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RESEARCH ARTICLE

Enhancing the impact strength of acrylic resin base plate by adding non-dental E-glass fiber

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ABSTRACT

Non-dental glass fiber is one of the materials that can be used to increase the impact strength of a acrylic resin base plate, containing a similar composition to that of dental e-glass fiber. Orientation and positions of fiber affect the reinforcement effectiveness. This research aimed to examine the effect of the orientation of non-dental glass fiber in the compression position on the impact strength of an acrylic resin base plate. The research was conducted on 16 acrylic resin plates with fiber (65 mm x 10 mm x 2.5 mm) addition. The samples were divided into 4 groups (combination of different woven orientation unidirectional, bidirectional woven in the compression position, and control). The material used in this study was heat-cured acrylic resin QC-20 brand, non-dental glass fiber (without any brand). Impact strength was tested using an impact testing machine. The data obtained were analyzed using one-way ANOVA test and LSD ($p < 0.05$). In this research the impact strength of the base plate with the addition of fiber increased 8.54 ± 2.21 ; 13.21 ± 2.34 ; 16.81 ± 2.80 kJ/m² compared to that of the control group, i.e. 4.98 ± 1.05 kJ/m². One-way ANOVA test showed a significant effect ($p < 0.05$) of the fiber orientation variations on the compression position. This research concluded that the addition of non-dental e-glass fiber (composed of SiO₂ 52.56-56.88%), diameter 17.12 – 20.03 μ m) in the compression zone increases the impact strength of acrylic resin base plate. Fibers with unidirectional orientation provides the highest increase in the impact strength of acrylic resin base plate.

Keywords: fiber orientation; impact strength; non-dental glass fiber

INTRODUCTION

Denture is a device which functions to replace a part or all of the original teeth that are lost and it is used in either upper or lower jaw. The main goal of denture treatment is to preserve and maintain the health of the present teeth and the entire masticatory system in order to function properly and stay healthy. Removable denture is the most commonly used treatment today.¹

The use of acrylic resin (poly-methyl metacrylate) as the base of removable denture is still an option because of its relatively low price, easy repair, and easy manufacturing process.² Denture base must be able to meet the physical requirements such as mimic the natural appearance of soft tissue, have a fairly high transition

temperature value, have good dimensional stability, and radiopaque.³ In addition, the requirements for mechanical properties must also be fulfilled, including having sufficient flexural strength which allows it to withstand fractures.

A study reported that the use of an acrylic denture base material is often found to fracture in the midline section of more than 60% of use for 2-4 years.⁴ The fracture of denture base plate can be caused by the bad fitting of denture, the absence of occlusion balance, fatigue and fall.⁵ Moreover, the fracture of denture can result from the burden of mastication and impact load when falling from a height, when the denture is cleaned.⁶

Impact loads when falling from a height hit the surface or the outer part (compression zone)

of the denture base, so additional reinforcement is needed in the area.⁷ The impact strength required by denture base material based on ISO 1567 is 2 kJ/M².

Several studies were conducted with an objective to strengthen acrylic resin as a denture base, by adding fiber to increase impact strength, flexural and fatigue resistance of a material.⁷ According to Zhang and Matinlinna, a widely used fiber in the field of dentistry is glass fiber because it has good aesthetic properties, contains similar mechanical properties to that of dentin and is biocompatible.⁸

In addition to being used in the field of dentistry, glass fiber is also widely used in other fields such as automotive, building industry, and gypsum reinforcement.⁹ An examination by using X-Ray Fluorescence test (XRF) showed that the composition of non-dental glass fiber is almost the same as that of dental glass fiber in spite of few differences. Based on the above mentioned reasons, it is necessary to study the effect of adding non-dental e-glass fiber to the compression zone on the impact strength of acrylic resin base plate.

The objective of this study was to examine the effect of adding non-dental e-glass fiber from the preparation in the compression zone on the impact strength of acrylic resin base plate. In this study we made the addition of non-dental fibers with different orientations, bidirectional (Figure 2), unidirectional (Figure 3), and woven. This study is expected to be able to provide information about the best



Figure 1. Bidirectional and woven fiber (Mallick, 2007).⁹

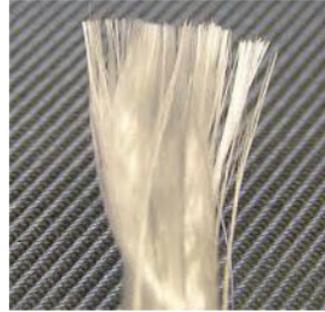


Figure 2. Unidirectional fiber (Mallick, 2007).⁹

orientation and position of non-dental glass fiber to be applied as a reinforcement in the manufacture of acrylic resin base plate.

MATERIALS AND METHODS

This research was a laboratory experiment conducted at the Laboratory of Mechanical and Industrial Engineering UGM and the SEM Laboratory of the Department of Mechanical Engineering ITS in June-July 2018. The materials used included heat-cured acrylic resin brand Qc20, non-dental fiber without brand (composed of SiO₂, diameter 17.6 μm).

The sample was made by making a sample mold made from a red plasticine with the size of 65 x 10 x 2.5 mm placed on a cuvette that had been filled with hard casts and left to harden then smeared with vaseline and later, the flask was closed and left to stand until the cast hardened.⁹ After the cast hardened, the flask was opened and the red plasticine was removed using hot water to clean the mold in order for the mold to be formed.

Fiber volume based on weight can be calculated using the following formula:

$$V_t = \frac{W_f}{W_s} \times 100\%$$

Note:

V_t = Fiber volume (%)

W_f = Weight of fiber (g)

W_s = Weight of sample (g)

Thus from the calculation, the results obtained showed that the fiber volume was 1.6% by weight. Preparation of making the first acrylic resin plate was

carried out by measuring fiber of which the length was 63 mm and moistened with monomers. Acrylic resin was manipulated by mixing the polymer and monomers according to the factory rules (Qc20) until it reached the dough phase, then the dough was put into the mold until reaching 2/3 of the mold.

First the acrylic dough was put at half of the mould, than the fiber placed in the middle acrylic dough next the last acrylic dough on the top to full fill the mould. The dough was coated with cellophane and the flask was closed for pressing. The flask was opened and the remaining dough was removed and pressed again for the next process of curing by means of cuvettes put into boiling water (100 °C) for 20 minutes. The sample was removed from the mold and trimmed with sandpaper and measured again to make sure that the sample size did not change. The samples were immersed in distilled water and stored in an incubator at 37 °C for 24 hours. Measurements were made by impact testing using universal testing machine with the Charpy method, namely by means of a pendulum released later swinging to the center of the fracture of the specimen part which was held at both ends. The amount of energy was calculated based on the energy lost from the pendulum when the fracture occurred by the ratio of the swing length which resulted in a fracture and the free swing which did not result in a fracture. Fractured samples were analyzed using scanning electron microscopy (SEM) to see the fracture illustration in the sample fracture area.

RESULTS

The results of the impact strength test in Table 1 including mean and standard deviation generally showed an increase in the mean of the impact strength, showing the results of the impact strength

of the non-dental fiber compare with a control group from the highest to the lowest as follows: unidirectional, woven, bidirectional. One-way ANOVA test results indicated a significant difference in the impact strength of the base plate added with fiber, while for determining the differences between groups, an LSD test was performed.

The LSD test results denoted the groups had an increase in the impact strength after fiber addition. The highest increase was found in the group with unidirectional fiber addition, followed by the group added with woven fiber, while the lowest increase was found in the group with bidirectional fiber addition.

Table 1. Mean and standard deviation (SD) of the impact strength of acrylic resin base plate by adding non dental-glass fiber

Group	Mean ± SD (KJ/m ²)
Control	4.98 ± 1.04
Woven Fiber	13.21 ± 2.34
Unidirectional Fiber	16.81 ± 2.79
Bidirectional Fiber	8.54 ± 2.20

Table 2. One Way ANOVA the impact strength of acrylic resin base plate

ANOVA					
Impact Strength	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.199	3	.066	22.886	.000
Within Groups	.035	12	.003		
Total	.234	15			

Table 2. Data normality of the impact strength of acrylic resin base plate using Shapiro-wilk test

Group	Impact strength	
	Statistic	p
Control	0.945	0.683
Woven Fiber	0.943	0.672
Unidirectional Fiber	0.862	0.267
Bidirectional Fiber	0.801	0.104

Table 3. Summary of the results of the LSD data is the impact of the acrylic base plate impact variation

	Woven Fiber	Unidirectional Fiber	Bidirectional Fiber
control	- 8.22000*	-11.82250*	-3.54750*
Woven Fiber	-	-3.60250*	4.67250*
Unidirectional Fiber	-	-	8.27500*
Bidirectional Fiber	-	-	-

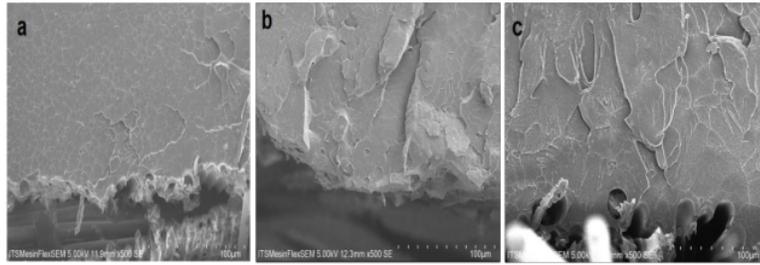


Figure 5. (A) SEM on sample with unidirectional fiber (B) Sample with unidirectional fiber (C) sample with woven fiber

DISCUSSION

Glass fiber is an inorganic substance; e-glass fiber composed of silica, oxidants, and alumina is considered as the dominant reinforcing material for polymer matrix due to its high mechanical properties, low water absorption, chemical resistance, high thermal stability and melting point. The effectiveness of fiber reinforcement involves many influential factors, one of which is the orientation of fiber to be added.¹¹

Fiber with unidirectional orientation had a Ratchet factor of 1 or 100% meaning that all fibers were exposed to the load, so the remaining load received by the matrix was only small. The lowest impact strength was in the addition of fiber with a bidirectional orientation which has a reinforcement efficiency of only 0.25 or 25%, meaning that the fiber exposed to the load was only 25%, and the remaining was borne by the matrix.

Fiber with a direction opposite to the force produced a good elasticity effect; the unidirectional orientation has been widely investigated because it has provided high elasticity and modulus in parallel directions to the fibers, so unidirectional fiber is used to reinforce material with an identified load direction. Impact strength increased when the flexural strength and tensile strength of a material was high. This is because the fiber added is unidirectional to the acrylic denture base, thus resulting in an increase in the flexural strength of the acrylic resin denture base and the highest reinforcement in impact strength.^{12,13}

Observations using SEM on the acrylic resin plate fracture area with the addition of unidirectional fiber showed small fragments, while the acrylic resin plate with the addition of woven and bidirectional fiber showed wider and deeper fragments. The small fragment on the addition of unidirectional fiber was caused by the small load / energy exposed to the matrix, while on the addition of woven and bidirectional fibers, wide and deep fragments resulted from the presence of considerable energy received by the matrix.

Compared to the control group, the addition of non-dental glass fiber increased the impact strength of the acrylic resin base plate. The highest value was found on non-dental glass fiber with unidirectional reinforcement, while the lowest impact strength was found on bidirectional glass fiber and the control group. However, in all the sample groups, the impact strength was lower than the standard value of 0.98 to 1.27 J.² In fact, it is crucial to conduct further research on the amount or volume of fiber to obtain impact strength according to the specified value.

CONCLUSION

Based on the results of the research conducted, it can be concluded that The addition of E-glass non-dental fiber in the compression zone increases the impact strength of acrylic resin base plate is unidirectional fiber provides the highest increase in the impact strength of acrylic resin base plate.

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