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Orientation and Type of Non-dental Glass Fiber Towards The Flexural of Fiber Reinforced Composite

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Abstract: Introduction : Non-dental glass fiber can used as alternative dental glass fiber. Flexural strength to withstand masticatory loads that influenced by various factors, including the orientation and type of fiber used. **Purpose :** The purpose of this study was to see the effect of orientation and type of non-dental glass fiber on flexural strength. **Method :** The research method used FRC samples measuring 65 x 10 x 2,5 mm which were reinforced with non-dental glass fiber mats, roving, woven roving, and dental glass fiber roving. Non-dental glass fiber mats and woven roving was cut according to the length and width of the sample, while the non-dental glass fiber roving was weighed according to the weigh tof 4 sheets of dental glass fiber roving to meet the sample mold zone. **Result :** Glass fiber placed in the tension position in the sample mold. The flexural strength was tested using universal testing machine. This study indicate that the type of glass fiber doesn't have a significant effect on the flexural strength of FRC with reinforced non dental glass fiber and dental glass fiber. **Conclusion :** The orientation of non-dental glass fiber roving as reinforcement of FRC has greater flexural strength than non-dental glass fiber with mats and woven roving orientation.

Keywords: fiber reinforced composite, fiber orientation, non-dental glass fiber

INTRODUCTION

Fiber reinforced composite is currently more widely used than porcelain fused to metal fixed prostheses, because of the increased demand for conservative and aesthetic restoration that is convenient because the restoration can adhere effectively to the teeth and cause minimal damage to the remaining teeth[1,2]. Fixed denture fiber reinforced composite is also chosen because it can be made directly in the clinic without going through laboratory procedures, and the nature of the material that does not corrode like metal material[3].

Fiber reinforced composite is a restoration consisting of a combination of fiber and resin matrix[1]. FRC in dentistry is widely applied to the base of removable denture made of acrylic resin, as a reinforcement of fixed dentures, periodontal splints, fixed orthodontic retainer and dental restoration[4]. The resin matrix acts fiber protectors, geometric settings and maintains that the fiber remains in a predetermined position, to provide optimal strength. Fiber in the composite matrix acts as an amplifier, providing stability and stiffness to improve the structural properties of the material and crack stopper[5,1].

Fiber used in dentistry serves to increase strength and stiffness, mechanical and physical properties, increase the resistance of materials to fractures, reduce shrinkage, and move loads from weak polymers to durable reinforcement fibers[3,6,7]. Types of fiber used to make fiber reinforced composite depending on the intended use and characteristics needed to achieve this goal[8]. The selection of the right fiber will increase the strengthening capacity and be important because it can affect the characteristics of density, tensile strength and modulus, compressive strength and modulus, fatigue strength, conductivity electrical and thermal fiber reinforced composite, and maintenance prices[9]. The ability and effectiveness of fiber as an amplifier in fiber-reinforced composites depends on several factors, namely adhesion, impregnation, quantity or volume, orientation, individual matrix and resin properties, position, length and diameter fiber, and water absorption by a composite matrix[10,11,12,13].

Fiber is arranged in various orientations, namely continuous unidirectional (roving), continuous bidirectional (woven), continuous random oriented (mat) and discontinuous random oriented (chopped) [14]. Mechanical properties, strength, and modulus of FRC elasticity depend on the direction of fiber in the polymer matrix and fiber volume fraction[14,15]. Multidirectional amplifiers show a unidirectional decrease in strength when compared to one-way fiber[16].

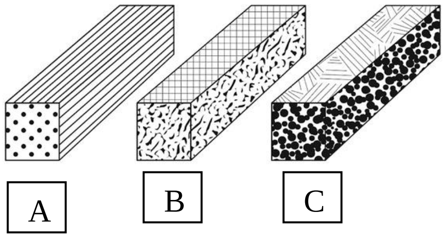

Figure 1. Unidirectional fiber (roving) orientation arranged in the same direction (A) bidirectional (woven) arranged in 2 different directions (B) random/ multidirectional (mat) arranged in different directions (C) [14].

Glass fiber is a thin strand based on silica (SiO2) which is most often used as reinforcing fiber for polymer composite matrices because it has tensile strength and high chemical resistance, and the best insulating properties[17,9]. More than 50% glass fiber is used for reinforcing the material, as in the application in the field of dentistry is E-glass[15]. Glass fiber dental which is widely used in Indonesia is still available in limited quantities, has a high price, and requires a long time to order. This condition can be overcome by using non-dental glass fiber which is available in large quantities and has a low price[4,18].

The composition of non-dental glass fiber has been known to have a composition similar to glass fiber dental but with a different percentage and has the same solubility properties as E-glass fiber dental[4,18]. There is currently no one utilizing non-dental glass fiber in medical care teeth, but these materials have been developed by several researchers. Cytotoxicity test of glass fiber non dental mats, roving, and woven roving on fibroblast cells shows that dead fibroblast cells are less than 10%, it means no cytotoxicity in fibroblast cells is found (Murdiyanto, 2017)[19].

Some researchers conducted research by comparing FRC reinforced using non-dental glass fiber and glass fiber dental. FRC with glass fiber dental reinforcement has a smaller flexural strength value (120 MPa) than FRC which is reinforced with non-dental roving glass fiber (133 MPa) and woven roving (145 MPa) after soaking for 7 days (Khalil, 2015)[20]. Sumantri (2015) stated that FRC shear strength with glass fiber dental reinforcement was smaller (11.37 MPa) when compared with non-dental mats glass fiber (11.51 MPa) and non-dental woven roving glass fiber (12.58 MPa) in volumetric 2.8vol%. Fiber orientation has an influence on FRC shear strength, where fiber unidirectional orientation provides the highest strength and stiffness for composites[21]. Sari (2015) states that the flexural strength value of FRC with 2.3vol% of volumetric fiberglass dental is lower (158.34 MPa) compared with FRC with non-dental mats glass fiber reinforcement (208.03 MPa), roving (165.28 MPa), and woven roving (204.65). so that it has the potential as an alternative to E-glass dental fiber in dental treatment[22].

METHODS

The type of this research is a laboratory experiment with variables affecting the influence of non-dental mats, roving, and woven roving glass fiber, and dental and non-dental glass fiber types, while the affected variables of this study are flexural strength fiber reinforced composite. The research was conducted at the Chemical Laboratory of Health Analyst at University of Muhammadiyah Semarang and Materials Laboratory of the Department of Mechanical and Industrial Engineering, Faculty of Engineering, UGM, which had received research ethics approval from the Ethics and Advocacy Unit of the Faculty of Dentistry, University of Gadjah Mada on April 25, 2018 with number 001400/KKEP/FKG-UGM/EC/2018.

The sample in this study is a beam of fiber reinforced composite with a size of 65 x 10 x 2.5 mm with a reinforcement of non-dental fiberglass and dental glass fiber totaling 16 which are divided into group I (FRC with non-dental roving glass fiber), group II (FRC with non-dental mats glass fiber), group III (FRC with non-dental woven roving glass fiber), and group IV (FRC with dental roving glass fiber). Non-dental glass fiber used is non-branded and non-impregnated non-dental glass fiber obtained from building shops in the Jakarta area with a diameter of 0.023 mm non-dental mats glass fiber, 0.053 mm roving, and 0.053 mm woven roving, while glass fiber dental is a glass fiber non impregnated with Ortho Net Fiber Ti-Es brand with a diameter of 0.035 mm per bundle.

Dental roving glass fiber and non-dental rovings glass fiber were measured and cut along 64 mm, while non-dental mats glass fiber and woven rovings were measured and cut along 64 mm in width by 9 mm, while dental roving glass fiber was used 4 sheets to fill the zone sample. Fiber is weighed using a digital balance with an accuracy of 0,0001 mg. The weight of non-dental roving glass fiber used is equated with glass fiber dental. Fiber used as a sample is stored in a desiccator for 24 hours to remove the water content in the fiber. Each glass fiber bundle, both dental and non-dental, was silanized by using a silane coupling agent as much as 1 time using a microbrush, then left to dry.

A B C

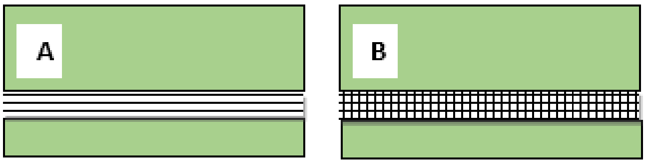

Figure 2. Fiber position scheme in a sample of fiber reinforced composite with roving (A), woven roving (B), and mats (C) glass fiber.

The sample is made by applying flowable composite resin with a thickness of 0.5 mm followed by fiber, so that it is in the tension position zone. Non-dental mats glass fiber and non-dental woven roving glass fiber are placed in such a way above the composite resin so that the orientation and position zone of the fiber are suitable. Non-dental roving glass fiber and dental roving glass fiber are placed in parallel to the sample zone. Flowable composite resins are injected until the mold is fully filled and polymerization is carried out using for 40 seconds by covering the non-shine parts using aluminum foil to avoid double polymerization. After hat finishing polishing is done, then the sample is soaked in distilled water in an incubator at 37^{o}C for 24 hours before flexural strength testing.

Flexural strength test is carried out using a universal testing machine by placing the two ends of the study sample on a buffer board with a bending distance of 50 mm, then given a load of 50 N/minute with a crosshead speed of 1 mm/minute given right in the middle until it fractures or until the peak load is reached (ISO 10477: 2004).

RESULTS AND DISCUSSION

RESULTS

Research on the effect of orientation and type of non-dental glass fiber on the flexural strength of fiber reinforced composite has been completed. The mean flexural strength of FRC with the orientation variable of non-dental glass fiber can be seen in Figure 3.

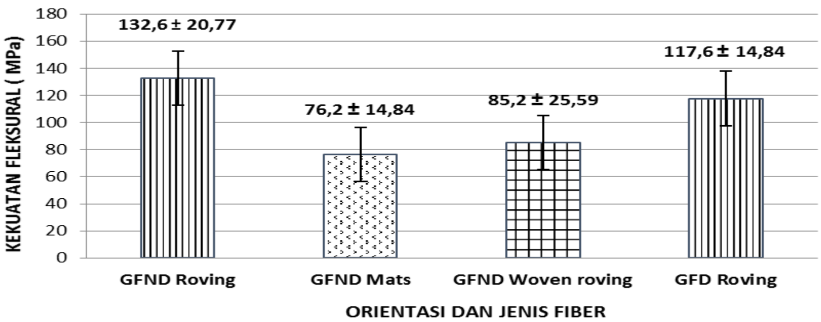

Figure 3. Flexural mean on non-dental roving, mats, woven roving glass fiber, and dental roving glass fiber.

Tests for normality and homogeneity before statistical analysis using one way ANOVA showed that the data distribution was normal ($p>0.05$) and homogeneous ($p>0.05$). One way ANOVA test results showed a statistical value of F = 8.432 with a significance of 0.009 ($p<0.05$), it means that the orientation of non-dental glass fiber used in FRC had a significant influence on the flexural strength of FRC.

Table 1. One-way ANOVA on flexural strength with fiber orientation variables

	Σ kuadrat	Derajat bebas	Rerata kuadrat	F	P
Antar kelompok	7344,960	2	3672,480	8,432	,009
Dalam kelompok	3919,680	9	435,520		
Total	11264,640	11			

Post hoc LSD test on flexural strength with orientation variable of non-dental glass fiber showed a significant difference ($p<0.05$), except in the FRC group with reinforcement of non-dental woven roving glass fiber on non-dental mats glass fiber which had a significance value of 0.557 (table 2).

Table 2. LSD tests on flexural strength with fiber orientation variables

Orientasi *Fiber*	Roving	Mats	Woven roving
Roving		56,40*	47,40*
Mats	-56,40*		-9,00
Woven roving	-47,40*	9,00	

* = significantly different (p<0.05)

Figure 3 shows the average value of flexural strength with a variable type on FRC with non-dental roving glass fiber higher than FRC with dental roving glass fiber. The normality test shows that the data is normally distributed (p>0.05) and homogeneous (p>0.05). The t-test statistical test (table 3) shows a value of 0.295 (p>0.05), it means that the type of glass fiber used in FRC does not have a significant difference between the flexural strength of FRC non-dental glass fiber and FRC glass fiber dental.

Table 3. Results of flexural strength t-test on fiber type

		t-test for Equality of Means				
		T	Df	*Sig.* (2-*tailed*)	*Mean Difference*	*Std. Error Difference*
Kekuatan Fleksural	*Equal variances assumed*	1,146	6	,295	15,0000	13,0859
	Equal variances not assumed	1,146	5,620	,298	15,0000	13,0859

DISCUSSION

Based on Table 1 and Figure 3, the average flexural strength with 3 different fiber orientations shows that the highest value was obtained in the FRC group with reinforcement of non-dental roving glass fiber (132.6 ± 20.77 MPa) and the lowest on non-dental mats glass fiber (76.2 ± 14.84 MPa), and showed a significant effect on fiber orientation on the flexural strength of FRC. Fiber orientation has an influence on mechanical properties through the spread of the load received along the fiber to be forwarded to the composite matrix of FRC.

The results of this study are consistent with the research of Ahmad et al. (2014) and Hadianto et al. (2013) which state that the average flexural strength is greater in FRC with a unidirectional fiber orientation compared to the bidirectional fiber orientation. Composite materials reinforced with fibers arranged unilaterally longitudinally and perpendicular to the direction of force show better flexural strength[23,24]. Hamid et al (2010) state that orientation of woven roving fibers tend to increase flexural strength compared to the orientation of the mats. The fiber orientation in the woven roving with an angle of 0/90 shows that the flexural strength is smaller than the 0/45 angle because the 0/90 angled woven roving has parallel oriented fibers that are linked to perpendicular oriented fibers[25].

The LSD statistic results showed no significant difference (p>0.05) between the orientation of mats and woven rovings due to the influence of the Krenckel factor on glass fiber mats: 0.2 and woven: 0.5. Based on the influence of the Krenckel factor in this study, the average value of flexural strength in the orientation of woven roving is greater than that of the mats. The orientation of fiber mats according to the Swiss factor makes the material is isotropic, which has the same properties in all directions of fiber and decreases the efficiency of reinforcement by 20% to 38% [27,28]. Krenchel factor of the 1 value is 90^{o} for the style because able to provide maximum reinforcement with the properties of anisotropic materials[27,28]. The orientation of non-dental woven roving glass fiber in this study has the value of flexural strength between the orientation of mats and roving because the material is orthotropic which has the same properties in 2 test fields with different properties in other test fields

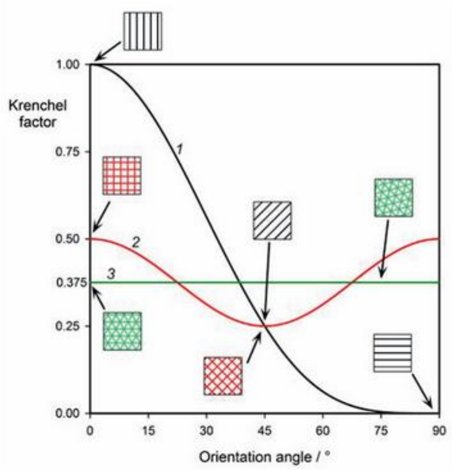

Figure 4. Factor of Chancellor efficiency. Single fiber arranged parallel with different angles (1), 2-way fiber with different angles (2), and 3-way fiber with an angle of 60° [26].

The type of fiber used has an influence on mechanical properties because the components of the fiber are different on different types of fiber, so the properties of each fiber are also different. The results of the t-test (table 3) statistic of glass fiber type variables did not show a significant difference ($p>0.05$) probably due to the use of the same type of glass fiber with relatively the same composition, so it tends to have almost the same properties. This condition is supported by Mosharraf and Givechian (2012) who state that FRC transversal forces tend to be influenced by fiber conditions and orientation compared to fiber types.

In this study, non-dental roving glass fiber without a brand provided relatively higher flexural strength than dental roving glass fiber. The components of SiO_2, Fe_2O_3, and Al_2O_3 on glass fiber can affect the ability of silane bonds with the resin matrix. SiO_2 components in non-dental glass fiber without a brand are higher (63.46%) than glass fiber dental (54.5%), but the Al_2O_3 component in glass fiber dental (14.5%) is higher than non-dental glass fiber (5.16%)[29] This condition allows the flexural strength value between the two types of glass fiber to have no significant effect, because the components of SiO_2 and Al_2O_3 can influence the ability of silane bonds with the resin matrix.

The number of SiO_2 components of 60-65% is making glass fiber has high strength, and good corrosion and thermal resistance. SiO_2 acts as the main component of glass fiber in forming stable condensation with silane reactive silane groups with Al_2O_3 which modifies tissue structure to improve glass fiber's working ability, while Fe_2O_3 forms weak condensation[30]. Good interfacial attachment between matrix and fiber is obtained by application of silane coupling agent by increasing the surface wetting ability of glass fiber and increasing surface energy, so as to create maximum load transfer[7,11]. According to the results of the values of flexural strength and force that can be accepted by FRC in this study indicate that FRC with reinforced non-dental roving, mats and woven roving glass fiber can be used in clinical applications because they meet the recommended mechanical strength requirements.

CONCLUSION

Flexural strength in non-dental glass fiber reinforced composite orientation roving is higher than the orientation of mats and woven rovings. Furthermore, the type of glass fiber does not have a significant effect on the flexural strength of fiber reinforced composite.

SUGGESTION

1. The treatment of impregnation needs to be done first on non-dental roving, mats and woven roving glass fiber used in this study, to make it easier to apply.
2. The advanced biocompatibility test needs to be done as a condition for non-dental glass fiber to be accepted for the health sector.

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