The effect of non-dental glass fiber volume fraction on flexural strength of heat cured acrylic resin

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ABSTRACT

Background: *Heat-cured acrylic resin is a material that is often used for the manufacture of removable partial dentures in dentistry because it uses simple equipment, relatively inexpensive, and is easy to repair. Acrylic resin also has a disadvantage, such as the low value of flexural strength so that it can cause the denture to fracture. This study determine the effect of non-dental glass fiber volume fraction on the flexural strength of heat cured acrylic resin.*
Method: *This research are post-test only control group design. Acrylic resins were divided into four groups (6 sample each group), group 1 without the addition of non-dental glass fiber or 0% and heat cured acrylic resin group with the addition of non-dental glass fiber 1%,2%, and 3% (group 2, 3 and 4).*
Result: *The average flexural strength of acrylic resin with a volume fraction of 2% of non-dental glass fiber had the highest value compared to other groups. The results of the Mann-Whitney test from several test groups showed significant differences in the value of flexural strength from each group (p<0.05), except for the 0% and 3% group.*
Conclusion: *There is an effect of volume fraction of non-dental glass fiber on the flexural strength of heat cured acrylic resin.*

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INTRODUCTION

Heat cured acrylic resin which are used to manufacture removable denture bases[1]. However, acrylic resin denture bases have several weaknesses. One of them, which often happens, is fracture[3]. Fracture on denture base may occur when a denture base drops and hits a hard object (impact force) or when it receives regular pressure during usage (flexural force) [4].

An addition of fiber to denture base can be performed to strengthen its physical and mechanical properties[5]. Glass fiber is an ideal reinforcing material for it[6]. However, glass fiber is limited and relatively expensive. An alternative type of glass fiber which is widely available and inexpensive in markets is non-dental glass fiber. The composition of non-dental glass fiber, as observed with X-Ray Fluorescence Spectrometer (XRF), is mostly similar with the composition of E-glass fiber which is normally used in dentistry.[7]

Several factors that influence the increase of the mechanical property of fiber as a reinforcing material are volume, adhesion and position[4]. Choosing the right volume of fibers for acrylic resin can increase the strength of acrylic resin denture plates. A study finds that fibers which are well positioned and have the right volume can enhance the strength of denture[6]. Based on the explanation above, therefore, this study determine the effect of non-dental glass fiber volume fraction on the flexural strength of heat cured acrylic resin.

RESEARCH METHOD

This study used the post-test only controlled group design. It involved four control groups: 6 sample each group, acrylic resin without an addition of volume fraction of non-dental glass fiber (K1), acrylic resin with an addition of 1% volume fraction of non-dental glass fiber (K2), acrylic resin with an addition of 2% volume fraction of non-dental glass fiber (K3), and acrylic resin with an addition of 3% volume fraction of non-dental glass fiber (K4).

The tools used in the study were cuvette, spatula, bowl, press, *stellon* pot, cement spatula, cellophane, and *ControLab* Universal Testing Machine (UTM) for testing flexural strength. The materials used during the study were heat cured acrylic resins, non-dental glass fibers, silane coupling agents, aquades water, CMS, Vaseline, white dental plaster and red wax.

The length of non-glass fibers were 63 mm. Then, they were weighted according to the volume fraction of each group. 1% fraction of volume had a mass of 0.041275 grams, 2% fraction of volume a mass of 0.08255 grams, and 3% fraction of volume a mass of 0.123825 grams.

The samples were created as follows. First of all, a dental impression for acrylic resin denture base was created from white dental plaster. A red wax model with a volume of 65 mm x 10 mm x 2.5 mm was placed on the plaster. Once the dental plaster hardened, Vaseline was coated on its surface. Then, antagonist dental cuvette was installed on it. After that, dough of white dental plaster was filled into it until the dough set. After the dough had set, the dental cuvette was opened and hot water was poured into the wax model until it melted and thus the dental impression was formed. Finally, the dental impression was coated with could mould seal (CMS).

Acrylic resins were created by mixing monomers and polymers of acrylic resins inside a stellon pot according to the manufacturer's requirements. Once the mixture reached the dough stage, it was placed into the half portion of the impression. Then, non-dental glass fibers were applied horizontally. The surface of non-dental glass fibers were coated with acrylic resins until they filled the impression fully. The dental cuvette was pressed until a metal-to-metal contact occurred. After that, a curing process was performed on the acrylic resins by putting the dental cuvette into the boiling water with 100°C temperature for 20 minutes. Then, the finishing process was applied to the acrylic resins. Next, the acrylic resins were soaked inside aquades water and they were kept inside an incubator with 37°C temperature for 24 hours.

The flexural strengths of acrylic resins were measured using Universal Testing Machine (UTM) with the three-point bending test method. The method was conducted by pressing the middle part of the sample whose ends were placed on supports until a fracture occurred. The flexural strength was calculated using the following formula:

$$S = 3IP/2bd^2$$

Notes:

S = flexural strength (N/mm2 = MPa)

I = supporting distance (mm)

P = load (N)

b = width of test beam (mm)

d = thickness of test beam (mm2)

RESULTS

In Table 4.1, there are differences among mean values of the four treatment groups. The values of flexural strength in the groups with the addition of 1% and 2% non-dental glass fiber volume fractions increased while the value of flexural strength in the group with the addition of 3% non-dental glass fiber volume fraction decreased.

The result of statistical analysis using the Kruskal-Wallis test shows that the significance value of 0.000 ($p< 0.05$) was acquired, signifying that there is a significant difference among four data groups (Table 2). The Mann-Whitney test was conducted to identify the differences among the significant values of flexural strength of each group ($p<0.05$). Its result can be seen in Table 3.

Table 1. Mean values of the flexural strength of several volume fractions

Group	N	Flexural strength	
		Mean	Standard Deviation
K1	6	62.0000	9.03327
K2	6	78.0000	6.57267
K3	6	102.000	12.58571
K4	6	66.0000	6.57267

Table 2. The result of the Kruskal-Wallis test

Kruskal-Wallis	**P**
	0.000

Table 3. The result of the Mann-Whitney test

Group	P			
	1	2	3	4
1	-	0.011	0.004	0.423
2	0.011	-	0.007	0.019
3	0.004	0.007	-	0.003
4	0.423	0.019	0.003	-

DISCUSSION

There are differences among mean values of the flexural strength of non-dental glass fiber with different volume fractions. The research results show that the addition of 2% non-dental glass fiber volume fraction gives the highest flexural strength compared to others.

The addition of fiber to acrylic resin can improve its flexural strength because any pressure that a plate made from acrylic resin and fiber receives will be distributed evenly[8]. Fiber as a reinforcing material is capable of distributing pressure, thus preventing fracture spread. Fibers with strength higher than the strength of acrylic resin plate can also absorb pressure and improve the strength of acrylic resin plate[9].

The research results showed the increase of the flexural strength according to the additions of non-dental glass fiber with volume fractions. The additions of 1% and 2% non-dental glass fiber volume fractions enhanced the flexural strength while the 3% addition reduced the flexural strength. The reduction was caused by the fact that an addition of fiber to acrylic resin which exceeds a maximum value may reduce its mechanical strength since the resin cannot contact closely with fiber, reducing its value of energy absorption[5]. Another research shows that an addition of fiber to heat cured acrylic resin which exceeds 2% concentration may cause bigger volume to cover with monomer[10].

Before fibers were applied, an impregnation process with dimethyl silane was performed. Silane may increase adhesion between fibers and acrylic resin so that mechanical strength of acrylic resin is increased[11]. The impregnation process prevents space creation and porosity so that a good contact between fiber surface and resin can be ensured. Impregnation is conducted to prevent excessive water absorption which can reduce the flexural strength of acrylic resin[7]. Impregnation will affect the formation of siloxane bond from a condensation reaction between silanol and the surface of glass fiber, while the relationship between polymer matrix and bonding agent is formed from a reaction of co-polymerization[13].

The standard of flexural strength owned by a material for denture base is 65 MPa[14]. Flexural strength is important because it reduces pressure during the mastication process[15]. According to the research results, the mean values of the flexural strength of acrylic resins after additions of 1-2% non-dental glass fiber volume fractions increased (78 Mpa dan 102 Mpa). This shows that an addition of a non-dental glass fiber volume fraction which is in accordance with the maximum threshold of flexural strength of acrylic resin enhances its strength, making it possible to absorb greater force.

CONCLUSION

Based on the study, it can be concluded that:

1. There is an effect of non-dental glass fiber volume fraction on the flexural strength of acrylic resin.
2. The flexural strength of acrylic resin with an addition of 2% non-dental glass fiber fraction volume has the highest flexural strength compared to additions of 0%, 1%, and 3% non-dental glass fiber volume fractions.

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