flexural properties of a fiber-reinforced composite. Brazilian Dental Journal. 2015; 26(5):490-496. doi: 10.1590/0103-644020130225
10. Yanti D, Heriyanti A, Erwan S. Perbedaan kekuatan transversal fiber reinforced composite dengan struktur leno weave dan long longitudinal polyethylene pada gigi tiruan cekat adhesif. Jurnal Kedokteran Gigi. 2011; 2(4): 230-235.
11. Tiberio CU, Matheus, Cynthia MF, Kauffman, Ana KS, Claudia CBO, Anderson SL. Fracture Process Characterization of Fiber-Reinforced Dental Composites Evaluated by Optical Coherence Tomography, SEM and Optical Microscopy. Braz. Dent. J. 2010; 21(5). doi: 10.1590/S0103-64402010000500008
12. Sakaguchi R, Jack F, John P. Craig's Restorative Dental Materials. 14th ed. St. Louis: Elsevier; 2018. 252.
13. Fediuk R., Aleksey S, Aleksandr M. Mechanical Properties of Fiber-Reinforced Concrete Using Composite Binders. Hindawi. 2017. 1-13
14. Mallick PK. Fiber Reinforced Composite: Material, Manufacturing, and Design. 3rd ed. France: CRC Press; 2007. 338.
15. Budiharjo A, Endang W, Erwan S. Pengaruh lama pemanasan pasca pemanasan dengan microwave terhadap sisa monomer dan kekuatan transversa pada reparasi gigi tiruan resin akrilik. Jurnal Kedokteran Gigi. 2014; 5(2):1-13
16. Vallittu PK. Interpenetrating polymer networks (IPNs) in Dental Polymers and Composite. Journal of Adhesion Science and Technology. 2009; 23(7-8): 961-972. doi: 0.1163/156856109X432785
17. Al-Darwish M, Hulrey RK, Drummond JL. Flexure strength evaluation of a laboratory processed fiber reinforced composite resin. The Journal of Prosthetic Dentistry. 2007; 97(5): 266-270. doi: 10.1016/j.prosdent.2006.09.001
18. Noort RV. Introduction to Dental Materials. 4rd ed. St.Louis: Mosby Ltd; 2013. 164-170
19. Lung CYK, Matinlinna. Aspects of silane coupling agents and surface conditioning in dentistry: an overview. Dent Mater. 2012; 28(5): 467-477. doi: 10.1016/j.dental.2012.02.009
20. Bahramian N, Mohammad A, Naimi J. Plasma Surface Treated UHMWPE Fibers for Dental FRCs: Surface Nanostructure and Chemistry. Proccedings of the 8th International Chemical Engineering Congress and Exhibition. 2014.
21. Anusavice KJ, Chiayi SH, Ralph R. Phillips' Science of Dental Materials. 12th ed. Philadelphia: W.B. Saunders; 2012. 108-119.
22. Choksi RH, Mody PV. Flexural properties and impact strength of denture base resin reinforced with micronized glass flakes. J Indian Prosthodont Soc. 2016; 16(3): 264-270. doi: 10.4103/0972-4052.176532
23. Vakiparta M, Yli-Urpo A, Vallittu PK. Flexural properties of glass fiber reinforced composite with multiphase biopolymere matrix. J Mater Sci Mater Med. 2004; 15(1): 7-11. doi: 10.1023/b:jmsm.0000010091.34422.45