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The Effect Addition of Reinforced Fiber and Thermocycling on Flexural Strength of Heat Cured Acrylic Resin Denture Base

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Abstract:

Background: *Addition of reinforced fiber on heat cured acrylic denture needed because this material lack of flexural strength that easy to fracture. The reinforced fiber used is E-glass fiber and UHWMPE fiber, however along the denture usage in oral cavity the flexural strength can be reduced due to water absorption.*

Materials and Methods: *This is an experimental laboratory study with 36 samples divided into 6 groups, consist of without reinforced fiber, with addition of glass fiber and polyethylene fiber (with and without thermocycling). The effect thermocycling on the flexural strength of heat cured acrylic resin denture base with and without reinforced fiber analyzed with T-Independent Test. The effect reinforced fiber on flexural strength of heat cured acrylic resin denture base with and without thermocycling analyzed with One Way ANOVA and need to LSD analysis to see which fiber has the best effect to strengthen the flexural strength.*

Results: *There was no effect of thermocycling with the simulation of oral cavity condition for 3 years denture usage on flexural strength in all group. But there was a significant effect the addition of the reinforced fiber to improve the flexural strength of heat cured acrylic resin denture base with and without thermocycling.*

Conclusion: *There was no significant effect of 3000 cycle of thermocycling but the glass fiber material can significantly increase the flexural strength.*

Key Word: *e-glass, UHMWPE, flexural strength, thermocycling.*

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I. Introduction

The denture base is a part of denture which functioned to replace alveolar bone, receive mastication load and distributing to periodontium or abutment teeth, and to support the artificial teeth.[1] Denture base has requirements for ideal material such as, biocompatible, nonirritating, dimensionally stable, not too expensive, easy to kept clean, great aesthetic and great mechanical properties.[2] Acrylic resin is most widely used for denture base since 1940 because this material has advantages that are low cost, easy to manipulate, and great aesthetic.[6] This material has several types based on their activation such as: heat cured acrylic resin, light cured acrylic resin and chemical cured acrylic resin.[3] Heat cured acrylic resin is the most used material among the other types. These materials are supplied in the form of powder and liquid.[4] Powder contains of pre-polymerized PMMA beads (PMMA) and liquid or monomer which contains methyl methacrylate (MMA).[4] Later on, the two material are mixed until homogenous, meanwhile it mixed, the benzoyl peroxide as the initiator of PMMA creates heat energy to start the polymerization process. The process needs a lot of monomers; therefore, this material had a few residual monomers than the other type of acrylic.[5] However, heat cured acrylic resin lack some of the properties such as, easy to occur abrasion, low thermal conductivity and poor of mechanical properties.[6] One of the poor mechanical properties is lack of flexural strength. So, this material occurring midline fracture when used for a long time in oral cavity. In spite of that, reinforced material needed to improve flexural strength on heat the cured acrylic resin denture base.[6]

Reinforced material are used because it had a good strength for inadequate denture base so that it can use for long time.[7] The reinforced material frequently used is reinforced fiber because it is easy to manipulate.[7] Reinforced material consist of several types, there is carbon fiber, aramid fiber, glass fiber and polyethylene fiber. However, glass fiber and polyethylene fiber had a great aesthetic and a good mechanical strength.[8] S Gokul, (2018) state, fiber glass showed significantly improve of flexural strength on the heat cured acrylic denture base.[9] That is because glass fiber contain of silica dioxide can produce a strong covalent isotropic chemical bond so it absorbs load that prevent bending of denture base and contain of boron dioxide that can improve the stability of hydrolytic to reduce water absorption.[10] But, glass fiber and heat cured acrylic denture base had lack of adhesion, for that reason it is important to adding silane coupling agent so it can be modify surface energy of glass and create a new chemical bond that makes more homogeneous.[11] Polyethylene fiber also able to improve flexural strength.[12] Hadianto, (2013) state that, polyethylene fiber showed a significant improve to increase flexural strength on the heat cured acrylic denture base.[12] In spite of that, polyethylene fiber and heat cured acrylic denture base had lack of adhesion because it has a weak bonding between the polar hydrophilic UHMWPE fiber and nonpolar hydrophobic PMMA.[7] Hence, this material needs to surface treatment that able to distribute the stress to be balanced to improve the flexural strength of heat cured acrylic denture base. That two reinforced fiber can prevent fracture and increase flexural strength.[13]

Flexural strength is a combination of compression, tensile, and shear strength. This testing machine called universal testing machine (UTM) for determines occlusal stress that material can take when mastication process. UTM also determine total of distortion, strain and deflection of material.[14] According to ISO 20795, denture base must not be less than 60 - 65 MPa.[15] The higher value of the flexural strength of the denture base, the better it will be to distribute the mastication load to prevent fracture.[14] Along with the use of denture in oral cavity in a long period of time, there is a change on the mechanical properties due to the aging process. Condition in the oral cavity can be simulated with thermocycling.[14]

Thermocycling is a simulation oral cavity to evaluate the physical and chemical properties of dental material occurring aging process with the temperature 5-55°C.[16] That temperature is close to various types of cold and hot food and beverage.[7] The aging effect occurs because the temperature change in thermocycling increases water absorption which can be caused by changes in the distance between the polymer chain structures so that the denture base becomes plastic and soft which results in a decrease in flexural strength. This can be prevented by adding reinforced fiber.[16] Nayan K. (2016) state that, the heat cured acrylic denture base reinforced with chopped strand E-glass fiber and *thermocycling* showed significant improvement of flexural strength on the heat cured acrylic denture bases.[17] Lim E (2015) state that, heat cured acrylic denture base reinforced with woven ultra-high modulus weight polyethylene (UHMWPE) fiber had been plasma treatment *thermocycling* showed significantly improve of flexural strength on the heat cured acrylic denture bases.[10]

Based on the text above, the researcher need to evaluate of the effect of addition of chopped strand E-glass fiber and woven UHMWPE fiber with and without thermocycling on flexural strength of heat cured acrylic resin denture base and evaluate the effect of thermocycling with chopped strand E-glass fiber and woven UHMWPE fiber of heat cured acrylic resin denture base

II. Material and Methods

This is an experimental laboratory study with 36 heat cured acrylic resin sample were divided into 6 groups such as, without reinforced fiber and without thermocycling, without reinforced fiber and with thermocycling, with addition chopped strand E-glass fiber and without thermocycling, with addition chopped strand E-glass fiber and with thermocycling, with addition woven UHMWPE fiber and without thermocycling and with addition woven UHMWPE fiber with thermocycling. The test sample is 65 mm x 10 mm x 2,5 mm (ADA 12:1999). The manipulation of chopped strand E-glass fiber of 3 mm size with 1% weight is carried out by immersing in the silane coupling agent (Silane, Ultradent, USA) for 40 minutes, then heat the fiber with 115°C temperature for one hour. Inside the acrylic pot, the next step is to put the glass fiber on heat cured acrylic resin denture base (Acron, GC, Japan) powder and then add monomer and stirred until it become homogeneous, when acrylic entering the dough phase, the next step is to put it into a mold. For woven UHMWPE fiber of 2 mm width (Bianinastro, Biancaden, Italy) manipulation; The first step, cut the fiber with a length of 60 mm, then soak the fiber in the monomer for 60 minutes in a container and drain it. The second step, mix the PMMA powder and monomer stirred until homogeneous, then put acrylic dough inside 1/3 of the mold. The soaked polyethylene fiber is placed using tweezers into the mold in the center position. When the acrylic entering the dough phase, then put remaining dough into the mold. Cover the cuvette with plastic sheet. The upper and lower cuvettes are attached and then pressed gently with a hydraulic press with a pressure of 1000 psi and 2200 psi. Remove the cuvette from the press and install and screw the cuvette for 30 minutes. Then put cuvette in water bath (Filli Manfredi, Italia) with distilled water, set the temperature and time on the water bath with a temperature of 70ºC for 90 minutes. After 90 minutes, set the temperature and time on the water bath with a temperature of 100ºC for 30 minutes, after that the cuvette was left in the water bath until the water reached room temperature.

The flexural strength testing is done in Impact and Fracture Research Center in Universitas Sumatera Utara, Indonesia and thermocycling testing in Faculty of Dentistry in Chulalokorn University, Thailand. Thermocycling (TC 301, 0-999,999 cycle, Thailand) is carried out at 3000 cycles with a temperature of 5-55ºC for a total of 60 seconds, which is calculated as 1 cycle. Flexural strength testing was performed using Universal Testing Machine (Orientec Corporation RTF-1350, Japan). The distance between two supports is 50 mm. Samples are numbered at both ends and placed such that the tool will press until the sample fracture. The energy listed on the machine is read and recorded and then the flexural strength is calculated. The unit used in this tool is MPa.

Data was analyzed using SPSS version 23 (SPSS Inc., Chicago, IL), using T-Independent Test to obtain the effect of thermocycling on flexural strength of heat cured acrylic resin denture base material without reinforced fiber and addition with chopped strand E-glass fiber and woven UHMWPE fiber. ANOVA test was used to obtain the effect of addition chopped strand E-glass fiber and woven UHMWPE fiber analyzed the impact on flexural strength of heat cured acrylic resin denture base material with and without thermocycling. LSD analysis and performed to see which fiber has the best effect to strengthen the flexural strength of heat cured acrylic resin.

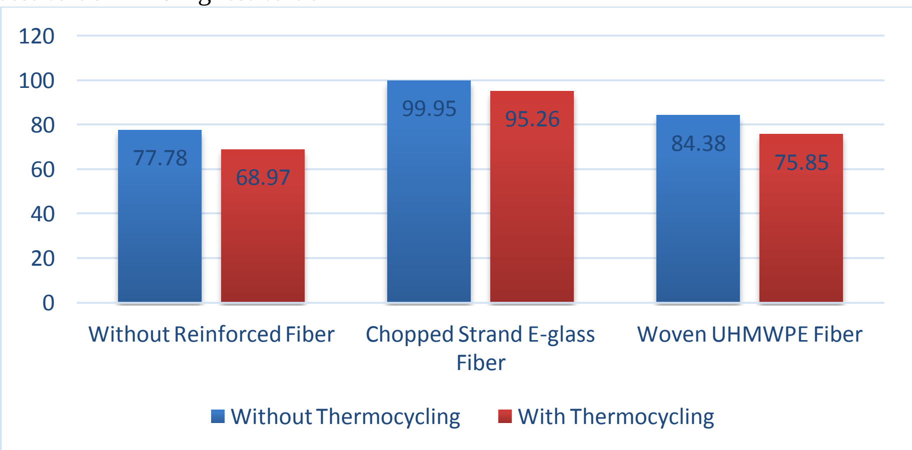
III. Results

The result showed mean of flexural strength were analyzed with Univariate test. It showed the group of without reinforced fiber (55,77 MPa) and with addition of woven UHMWPE fiber (64,33 MPa) has a lowest value of themocycling group which means is below the standard of flexural strength (60-65 MPa). And it showed that the mean and the standard deviation of the heat cured acrylic resin denture base of a group without reinforced fiber and without thermocycling is 68,97 ± 8,22 MPa, and with thermocycling is 77,78 ± 8,21 MPa. The other group of the heat cured acrylic resin denture base with addition chopped strand E-glass fiber showed mean and standard deviation with thermocycling is 99,95 ± 4,59 MPa, and without thermocycling is 95,26 ± 7,67 MPa. And the last group of the heat cured acrylic resin denture base with addition woven UHMWPE fiber showed mean and standard deviation with thermocycling is 84,38 ± 10,85 MPa, and without thermocycling is 75,85±13,37 MPa. (Table 1)

Table 1: The test value of flexural strength of heat cured acrylic resin denture bases without reinforced fiber and with addition of chopped strand E-glass fiber and woven UHMWPE fiber.

Group	Number of samples	Flexural Strength (MPa)	
		Without Thermocycling	**Thermocycling**
Without Reinforced Fiber	1	75,26	63,92
	2	74,38	77,17
	3	66,27*	69,47
	4	86,58	77,28**
	5	88,08**	55,77*
	6	76,13	70,19
	Mean ± SD	**77,78 ± 8,21**	**68,97 ± 8,22**
Chopped Strand E-glass Fiber	1	103,75**	84,30*
	2	100,20	103,09**
	3	103,14	99,82
	4	92,29*	88,38
	5	96,83	101,78
	6	103,48	94,19
	Mean ± SD	**99,95 ± 4,59**	**95,26 ±7,67**
Woven UHMWPE Fiber	1	71,08*	85,76
	2	91,63	66,54
	3	73,42	76,13
	4	99,78**	97,29**
	5	85,04	64,33*
	6	85,33	65,07
	Mean ± SD	**84,38 ± 10,85**	**75,85±13,37**

Note :* : lowest value ** : highest value



Graphic 1: The mean value of flexural strength of heat cured acrylic resin denture bases without reinforced fiber and with chopped strand E-glass fiber and woven UHMWPE fiber and with and without thermocycling.

Effect of thermocycling to flexural strength with and without reinforced fiber

The result of T-Independent Test showed there is no significant effect of thermocycling without reinforced fiber with p = 0,093 (p<0,05), the other group also showed no significant effect of thermocycling with chopped strand E-glass fiber with p = 0,227 (p<0,05), and last group showed no significant effect of thermocycling with Woven UHMWPE Fiber with p = 0,253 (p<0,05). All group showed there is no effect of thermocycling to flexural strength with and without reinforced fiber. (Table 2)

Table 2: The test value of thermocycling to flexural strength with and without reinforced fiber.

Group	n	Flexural Strength (MPa)		p
		Without Thermocycling	**With thermocycling**	
Without Reinforced Fiber	6	68,97 ± 8,22	77,78 ± 8,21	0,093
Chopped Strand E-glass Fiber	6	95,26 ± 7,67	99,95 ± 4,59	0,227
Woven UHMWPE Fiber	6	75,85 ± 13,37	84,38 ± 10,85	0,253

Effect reinforced fiber to flexural strength with and without thermocycling

The result of One-Way ANOVA Test showed, there is a significant effect after adding chopped strand E-glass fiber and woven UHMWPE fiber to improve flexural strength on heat cured acrylic resin without thermocycling with p = 0,001 (p>0,05). Later on, tested with LSD Test to analysis and performed to see which fiber has the best effect to strengthen the flexural strength of heat cured acrylic resin. LSD Test showed there is significant difference with a group of without reinforced material and with addition of chopped strand E-glass fiber to flexural strength with p = 0,001 (p<0,05). (Tabel 3)

Table 3: The test value of reinforced fiber to flexural strength without thermocycling.

Group	n	Flexural Strength (MPa) Mean ± SD	p
Without Reinforced Fiber	6	77,78 ± 8,21	
Chopped Strand E-glass Fiber	6	99,95 ± 4,59	0,001*
Woven UHMWPE Fiber	6	84,38 ± 10,85	
The difference between the flexural strength means between;			
– **Without reinforced fiber and with chopped strand E-glass fiber**			0,001*
– **Chopped strand E-glass fiber and with woven UHMWPE fiber**			0,005*
– **Woven UHMWPE fiber and Without reinforced fiber**			0,188

A significant difference is also found with a group of addition of and addition of woven UHMWPE fiber to flexural strength with p = 0,005 (p<0,05). However, there is no significant difference with a group of addition of woven UHMWPE fiber and without reinforced material on flexural strength with p = 0,188 (p<0,05). (Table no 3)

The result of One-Way ANOVA Test showed there is a significant effect after adding E-glass chopped strand fiber and woven UHMWPE fiber to improve flexural strength on heat cured acrylic resin with thermocycling with p = 0,001 (p>0,05). Later on, tested with LSD Test to analysis and performed to see which fiber has the best effect to strengthen the flexural strength of heat cured acrylic resin. LSD Test showed there is a significant difference with a group of without reinforced material and with addition of chopped strand E-glass fiber to flexural strength with p = 0,001 (p<0,05). A significant difference is also found with a group of addition of chopped strand E-glass fiber and addition of woven UHMWPE fiber to flexural strength with p = 0,005 (p<0,05). However, there is no significant difference with a group of addition of woven UHMWPE fiber and without reinforced material on flexural strength with p = 0,255 (p<0,05). (Tabel 4)

Table 4: The test value of reinforced fiber to flexural strength with thermocycling.

Group	n	Flexural Strength (MPa) Mean ± SD	p
Without Reinforced Fiber	6	68,97 ± 8,22	
Chopped Strand E-glass Fiber	6	95,26 ± 7,67	0,001*
Woven UHMWPE Fiber	6	75,85 ± 13,37	
The difference between the flexural strength means between;			
– **Without reinforced fiber and with E-glass chopped strand fiber**			0,001*
– **Chopped E-glass fiber strand fiber and with woven UHMWPE fiber**			0,005*
– **Woven UHMWPE fiber and Without reinforced fiber**			0,255

IV. Discussion

Thermocycling machine runs by inserting the sample into the machine which filled of artificial saliva, this machine can create temperature change from 5-55°C.[18] This simulation could influence of water sorption, that is occur because of temperature change. The water molecules can diffuse to denture base and dissolve the component of heat cured acrylic such as; residual monomer, plasticizer and initiator.[19] Consequently, it can make a form of small voids of denture base and water can easily absorbed and act as a plasticizer.[16] Therefore, water can penetrate and break the polymer chain.[19] The heat that produces during the testing process also cause to increase the absorption of water into heat cured acrylic denture base allowing the chain to become unstable when given a load and it became weak and stiff.[16] Thereby, that procedure reducing the flexural strength, as Machado AL. (2011) state, there is an effect of thermocycling on flexural strength of heat cured acrylic resin and also there is a significant decreased flexural strength of denture base with and without thermocycling.[16] In this study, there is decreasing of flexural strength on heat cured acrylic resin denture base, but there is no significant difference between with and without thermocycling to all group. This is in accordance with the research of Ayaz EA, et al. (2013) state, thermocycling can reduce the flexural strength of heat cured acrylic denture bases, but there is no significant difference between with and without thermocycling on flexural strength.[20] This study showed that thermocycling with 3000 cycles can reduce the flexural strength of the base denture heat cured acrylic denture bases, but there is no significant difference between with and without thermocycling. This can happen because there are only few cycles occurred and the base of the heat cured acrylic denture bases with this brand had a good enough flexural strength for a 3-year usage period.

There is an significant effect of adding reinforced fibers to the heat cured acrylic denture base of the denture with and without thermocycling. The addition of chopped strand E-glass fiber showed a significant increase on flexural strength compared to control with and without thermocycling. This is because the glass fiber have a composition of silica dioxide and boron dioxide, thus create strong chemical bond and reduce water absorption.[11] And also with addition the silane coupling agent could increase the chemical adhesion between the glass fiber and the acrylic denture base.[11] Therefore, the silane treated glass fiber can distribute the load properly, so the addition of glass fiber can increase the flexural strength of the heat cured acrylic resin denture base.[11] However, there was no significant difference on flexural strength between addition of polyethylene fiber compared to control with and without thermocycling. This occurs due to inadequate surface treatment which causes poor adhesion. The use of polyethylene fiber as reinforcement can cause poor interfacial interaction between polyethylene fiber and heat cured acrylic resin can lead to the decrease in flexural strength.[3] According to Debnath S, et al. (2004) who reported the effect of various chemical surface treatments, one of which is MMA or heat cured acrylic resin monomer which shows that there is a slight increase in adhesion between polyethylene fiber and heat cured acrylic resin denture base, but there is no significant difference on flexural strength compared to polyethylene fiber without treatment.[21] Polyethylene fiber and heat cured acrylic denture base have lack of adhesion because it has a weak bonding between the polar hydrophilic polyethylene fiber and nonpolar hydrophobic PMMA.[7] To overcome similar issues, there had been physically modify and control the surface properties of the materials by incorporating polar groups onto the surface to enhance hydrophilicity, adhesion, and biocompatibility characteristics.[22]

IV. Conclusion

The simulation of denture base for 3000 cycles (3 years) with thermocycling shows a decrease on flexural strength but there is no significant difference with and without thermocycling. This happens because there are only few cycles occurred and the denture base of the heat cured acrylic resin with this brand had a good flexural strength for a 3-year usage period. The addition of reinforced fiber such as glass fiber and polyethylene fiber can increase the flexural strength with and without thermocycling. Therefore, the glass fiber material can increase significantly the flexural strength. Poor interfacial interaction between between UHMWPE fiber and heat cured acrylic resin can cause the addition of polyethylene fiber but did not show a significant increase on flexural strength.

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