

**To Evaluate and Compare The Flexural Strengths of Heat Polymerised PMMA Reinforced With 6 Wt% NaoH Treated Bamboo Fibres, Heat Polymerised PMMA Reinforced With A Layer of Silane Coupling Agent Coated Glass Fibre Mesh And Heat Polymerised PMMA.**

<sup>1</sup>Dr. Anshul Singh, Postgraduate, Department of Prosthodontics and Crown and Bridge, Vokkalighara Sangha Dental College and Hospital, Bengaluru. India

<sup>2</sup>Dr. Surendra Kumar G P, Professor, Department of Prosthodontics and Crown and Bridge, Vokkalighara Sangha Dental College and Hospital, Bengaluru. India

<sup>3</sup>Dr. Vandana R, Lecturer, Department of Prosthodontics and Crown and Bridge, Vokkalighara Sangha Dental College and Hospital, Bengaluru. India

<sup>4</sup>Dr. Divya Rani P, Lecturer, Department of Prosthodontics and Crown and Bridge, Vokkalighara Sangha Dental College and Hospital, Bengaluru. India

**Corresponding Author:** Dr. Anshul Singh, Postgraduate, Department of Prosthodontics and Crown and Bridge, Vokkalighara Sangha Dental College and Hospital, Bengaluru. India.

**Citation of this Article:** Dr. Anshul Singh, Dr. Surendra Kumar G P, Dr. Vandana R, Dr. Divya Rani P, “To Evaluate and Compare The Flexural Strengths of Heat Polymerised PMMA Reinforced With 6 Wt% NaoH Treated Bamboo Fibres, Heat Polymerised PMMA Reinforced With A Layer of Silane Coupling Agent Coated Glass Fibre Mesh And Heat Polymerised PMMA”, IJDSIR- December - 2023, Volume – 6, Issue - 6, P. No. 91 – 98.

**Copyright:** © 2023, Dr. Anshul Singh, et al. This is an open access journal and article distributed under the terms of the creative common’s attribution non-commercial License. Which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given, and the new creations are licensed under the identical terms.

**Type of Publication:** Original Research Article

**Conflicts of Interest:** Nil

**Abstract**

**Background:** Denture base reinforcement has been attempted by adding different kinds of fibres in fracture-prone locations. Reinforcement of PMMA is done with different fibres, including carbon, polyethene, polyaramide fibres, glass mesh fibres, nylon fibres and bamboo fibres. The need for strengthening by fibre reinforcement is that the polymer matrix has the entire capacity to transfer an applied load to the fibres through shear stresses at the interface.

**Aim:** To evaluate and compare the flexural strengths of heat polymerised PMMA reinforced with 6wt% NaOH treated bamboo fibres , heat polymerised PMMA reinforced with a layer of silane coupling agent coated glass fibre mesh and heat polymerised PMMA.

**Materials And Methodology:** Forty-five specimens were divided into three groups as follows:-  
Group 1 (n=15):- Heat polymerised PMMA reinforced with 6 wt% NaOH treated bamboo fibres.

Group 2 (n=15):- Heat polymerised PMMA reinforced with a layer of silane coupling agent coated glass fibre mesh.

Group 3 (n=15):- Heat polymerised PMMA.

Specimens were then subjected to a flexural test by universal testing machine.

**Result:** Flexural strength was increased when both silane coupling agent coated glass fibre mesh and 6 wt% NaOH treated bamboo fibres were added to heat polymerised PMMA resins.

**Conclusion:** The results infer that heat polymerised PMMA reinforced with a layer of silane coupling agent coated glass fibre mesh showed significantly higher mean flexural strength followed by heat polymerised PMMA reinforced with 6 wt% NaOH treated bamboo fibres and least with heat polymerised PMMA at  $P < 0.001$ .

**Keywords:** PMMA, Flexural Strength, Silane coupling agent, glass fibre mesh,

### Introduction

Poly(methyl methacrylate), or PMMA, is a versatile and widely used polymer known for its transparency, impact resistance, and excellent optical properties. In various applications, PMMA can be reinforced to enhance its mechanical properties, making it suitable for a broader range of uses. Reinforcement refers to the incorporation of additional materials into a polymer matrix to improve its strength, stiffness, and other mechanical characteristics.<sup>1</sup>

PMMA reinforcement typically involves the addition of various reinforcing agents, such as fibres or nanoparticles, to the polymer matrix. These reinforcements contribute to the overall mechanical performance of the material, making it more robust and durable. The choice of reinforcement depends on the specific properties desired for the end product.<sup>1</sup>

Fibre reinforcement is a common method used to enhance the mechanical properties of PMMA. Fibres, such as glass fibres or carbon fibres, are embedded in the polymer matrix to provide increased strength, stiffness, and impact resistance<sup>1</sup>

Bamboo fibres have a distinct structural anatomy that offers great rigidity and low weight among natural fibres. Bamboo can be utilized for reinforcement in a variety of ways, including pieces, strips, threads, and complete bamboo. Various thermoplastic and thermoset polymers have been utilized with bamboo fibres as reinforcement.<sup>2</sup>

The silane-treated glass fibres significantly strengthened PMMA when compared to the samples with untreated fibres. Compared to carbon, graphite, or other metal fibres, glass fibres are more aesthetically pleasing and can be utilized in visible locations.<sup>3</sup>

Therefore the purpose of this study was to evaluate and compare the flexural strengths of heat polymerised PMMA reinforced with 6wt% NaOH treated bamboo fibres, heat polymerised PMMA reinforced with a layer of silane coupling agent coated glass fibre mesh and heat polymerised PMMA.

### Materials And Methodology

The sample size was established using the G Power software version 3.0.1(Franz Faul Universitat, Kiel, Germany). Considering the effect size to be measured(f) at 60%, power of the study at 80% and the margin of error at 5%, the total sample size needed was 45. Three groups of 15 samples each (15 samples× 3 groups = 45 samples). Forty-five wax samples of dimensions 65mm×10mm×3mm were prepared (FIGURE 1). These wax samples were invested in a flask using two pour technique, the first pour being of Plaster of Paris (Gypsum type II) and the second pour of dental stone. Once the second pour was set, the flasks were immersed

in thermally controlled hot water bath for dewaxing. Following dewaxing separating media was applied in the mold space and the flasks were left to reach room temperature (FIGURE 2).



Figure 1: Wax Patterns of Dimensions 65\*10\*3mm were fabricated

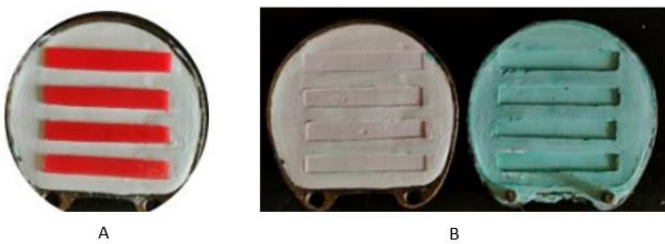


Figure 2: (A) Wax Patterns were flasks and (B) mold space after dewaxing.

**Group 1 (n=15):** Heat polymerised PMMA reinforced with 6 wt% NaOH treated bamboo fibres.

#### Incorporation of Bamboo Fibres In PMMA Samples

The fibres were weighed and added to the reinforced samples in the ratio of 5% w/w of the unreinforced sample. The cut bamboo fibres were soaked in 6% NaOH solution for 12 hours and dried under sun for 2 weeks. The dry fibres were cut and soaked in monomer for 10 minutes in a glass beaker and then polymer of the heat polymerised PMMA material was mixed and filled in the mold. Then the samples were acrylized using compression molding technique (FIGURE 3 & 4).



Figure 3: Bamboo fibres soaked in 6% NaOH for 12 hours and dried under sun for 2 weeks

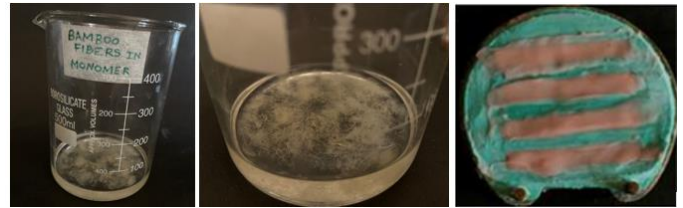


Figure 4: The dry fibres were cut and soaked in monomer for 10 minutes in a glass beaker for improved adhesion of bamboo fibres with PMMA resin matrix.

**Group 2 (n=15):** Heat polymerised PMMA reinforced with a layer of silane coupling agent coated glass fibre mesh.

#### Incorporation Of Silane Coupling Agent Coated Glass Fibre Mesh In Heat Polymerised PMMA Samples

The monomer and polymer of the heat polymerised PMMA material was mixed and filled in the mold until it is half full. A single layer of glass mesh fibres was treated with silane coupling agent for 5 minutes and allowed to air dry completely and then was placed in the mold and then remainder of the mold was filled. Then the samples were acrylized using compression molding technique (FIGURE 5).

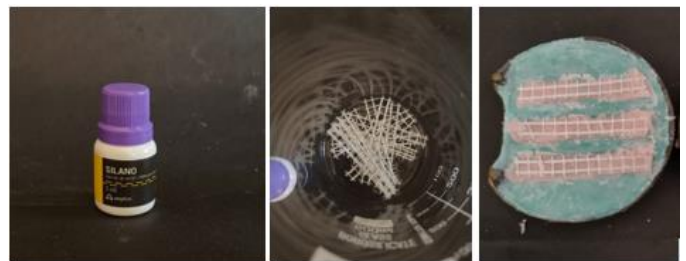


Figure 5 : Incorporation of silane coupling agent coated glass fibre mesh in PMMA resin matrix

**Group 3 (n=15):** The control group received a full mix of unmodified polymethylmethacrylate resin. Then the samples was acrylized using compression molding technique (FIGURE 6 & 7).



Figure 6: Heat cure PMMA samples of dimensions 65\*10\*3mm were obtained after acrylization.



Figure 7: Heat cure PMMA samples were obtained after acrylization.

All PMMA samples were placed in artificial saliva for 2 weeks before testing (FIGURE 8).



Figure 8: All specimens were placed in artificial saliva for 2 weeks before testing of samples

A three-point flexural test [International Organization for Standardization (ISO)] was used to test the flexural strength of freshly retrieved samples from the distilled water by using a universal testing machine (Mecmesin Multi Test 10-i) (FIGURE 9). The maximum load at fracture was recorded and flexural strength of each sample was calculated using the formula:  $FS(Mpa) = 3 WL / 2 bd^2$  where FS is flexural strength(MPa), W is maximum load at fracture(N), L is distance between supports (50mm) and b and d are specimen width (10mm) and thickness (3 mm) respectively.



Figure 9: Three-point flexural test using universal testing machine.

### Results

SPSS (Statistical Package For Social Sciences) version 20. (IBM SPASS statistics [IBM corp.released 2011]) was used to perform the statistical analysis. The values obtained were subjected to ANOVA test to compare the flexural strength among the groups with post hoc Bonferroni test for inter group comparison and the level of significance is set at 5% (TABLE 1& 2). Flexural strength of Group 2 was higher-  $189.15 \pm 3.67$  as compared to Group 1-  $114.93 \pm 3.43$  and Group 3-  $66.62 \pm 4.02$ . ANOVA test was applied to compare the flexural strength among the groups. ANOVA showed statistically significant difference among the groups ( $p=0.001$ ) (GRAPH).

Table 1: Comparison of The Mean Flexural Strength Among The Groups Using Anova

Groups	N	Minimum	Maximum	Mean	S.D	p value
PMMA with bamboo fibres	15	109.00	120.20	114.93	3.43	0.001*
PMMA with fibre glass mesh	15	183.10	195.60	189.15	3.67	
PMMA	15	61.30	74.66	66.62	4.02	

\*Significant

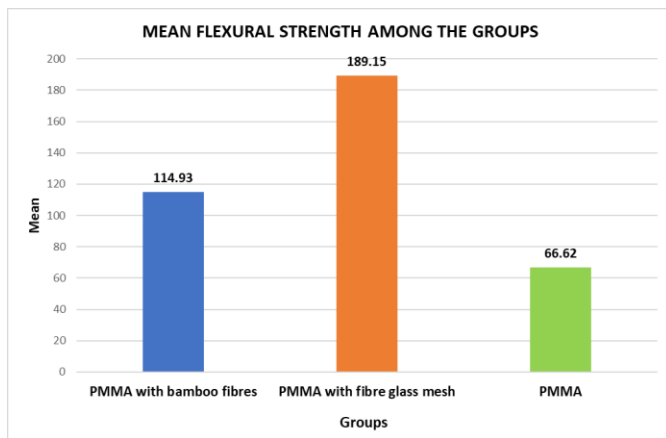


Table 2: Inter Group Comparison of The Flexural Strength Using Post-Hoc Bonferroni

	Mean Difference	p value
(PMMA with bamboo fibres) Vs (PMMA with fibre glass mesh)	-74.216	.001*
(PMMA with bamboo fibres) Vs (PMMA)	48.310	.001*
(PMMA with fibre glass mesh) Vs (PMMA)	122.526	.001*

\*significant

**Discussion**

Poly methyl methacrylate (PMMA) is the most commonly used material for fabrication of dentures. Dentures fracture mostly inside mouth during its function. The various stresses that the denture experiences are shear, tensile and compressive stresses.<sup>6</sup>

Bamboo fibres have garnered significant interest as reinforcement materials due to their reduced weight, rapid growth, renewable nature, and mechanical qualities that are comparable to those of glass fibres. Bamboo is available in a variety of forms that can be utilized as reinforcement, including sections, strips, fibres and whole bamboo. Bamboo fibres have been used to reinforce a variety of thermoset and thermoplastic polymers.<sup>2</sup> The bamboo fibres on treatment with 6 wt% NaOH for 12 hours, the surface becomes rough and surface area increases for better adhesion of polymer and fibres.<sup>2</sup>

Untreated glass fibres cause the acrylic resin to become weaker by acting as inclusion bodies in the resin. The homogeneous matrix could be broken up by the fibres. Glass fibres are chemically bonded to the resin matrix by silane coupling agents, which also have the potential to increase mixture homogeneity and produce stronger PMMA.<sup>3</sup>

Results of a study to evaluate and compare the flexural strength (FS) of heat polymerised polymethyl methacrylate (PMMA) denture base resins after reinforcement with nylon fibres and different concentration of glass fibres (GFs) showed that the fibres significantly affected the FS of PMMA. FS increased to the maximum with 5% GFs as compared to 2% glass, 2% nylon and 10% GFs. It was concluded that polymers used in denture base fabrication, reinforced with GFs have shown to have a positive effect on the fracture resistance of dentures as compared to unreinforced PMMA.<sup>1</sup>

A study was conducted to evaluate reinforcing effect of bamboo fibers and the samples comprised of unreinforced PMMA, PMMA resin reinforced with bamboo fibres, unreinforced BAC ( Bis acryl composite) and BAC resin reinforced with bamboo

fibres. The bamboo fibres were pretreated for 12 hours with a 6% sodium hydroxide solution and dried for two-weeks. Using layering technique, the dry fibres were added to the reinforced samples. The specimens were tested for flexural strength on a universal testing machine. According to the results, it was concluded from this study that bamboo fibres have a reinforcing effect on autopolymerizing PMMA and bis-acrylic composite resins and it significantly increased their flexural strength.

Three-dimensional strength of PMMA after addition of various glass fibres, was studied under two groups-untreated fibres and fibres treated with silane. Group I (control) consisted of five PMMA samples with no fibres added. Group II contained 15 samples: Five PMMA samples had type A fibres added to the mixture, five samples had type B fibres, and five samples had type C fibres. All fibres in group II were cut to various lengths and mixed into the monomer before polymer was added. Fibres were completely dry before they were applied. Group III also contained 15 samples. All samples in this group contained fibres that were treated with silane before they were incorporated into the PMMA mixture. Fibres were soaked in a silane coupling agent for 5 minutes and allowed to air dry completely before they were used. The silane coupling agent was mixed 30 minutes before use to allow activation of the molecules. Five samples had type A fibres, five samples had type B fibres, and five samples had type C fibres. All samples were tested for transverse strength with the Instron testing machine. The results showed that samples with untreated fibres tested weaker than samples without fibres. Samples with silane-treated fibres were stronger compared to samples containing untreated fibres.<sup>3</sup>

The impact of electrospun nylon nanofibres and a methacrylic preimpregnated resin glass fibre mesh on the

flexural strength of a heat-cured PMMA denture base resin was investigated. There were two reinforced groups using glass fibre mesh and electrospun nylon nanofibres, and a non-reinforced PMMA control group. A universal testing machine's 3-point bend test was used to determine the flexural strength. As compared to the non-reinforced PMMA control, the mean flexural strength of PMMA glass fibre mesh reinforced group was statistically higher. Thus, it was determined that adding glass fibre mesh to PMMA denture base resin increased its flexural strength, whereas electrospun nylon nanofibres had no such effect.<sup>4</sup>

To ascertain whether adding siwak fibres and bamboo fibres, which were cut into 2, 6, and 12 mm lengths and applied at three different concentrations of (3, 6, and 9 wt%), improved the tensile capabilities of self-cure acrylic resin, a study was conducted. The resin and fibre combination was cured for 30 minutes in a water bath at 2.5 bar and 55°C. Tensile properties of the cured resin specimen were examined in accordance with ASTM No. 638 specifications. The results showed that fibre length and concentration tend to improve tensile strength and young modulus. The highest values of tensile strength and young modulus were found in specimens reinforced with bamboo fibres (72.4 MPa and 5.208 GPa), while the highest values found in specimens reinforced with siwak fibres are 71 MPa and 4.9 GPa at optimum condition of weight fraction (9%) and fibre length (12 mm) which was significantly higher than other formulations.<sup>5</sup>

The present study was taken up to evaluate and compare the flexural strengths of heat polymerised PMMA reinforced with 6wt% NaOH treated bamboo fibres, heat polymerised PMMA reinforced with a layer of silane coupling agent coated glass fibre mesh and heat polymerised PMMA. 45 samples of dimensions

65mm×10mm×3mm were prepared from PMMA using compression molding technique. 15 samples were prepared by incorporation of 6wt% NaOH treated bamboo fibres in PMMA using compression molding technique. 15 samples were prepared by incorporation of silane coupling agent coated glass fibre mesh in PMMA using compression molding technique. The remaining 15 samples were unreinforced PMMA fabricated by compression molding technique.

All PMMA samples were placed in artificial saliva for 2 weeks before testing. All samples were put under a three point flexural test. The maximum load at fracture was recorded and flexural strength of each sample was calculated using the formula:  $FS(Mpa) = 3 WL / 2 bd^2$  where FS is flexural strength(MPa), W is maximum load at fracture(N), L is distance between supports (50mm) and b and d are specimen width (10mm) and thickness (3 mm) respectively.

The results of this study showed that Heat polymerised PMMA reinforced with a layer of silane coupling agent coated glass fibre mesh had highest mean flexural strength followed by heat polymerised PMMA reinforced with 6 wt% NaOH treated bamboo fibres and least with heat polymerised PMMA. All the results obtained were statistically significant.

The in-vitro design of this study, which lacked full oral simulation, is one of its main limitations. To ascertain the impact on other mechanical qualities including microhardness and fracture toughness, more investigation is needed. Researches can also be conducted to assess the impact of varying fibre concentrations and orientations on the mechanical characteristics.

### Conclusion

Within the limitations of the study, it was concluded that:-

Heat polymerised PMMA reinforced with a layer of silane coupling agent coated glass fibre mesh showed significantly higher mean flexural strength followed by heat polymerised PMMA reinforced with 6 wt% NaOH treated bamboo fibres and least with heat polymerised PMMA at  $P < 0.001$ .

### References

1. Singh K, Sharma S, Negi P, Kumar M, Rajpurohit D, Khobre P. Comparative evaluation of flexural strength of heat polymerised denture base resins after reinforcement with glass fibres and nylon fibres: An in vitro study. *Advances in Human Biology*. 2016 May 1;6(2):91-.
2. Natarajan K, Srinivasan S, Krishnan M, Balasubramanian M. Evaluation of Flexural Strength of Autopolymerizing Polymethyl Methacrylate and Bis-acrylic Composite Provisional Restorative Resins Reinforced with Bamboo Fibres: An In Vitro Study. *Evaluation*. 2021;11(3).
3. Solnit GS. The effect of methyl methacrylate reinforcement with silane-treated and untreated glass fibres. *The Journal of prosthetic dentistry*. 1991 Sep 1;66(3):310-4.
4. Aarts JM, Jansen Van Vuuren WA, Withy K, Choi JE, Waddell NJ. A pilot study on the influence of two reinforcing materials (glass fibre mesh and electro-spun nylon nano fibres) on the flexural strength of a heat-cured poly (methyl methacrylate) denture base resin. *New Zealand Dental Journal*. 2017 Sep 1;113(3).
5. Oleiwi JK, Salih SI, Fadhil HS. Effect of siwak and bamboo fibres on tensile properties of self-cure acrylic resin used for denture applications. *J Material Sci Eng*. 2017;6(370):2169-0022.
6. Aarthy S. Evaluation of the Flexural Strength of Heat Polymerized Poly (Methyl Methacrylate)

- Denture Resin Reinforced With Fibres: An In Vitro Study (Doctoral dissertation, Madha Dental College and Hospital, Chennai).
7. Tacir IH, Kama JD, Zortuk M, Eskimez S. Flexural properties of glass fibre reinforced acrylic resin polymers. *Australian dental journal*. 2006 Mar;51(1):52-6.
  8. Nagai E, Otani K, Satoh Y, Suzuki S. Repair of denture base resin using woven metal and glass fiber: effect of methylene chloride pretreatment. *The Journal of prosthetic dentistry*. 2001 May 1;85(5):496-500.
  9. Vallittu PK. Comparison of two different silane compounds used for improving adhesion between fibres and acrylic denture base material. *Journal of Oral Rehabilitation*. 1993 Sep;20(5):533-9.
  10. Zhang K, Sun Y, Wang F, Liang W, Wang Z. Progressive failure and energy absorption of chopped bamboo fiber reinforced polybenzoxazine composite under impact loadings. *Polymers*. 2020 Aug 12;12(8):1809.
  11. Raghavendara Rao H, Hari Sankar P, Murali Mohan M. Chemical resistance and impact properties of bamboo/glass FIBRES reinforced polyster hybrid composites. *Int J Engineer Res*. 2014;3(2):79-81.
  12. Chung, Lin, Wang. Flexural strength of a provisional resin material with fibre addition. *Journal of oral rehabilitation*. 1998 Mar;25(3):214-7.
  13. Stafford GD, Handley RW. Transverse bend testing of denture base polymers. *Journal of Dentistry*. 1975 Nov 1;3(6):251-5.
  14. Kanie T, Arikawa H, Fujii K, Ban S. Deformation and flexural properties of denture base polymer reinforced with glass fiber sheet. *Dental materials journal*. 2005;24(3):297-303.
  15. Kemp PL, de Wet FA, Botha SJ, Levin J. Flexural properties of denture-base polymer reinforced with glass-fibre polysulphone composite. *SADJ: journal of the South African Dental Association= tydskrif van die Suid-Afrikaanse Tandheelkundige Vereniging*. 2004 Jun 1;59(5):190-2.
  16. Vallittu PK. A review of fiber-reinforced denture base resins. *Journal of Prosthodontics*. 1996 Dec;5(4):270-6.
  17. Stipho HD. Repair of acrylic resin denture base reinforced with glass fiber. *The Journal of Prosthetic Dentistry*. 1998 Nov 1;80(5):546-50.