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RESEARCH ARTICLE

Effect of Glass Fiber Reinforcement on the Mechanical Properties of Acrylic Resin Denture Base

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ABSTRACT

Background: *Acrylic resin dentures are frequently reported to experience damage within a few years after fabrication. Intraorally, repeated masticatory forces can lead to fatigue failure and fracture, while high extraoral impact forces, such as accidental drops, may also lead to fractures of the denture base.* ***Objective:*** *To determine the optimal concentration of glass fibers reinforcement that provides the highest values of impact strength, transverse strength, and hardness in acrylic resin.* ***Materials and Methods:*** *A total of 48 acrylic resin samples were divided into four groups based on glass fiber concentration: 0%,6%,9%, and 12%. Each group was tested for impact strength, transverse strength, and hardness. Samples dimension for impact strength: 65 mm x 10 mm x 2.5 mm, 80 mm x 10 mm x 4 mm for transverse strength, and tube-shaped with a diameter of 5 mm and a thickness of 3 mm for hardness test. Testing equipment for impact strength: Charpy testing machine (Resil Impactor Ceast 6958.000), Universal Testing Machine (Shimadzu AGS-X 10kN for transverse strength, and Vickers machine (HMV-G) for hardness test.* ***Results:*** *The highest impact strength was observed in the group with 0% glass fibers. Meanwhile, the addition of 12% glass fibers exhibited the highest transverse strength exhibited and the highest hardness was achieved in samples containing 6% glass fibers.* ***Conclusion:*** *The addition of 12% glass fiber enhances the transverse strength of acrylic resin but decreases impact strength. Meanwhile, adding 6% glass fiber improves the hardness of acrylic resin.*

Keywords: *Acrylic Resin Base, Impact Strength, Transverse Strength, Hardness*

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INTRODUCTION

Tooth loss is currently one of the most common oral health issues in Indonesia.[1,2] According to the 2018 Basic Health Research (Riskesdas) report, 19% of Indonesians have experienced tooth loss, with the highest prevalence found in individuals aged over 65 (30.6%), followed by those aged 55–64 (29%).[3] Dentures are commonly used to replace missing teeth. Generally, there are two types of dentures: fixed dentures and removable dentures. The most widely used material for denture-based is heat-polymerization acrylic resin[4], due to its numerous advantages, including good aesthetics, low water absorption, favorable thermal conductivity, biocompatibility, ease of handling and repair, and cost-effectiveness. [5–7]

However, heat-polymerized acrylic resin dentures are susceptible to cracking or fracturing after extended use, particularly as a result of repeated impacts. These materials have certain mechanical limitations, especially in terms of impact strength, compressive strength, and transverse strength. Biomaterials used in the fabrication of dentures, denture bases, bridges, and similar prosthetic devices are subjected to complex stress patterns during use, including combinations of compressive, tensile, and shear forces. Therefore, analyzing flexural strength is essential in evaluating the durability and performance of these prostheses.[8–10] Fracture is the most common problem encountered by both patients and dentists in relation to polymethyl methacrylate (PMMA) denture bases. According to Johnston et al., impact failure accounts for nearly 68% fractures observed in acrylic denture bases a few years after fabrication.[10] To enhance the mechanical properties of denture base materials have been improved by adding a polyfunctional crosslinking agent, rubber phase, metal wires or meshes, and fibers have been explored. [4,11]

Surface characteristics such as roughness, hardness, and wettability also play a critical role in denture-associated stomatitis. Rougher denture surfaces are more likely to harbor microorganisms, contribute to halitosis, and are more prone to discoloration than smoother surfaces, thereby decreasing patient comfort.[4,12]

MATERIALS AND METHODS

The research was conducted in the Laboratory of the Faculty of Dentistry, Maranatha Christian University for the transverse strength and hardness tests, while the impact strength tests were performed at the Bandung Institute of Technology Laboratory between May and July 2024. The study used a laboratory-based experimental design with a post-test-only control group design. The tools used in this research are a Charpy testing machine (Resil Impactor Ceast 6958.000) to test impact strength and a universal testing machine (Shimadzu AGS-X 10kN) to test transverse strength, and Vickers hardness tester to test hardness (HMV G). Specimens were divided into three groups tested for impact and transverse strength: Group 1: heat-polymerized acrylic resin with 6% glass fibers; Group 2: heat-polymerized acrylic resin with 9% glass fibers; Group 3: heat-polymerized acrylic resin with 12% glass fibers.

The procedures of spesimen's preparation include the fabrication of heat-polymerized acrylic resin specimens with and without glass fiber reinforcement, followed by testing for impact strength, transverse strength, and hardness. Then, the glass fiber was added to the acrylic powder before mixing with the liquid monomer. The glass fiber concentrations used were 6%, 9%, and 12%, calculated as follows: as a base mixture, 9 grams of polymer was added to 4.5 ml of liquid monomer to get a result of 13.5 g. Then 13.5 g is multiplied by 6% to get a result of 0.81 g of glass fiber (Group 1). Meanwhile, the percentage of 9% is 13.5 multiplied by 9% to get a result of 1.215 g of glass fiber (Group 2). For a percentage of 12%, that is 13.5, multiplied by 12% to get a result of 1.62 g of glass fiber (Group 3).

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The heat-polymerized acrylic resin specimens were prepared after immersing the glass fibers in liquid monomer. Six samples were prepared with dimensions of 80 mm x 10 mm x 4 mm for the impact strength test for each Group (ISO No. 806 104 377514). Next, six samples were prepared with dimensions of 65 mm x 10 mm x 2.5 mm for the transverse strength test (ISO No. 20795). Then, six samples were prepared with dimensions a tube-shaped with 5 mm diameter and 3 mm thickness (ADA specification No. 12) for the hardness test. The following are the sample-making stages: Prepare the cuvette, prepare the wax pattern with dimensions of 65 mmx10mmx2.5mm and 80 mmx10mmx4mm, stir the plaster, then pour it into the cuvette above the vibrator. Place the wax pattern that has been made on the plaster cast evenly before it hardens. After the plaster cast hardens, apply a thin layer of vaseline to the surface of the cast using a brush. Fill the top cuvette by inserting the cast plaster and lock the cuvette by pressing it using a pressing machine. Then clean the excess cast and do the boiling out.

After the plaster has hardened, open the cuvette, apply Cold Mold Seal (CMS) evenly using a brush, put the heat polymerized acrylic mixture into the cavity, then insert the mold, then line it with cellophane and press with a pressing machine, lock the cuvette, and boil the cuvette.

The impact strength test procedure is as follows: the researcher ensures that the sledgehammer is in the zero position when the sledgehammer hangs freely at an angle of 45 degrees; the sample is placed on a support and ensures that the sledgehammer hits the center of the notch; raise the sledgehammer slowly until the sledgehammer shows the initial angle (the sledgehammer is automatically locked); press the lock release button so that the sledgehammer will swing down and break the sample; after the sample is broken, observations are made and data is recorded.

The transversal strength test procedure is as follows: the sample is placed on the bottom plate of the machine, and the universal testing machine will apply a compressive force at a speed of 20 mm/minute. After pressing the data parameters on the monitor, it will display the results of the test process. Hardness testing was carried out using a Vickers indenter in the form of a pyramid-shaped diamond.

Prepare the sample with ground flat with a thickness of 2.5 ± 0.5 mm andburied in clear resin for Vickers hardness tes, this is inaccordance with the ADA standard AAT hardness test. The test specimens were sanded using grade 120, 240, and 400 sandpaper to obtain a flat shape and surface and accurate results. Next, the specimen was placed on the Vickers working platform and loaded (300 grams) with a loading time of 10 seconds. The minimum indenter distance is 1 mm on the surface of the polished material. Next step is the machine calculates the microhardness value digitally.

The data were analyzed using the *One-way* ANOVA and *post-hoc* LSD. Furthermore, the *Scanning Electron Microscope* (SEM) (JEOL JSM IT-200) was used to evaluate the surface characteristics of the heat-polymerized acrylic resin with glass fibers.

RESULTS

Table 1. The transverse strength results were evaluated based on the addition of glass fibers at varying concentrations.

Transversal Strength	Glass Fiber 0%	Glass Fiber 6%	Glass Fiber 9%	Glass Fiber 12%
Specimen 1	201.601	233.419	250.511	309.282
Specimen 2	222.065	223.081	285.972	255.580
Specimen 3	187.582	245.347	286.192	258.650
Specimen 4	229.471	267.924	232.106	256.266
Specimen 5	236.558	276.960	237.780	245.135
Specimen 6	166.512	219.563	212.047	216.152

Table 1. shows Group 3 contained 12% of glass fibers had the highest result of transverse strength, 309.282 N/mm^2.

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Meanwhile, Group 3 showed the lowest impact strength compare to the other groups (Table 2).

Table 2. The impact strength results were evaluated based on the addition of glass fibers at varying concentrations.

Impact Strength	Glass fibers 0%	Glass fiber 6%	Glass fibers 9%	Glass fibers 12%
Specimen 1	12.404	11.435	7.519	8.569
Specimen 2	12.485	12.314	7.033	9.079
Specimen 3	13.634	9.427	7.339	8.428
Specimen 4	14.050	9.346	7.028	9.042
Specimen 5	14.408	14.235	6.996	8,055
Specimen 6	10.325	9.118	6.641	7.304

Table 3. The hardness results were evaluated based on the addition of glass fibers at varying concentrations.

Hardness	Glass fibers 0%	Glass fibers 6%	Glass fibers 9%	Glass fibers 12%
Specimen 1	21,0; 19,2; 21,1	10,6; 11,5 ;9,0 1	20,6; 21,3; 21,9	14,8; 15,8 ;14, 1
Specimen 2	20,9; 19,0; 18,4	13,4; 12,7; 12,6	19,7; 19,5; 20,4	10,1; 10,2; 10,3
Specimen 3	10,9; 9,83; 10,7	11,1; 12,2; 11,6	14,3; 12,6 ;11, 8	16,5; 16,1; 17,2
Specimen 4	21,3; 20,7; 20,4	11,1; 10,7; 12,4	12,1; 11,9; 11,7	11,3; 11,5; 11,6
Specimen 5	13,6; 13,8; 13,4	12,6; 12,9; 12,1	12,9; 13,5; 12,2	19,5; 17.8; 19.0
Specimen 6	12,8; 11,8; 12,2	10,4; 10,9; 10,5	13,7; 13,9; 14,3	13,7; 13,1; 15,6

Table 3 shows that Group 2 contained 9% of glass fibers performed the highest average of hardness compared to the other groups, except the control group. Meanwhile, Group 1 contained 6% of glass fibers showed the lowest hardness compared to the other groups.

Table 4. The statistical analysis of the impact strength and the transversal strength

	Total square	dk	Mean square	F Value	Significance
Impact strength test					
Between groups	120.902	3	40.301	23.030	<0.001
In groups	34.998	20	1.750		
Total	155.900	23			
Transversal strength test					
Between groups	8928.993	3	2976.331	3.837	0.025
In groups	15515.312	20	775.766		
Total	24444.305	23			

Table 4 shows data the impact strength and transverse strength were proven to be normally distributed and homogenous, so the process used next was *One-Way ANOVA*.

Table 5. The statistical analysis of the hardness

	Total square	dk	Mean Square	F Value	Significance
Hardness test					
Between grouo	203.054	3	67.685	3.671	0.030
In group	368.744	20	18.437		
Total	571.798	23			

Tabel 5 proven that the hardness was normally distributed and homogeneous, so the process used next was One-Way ANOVA.

Table 6. Comparison test results data of impact strength test (*post-hoc* LSD)

	SK0	SK6	SK9	SK12
SK0		0.021	0.001	0.001
SK6			0.001	0.003
SK9				0.099
SK12				

Tabel 6 shows that the next data analysis carried out was *post-hoc Tukey* LSD. The purpose of this analysis was to determine the most significance differences between all specimens. The smallest mean in *post-hoc Tukey* LSD can be determined to be the most significance difference. The most significant impact strength results are at 0% glass fiber to 9% glass fiber, 12%, 6% glass fiber to 9% glass fiber because it shows a result of 0.001. Meanwhile, the least significant is 9% glass fiber

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to 12% glass fiber because it showed the value was 0.099.

Table 7. Comparison test results data of transverse strength test (*post-hoc* LSD)

	SK0	SK6	SK9	SK12
SK0		0.032	0.014	0.006
SK6			0.695	0.447
SK9				0.710
SK12				

Tabel 7 In terms of transverse strength, significant forces were associated with glass fiber content ranging from 0% to 12%. Conversely, the least significant forces were observed in the same range, with glass fiber content ranging from 9% to 12%.

Table 8. Comparison test results of hardness test data (*post-hoc* LSD)

	SK0	SK6	SK9	SK12
SK0		0.004	0.106	0.045
SK6			0.132	0.277
SK9				0.657
SK12				

In the hardness test, the most significant results were obtained from 0% to 6% glass fiber, indicating a value of 0.004. Conversely, the least significant results were observed from 9% to 12% glass fiber, resulting in a value of 0.657.

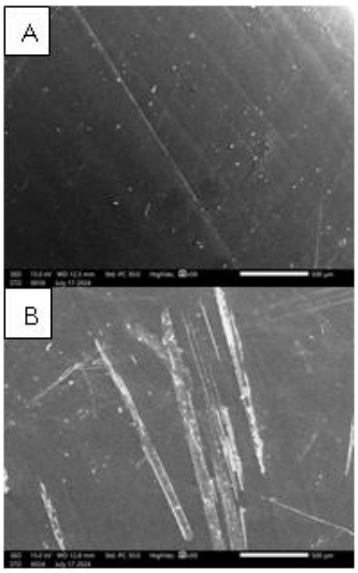

Figure 1. (A) Scanning electron microscope of acrylic without glass fiber; (B) acrylic with 12% glass fiber.

Scanning electron microscope in Figure 1 shows agglomeration of glass fibers in acrylic.

DISCUSSION

Table 6 and 7 showed varying values were caused by several factors, including the uncontrolled sample manipulation, manufacturing process, one of which was due to the mixing of monomer and polymer in heat polymerization denture base materials. Manual mixing techniques tend to trap air in the heat polymerized acrylic resin denture base. The presence of this porosity (Figure 1) affects the strength of the heat polymerized acrylic resin denture base[13], therefore in this study a vacuum mixer was used to mix the monomer, polymer, and glass fiber. Lee et al. (2012) noted that previous studies often compared impact strength with transverse and fracture resistance. However, they found a weak correlation between impact strength and transverse strength or modulus of elasticity. Zappini et al. reported that impact strength only showed a moderate correlation with fracture resistance.[15]

It is possible to draw the conclusion, based on the findings of the tests that were carried out, that the composition of the glass fibers has an effect on the impact strength, transversal strength, and hardness of the heat polymerized acrylic resin denture base. Glass fiber, a fiber composed of fine glass fibers containing silica dioxide (Si_2O_3), exhibits strong covalent bonds and isotropic chemical structures. These characteristics contribute to its denser and stronger structure, enabling it to absorb loads generated by heat polymerized acrylic resins. Moreover, the addition of boron trioxide enhances the hydrolytic stability of the glass fiber surface, reducing water absorption. Consequently, the water absorption by the heat-polymerized acrylic resin denture base is indirectly minimized, leading to improved impact and transverse strength. Because the heat polymerized acrylic resin denture base achieved maximum transversal strength at 12% of

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309,282 N/mm2. The addition of 12% glass fiber was the most effective for increasing the transversal strength.[14] Nirwana (2005) stated that there was an increasing in transverse strength significantly after the addition of glass fiber in hybrid acrylic resins. The glass fiber's SiO2 content is what gives glass fiber its strength and ability to absorb the RAPP denture base material's loads, both those that come from chewing and from inside the mouth and those that come suddenly when the denture base falls.[15]

Goguta et al. (2006) reported that there was an increase in the impact strength of heat-polymerized acrylic resin with the addition of rod and woven glass fibers.[15] The addition of glass fiber to the heat polymerized acrylic resin denture base for impact strength can be said to be not optimal if it is added by 6% at 9,865 kJ/m2 or more because the results obtained show a lack of strength compared to without the presence of glass fiber and compared to the addition of glass fiber 3 %.12 Impact strength continues to decrease at 9% by 9,068 kJ/m2 and at 12% by 9,472 kJ/m2. This happens because glass fiber has stiff properties so that as glass fiber is added to the acrylic resin material, it will weaken the impact strength if added too much. The value of this test result may vary due to several factors that cannot be controlled during this research, one of which is the distribution of fibers that spread out through the mold resulting in reduced fiber concentration.[15,16]

The role of glass fiber in this research is as a filler. The reaction of glass fiber with hot polymerization acrylic resin, namely the silicon dioxide content, causes the glass fiber to become denser and stronger.[15,17]

The addition of glass fiber in a concentration of 6% showed the highest increase in hardness (Table 8), then decreased at 9% and 12%. Therefore, both the impacts of the included fibers and the decreased amount of resin matrix may be to blame for the bulk reinforced acrylic resin's decreased surface hardness.[18] Figure 1 shows agglomeration of glass fibers in acrylic on sampel with 12% glass fiber. On the other hand, the interparticle distance decreases with increasing filler loading, allowing for more agglomeration. When the reinforcing agent's content reached the ideal amount, agglomeration occurs. Stress is created at clumped particles, reducing the material's mechanical qualities.[19]

CONSLUSION

Incorporating 12% glass fiber enhances transverse strength; however, it negatively affects impact strength. Meanwhile, a 6% glass fiber addition increases the hardness of the material.

REFERENCES

1. Chairunnisa R, Julia Sihombing R. The Association between Number of Tooth Loss, Tooth Loss Quadrants, and Occlusal Support with Temporomandibular Disorders in Partially Edentulous Patients. 2018;8(Idcsu 2017):255–8.
2. Campbell SD, Cooper L, Craddock H, Hyde TP, Nattress B, Pavitt SH, et al. Removable partial dentures: The clinical need for innovation. Journal of Prosthetic Dentistry [Internet]. 2017;118(3):273–80.
3. Silalahi SKY, Nasution I. Association between the number of bilateral free-end posterior tooth loss and mastication performance in RSGM USU patients. Journal of Syiah Kuala Dentistry Society. 2023;7(2):118–24.
4. Al-Dwairi ZN, Tahboub KY, Baba NZ, Goodacre CJ, Özcan M. A Comparison of the Surface Properties of CAD/CAM and Conventional Polymethylmethacrylate (PMMA). Journal of Prosthodontics. 2019;28(4):452–7.
5. Gad MM, Rahoma A, Al-Thobity AM. Effect of polymerization technique and glass fiber addition on the surface roughness and hardness of PMMA denture base material. Dent Mater J. 2018;37(5):746–53.
6. Gad MM, Al-Thobity AM, Rahoma A, Abualsaud R, Al-Harbi FA, Akhtar S. Reinforcement of PMMA denture base material with a mixture of ZrO 2 nanoparticles and glass fibers. Int J Dent. 2019;2019.

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Available at http://journal-denta.hangtuah.ac.id/index.php/jurnal/issue/view/27
DOI: https://doi.org/10.30649/denta.v19i2.4

7. Pawar E. A Review Article on Acrylic PMMA. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN [Internet]. 2016;13(2):1–04. Available from: www.iosrjournals.org
8. Mathew M, Shenoy K. Flexural Strength of E-glass-reinforced PMMA. 2014; 3(1):24–8.
9. Tomar Student P, Chauhan Assistant Professor S, Tomar P, Gope P, Chauhan S. Influence of fiber Reinforcement on properties of PMMA. ~ 23 ~ International Journal of Mechanical and Thermal Engineering [Internet]. 2023;4(1):23–7.
10. Rana MH, Shaik S, Hameed MS, Al-Saleh S, Alhamdan EM, Alshahrani A, et al. Influence of dental glass fibers and orthopedic mesh on the failure loads of polymethyl methacrylate denture base resin. Polymers (Basel). 2021;13(16):1–11.
11. Ayaz EA, Bağış B, Turgut S. Effects of thermal cycling on surface roughness, hardness and flexural strength of polymethylmethacrylate and polyamide denture base resins. J Appl Biomater Funct Mater. 2015;13(3):e280–6.
12. Alexandru-Titus F, Iulian A, Aurora A, Cətəlina F. SEM evaluation of denture base materials used in clinical practice. Key Eng Mater. 2016;695:91–5.
13. Fransisca W, Nasution ID. Pengaruh Penambahan Serat Kaca Dan Serat Poliester Terhadap Kekuatan Impak Bahan Basis Gigitiruan Resin Akrilik Polimerisasi Panas. B-Dent: Jurnal Kedokteran Gigi Universitas Baiturrahmah. 2018;2(1):16–22.
14. Schauperl Z, Ivanković L, Bauer L, Šolić S, Ivanković M. Effects of Different Surface Treatments of Woven Glass Fibers on Mechanical Properties of an Acrylic Denture Base Material. Int J Mol Sci. 2023;24(2).
15. Yuliharsini S, Nasution ID, Agusnar H, Ritonga PWU. Effect of E-Glass Fiber Addition on Mechanical Properties of Heat-Polymerized Acrylic Resin Denture Base. J Evol Med Dent Sci. 2019;8(12):872–8.
16. Felycia, Tarigan S. Pengaruh pelapisan kitosan pada basis gigi tiruan resin akrilik polimerisasi panas terhadap penyerapan air dan kekuatan transversal. Padjadjaran Journal of Dental Researchers and Students. 2021;5(1):57–63.
17. Karci M, Demir N, Yazman S. Evaluation of Flexural Strength of Different Denture Base Materials Reinforced with Different Nanoparticles. Journal of Prosthodontics. 2019;28(5):572–9.
18. Chen SY, Liang WM, Yen PS. Reinforcement of Acrylic Denture Base Resin by Incorporation of Various Fibers. 2001; 58(2): 203-208.
19. Aldegheishem A, AlDeeb M, Al-Ahdal K, Helmi M, Alsagob EI. Influence of Reinforcing Agents on the Mechanical Properties of Denture Base Resin: A Systematic Review. Polymers (Basel). 2021 Sep 13;13(18):3083.

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