ORIGINAL ARTICLE

The influence of bamboo fiber (gigantochloa apus) positioning on the flexural strength of heat-cured acrylic resin: an experimental research

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Received: 10 September 2025
Revised: 20 October 2025
Accepted: 22 November 2025
Published: 30 November 2025
DOI: 10.24198/pjd.vol37no3.62953

p-ISSN 1979-0201
e-ISSN 2549-6212

Citation:
Nawawi AP. Endro, H. Hamumpuni, T. The influence of bamboo fiber (gigantochloa apus) positioning on the flexural strength of heat-cured acrylic resin: an experimental research. Padjadjaran J. Dent, November. 2025; 37(3): 277-283.

ABSTRACT

Introduction: Acrylic resin is prone to fracture. Apus bamboo fiber (Gigantochloa apus), a natural fiber, is anticipated to enhance the flexural strength of acrylic resin. The fiber's position within the acrylic resin matrix is hypothesized to influence its effectiveness in improving flexural strength. The objective of this study was to investigate the impact of incorporating apus bamboo fibers, based on their position, on the flexural strength of heat-cured acrylic resin plates. **Methods**: This study employed a laboratory experimental design with a post-test only control group. Twelve rectangular heat-cured acrylic resin plates, measuring 65 mm × 10 mm × 2.5 mm, were prepared in accordance with ISO 178:2019 and were thoroughly polished. The samples were divided into four groups, including three groups with the addition of apus bamboo fiber at a concentration of 1.6%, positioned at the upper, middle, and lower sections and one negative control group consisting of heat-cured acrylic resin plate without the addition of apus bamboo fiber. The samples underwent a three-point bending test using a Universal Testing Machine (UTM). Data analysis was conducted using a one-way ANOVA and an independent t-test. **Results**: The average flexural strength was 89.34 MPa in the negative control group, 69.35 MPa in the upper fiber group, 82.54 MPa in the middle fiber group, and 106.98 MPa in the lower fiber group. Statistical analysis indicated that the position of apus bamboo fibers significantly affected flexural strength ($p<0.05$). **Conclusion**: It can be concluded that the position of apus bamboo fibers influences the flexural strength of heat-cured acrylic resin. Apus bamboo fibers placed in the lower position, corresponding to the anatomical base of the denture, exhibited the highest flexural strength among all groups.

KEYWORDS

Flexural strength, heat-cured acrylic resin, apus bamboo fiber, fiber position

INTRODUCTION

Tooth loss is one of the problems that affect the oral cavity, impacting mastication, phonetics, aesthetics, and temporomandibular joint (TMJ) function.[1] According to the 2018 Basic Health Research (RISKESDAS) report, the highest prevalence of tooth loss occur at the age of 45 years and over (14.5%), while the most denture users are in the 55-64 years age range (3.8%).[2] Dentures consist of fixed and removable types, the latter further divided into removable partial dentures and complete dentures.[3,4] The use of removable dentures is more common than fixed dentures, accounting for approximately 5.2%.[2]

The main components of a denture include connectors, direct retainers, indirect retainers, artificial teeth, and bases. The majority of denture bases are made of acrylic resin, which is divided into three types: self-cured, heat-cured, and light-cured.[5,6] The heat-cured acrylic resin, introduced in 1937, remains the material of choice for denture bases due to its aesthetic properties, ease of fabrication, and affordability.[7,8] However, this material has relatively low flexural strength, which can lead to cracks or fractures under masticatory loads.[9,10] Flexural strength is an important parameter used to determine the resistance of materials to mechanical stress before fracture occurs, with a minimum standard of 60-65 Mpa.[7]

Enhancing the durability of denture bases can be achieved through the incorporation of reinforcing materials, such as fibers. Natural fibers present a promising alternative due to their availability, biocompatibility, and cost-effectiveness compared to synthetic fibers. Examples of natural fibers used for denture base reinforcement include coconut husk, jute, banana, and pineapple fibers. The enhancement of mechanical properties through fiber reinforcement is contingent upon factors such as fiber type, concentration, bonding, and positioning.[11–13]

Bamboo, as a natural fiber, has advantages in terms of rapid reproduction, environmental friendliness, and its ability to reduce soil erosion and water pollution.[14,15] This plant is commonly used in construction, crafts, and textiles, and is widely found in Indonesia, including the Cimahi region.[16,17] Bamboo fiber exhibits antibacterial properties, possesses high lignin and cellulose content, and demonstrates excellent mechanical strength, thereby presenting itself as a viable alternative reinforcement material.[18,19] Bamboo fibers, characterized by their strength, durability, and smoothness, have the potential to enhance the resistance of heat-cured acrylic resins to masticatory forces.[16]

To date, no study has examined the effect of apus bamboo fiber positioning on the flexural strength of heat-cured acrylic resin denture bases. This study aims to evaluate the impact of apus bamboo fiber placement on the flexural strength of these resin plates. The research seeks to improve the durability of denture bases by utilizing materials that are both cost-effective and easily accessible, while also promoting the use of apus bamboo fiber as a reinforcing agent.

METHODS

This study was a laboratory-based experimental study employing a post-test only with control group design. Twelve samples of Rectangular heat-cured acrylic resin plates, measuring 65 mm × 10 mm × 2.5 mm, have been prepared in accordance with ISO 178:2019 and thoroughly polished. The samples were divided into four groups, consisting of three experimental groups with the addition of apus bamboo fiber at a concentration of 1.6%, positioned at the upper, middle, and lower sections, and one negative control group of heat-cured acrylic resin plates without fiber addition. The research procedure included processing of apus bamboo fiber, preparation of the alkalization solution, the alkalization process itself, and incorporation of the fibers into the acrylic resin to create test plates according to ISO 178:2019 standards (65 x 10, 2.5 mm), which were subsequently tested for flexural strength.[20]

The alkalization process began by cleaning the fibers for 30 minutes using ethanol in an ultrasonic cleaner, followed by drying in an oven at 80°C for 10 minutes. The fibers were then boiled in a 5% NaOH solution for 1 hour at 100°C in a glass baker. After cooling to room temperature, the fibers were washed again in an ultrasonic cleaner for 10 minutes. The next step was neutralization, achieved by boiling the fibers in a 6% CH3COOH solution at 100°C for 1 hour. After cooling, the fibers were again oven-dried at 80°C for 10 minutes. The weight of each acrylic resin plate sample without the addition of apus bamboo fiber was 1.5

grams. Therefore, for a 1.6% bamboo fiber concentration, 0.024 grams of fiber were added per sample for flexural strength testing.

The mold cavity was created using an iron master model measuring 65 x 10 x 2.5 mm. Group 1 (fiber above the plate), the parent model was placed on the cuvette with two thirds in the lower cuvette and one third in the upper cuvette. Group 2 (fiber in the middle), the parent model was placed on the cuvette with half part in the lower cuvette and half part in the upper cuvette. Group 3 (fibers under the plate), the parent model is placed on the cuvette with one third in the lower cuvette and two thirds in the upper cuvette. After the casting material hardened, the cuvette was opened, and the surface of the cast was sealed with Cold Mold Seal (CMS).

Acrylic polymer and monomer were mixed in a jar until the dough stage was reached, then placed in the mold cavity. Bamboo fibers were positioned accordingly: in the upper one-third (Group I), middle (Group II), or lower one-third (Group III) of the mold (Figure 1). The mold was covered with plastic sheeting, the cuvette was closed and then pressed using a hand press. The cuvette is opened again, the excess is cut and pressed again. The next process is curing, performed by boiling at 100°C for 30 minutes. After curing, samples were cooled to room temperature before testing.

Flexural strength testing was carried out using the three point bending test method using a Universal Testing Machine (UTM). The support span was 50 mm, with two reference lines drawn at both ends of the plate. The crosshead speed was set at 5 mm/minute, and a central line marked the loading point.

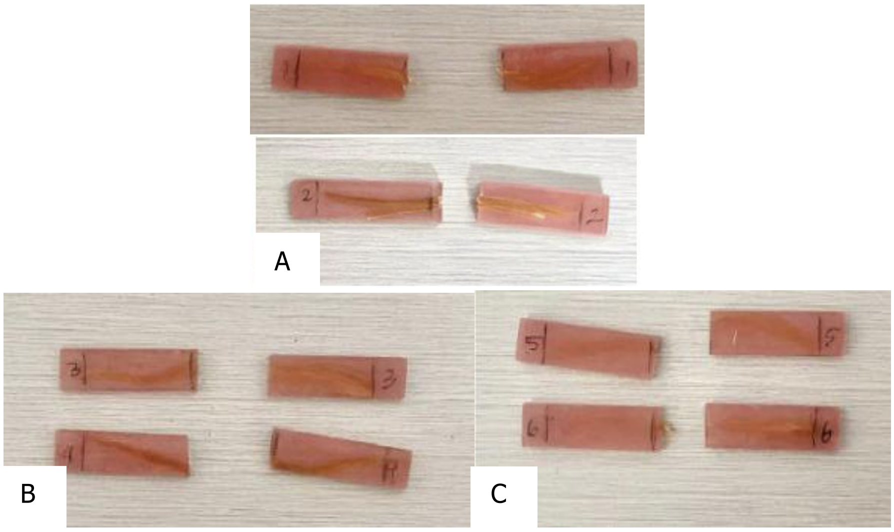

Figure 1. A. Sample Group I, B. Sample Group II., C. Sample Group III

The research data were analyzed using One Way ANOVA to detect differences in flexural strength values among the three groups. Subsequently, post hoc independent t-tests were conducted to determine the distinctions between the groups.

RESULTS

The results of research on the effect of 1.6% apus bamboo fiber position on flexural strength are summarized below.

Table 1. Mean flexural strength values of control and treatment groups

Groups	Mean (Mpa)	Standard Deviation
Control	89.34	4.94
Fiber above the plate (I)	69.35	-
Fiber in the middle (II)	82.54	11.84
Fiber under the plate (III)	106.98	6.04

Table 1 shows that groups III, in which apus bamboo fibers were positioned in the lower section (anatomical part) of the denture, exhibited the highest flexural strength among all groups. The lowest value was found in group I, where apus bamboo fibers were placed in the upper section (non-anatomical). Both group I and group II had lower mean values compared to the control group.

Table 2. Analysis of flexural strength results between groups

Flexural Strength	p-value
One way Anova	0,020

Table 3. Independent t-test Results

Group	Group	p-value
Control (-)	(I)	.073
	(II)	.411
	(III)	*0.17
(III)	(I)	.033
	(II)	.033
(I)	(II)	.437

Table 2 shows that the One Way ANOVA yielded a significance value of 0.020 ($p < 0.05$) indicating that the addition of apus bamboo fiber significantly affects the flexural strength of heat-cured acrylic resin. Pairwise comparisons were then performed using the independent t-test, and the results are presented in Table 3 to determine which groups differed significantly from one another.

DISCUSSION

This study shows that the treatment groups demonstrated higher flexural strength values than the control group, indicating that the addition of apus bamboo fiber contributes positively to the reinforcement of heat-cured acrylic resin. These findings are consistent with previous studies by Prawesti (2022), who incorporated ramie fiber, and Tarsis (2023), who used cellulose nanofibers derived from pineapple leaves. Both studies reported that fiber reinforced specimens exhibited greater flexural strength than non reinforced controls.[21,22]

Flexural strength is essential for resisting masticatory forces and preventing permanent deformation of acrylic resin.[9,23] The American Dental Association (ADA) specifies a minimum flexural strength value of 60-65 MPa for heat-cured acrylic resins (ISO 1567). All four groups in this study exceeded the ADA minimum (Tables 1 and 2), suggesting that fiber addition improves the flexural strength of heat-cured acrylic resin by enhancing stress distribution through the attachment of fibers and polymer matrix.

The alkalization process using NaOH reduces the hydrophilic nature of the fiber by reducing lignin and hemicellulose, thereby increasing the flexural strength of heat-cured acrylic resin.[19,24] Alkalization also enhances interfacial bonding through a mechanical interlocking mechanism.[22] Previous studies have shown that 5% NaOH treatment reduces water absorption and improves fiber-matrix bonds.[7,25]

Fiber orientation is another factor affecting flexural strength. According to the FRC (Fiber Reinforced Composite) Efficiency Theory, fibers arranged unidirectionally have maximum reinforcing efficiency (value of 1), whereas fibers positioned perpendicular to load have no reinforcing effect (value of 0), and in this study the apus bamboo fibers were arranged unidirectionally so they were able to withstand the applied forces more effectively..[7,26,27]

The position of the apus bamboo fibers is also one of the factors that can affect the mechanical properties of acrylic resin reinforced with fibers. According to Table 3, the highest strength was obtained in the apus bamboo fiber group placed at the bottom of the plate with an average flexural strength of 106.59 Mpa. This study is in line with research conducted by Demir, where the sample group with the addition of fibers at the bottom had the best flexural strength values.[28]

Loading the test sample causes the bottom to experience tensile stress, which results in elongation and a convex surface. If the tensile stress reaches its maximum limit, this area will be at risk of fracture initiation. Apus bamboo fibers placed at the bottom of the plate or anatomical part of the denture will increase the flexural strength more effectively because the load is distributed evenly into the apus bamboo fibers.[26,27]

The lowest flexural strength among the treatment groups was obtained for the apus bamboo fibers placed on top of the acrylic resin plate with an average of 69.35 Mpa. The top of the sample is the non-anatomical part of the denture. This research is consistent with the study conducted by Septomy, in which the sample group using fiber placed on top had the lowest flexural strength value.[29] This surface receives the maximum compressive load. The apus bamboo fibers located at the top will receive compression pressure instead of tensile which limits their influence on the flexural strength, because the lower part that experiences fracture initiation is directly borne by the acrylic resin as the apus bamboo fibers are located above the plate.[26,27]

Apus bamboo fibers placed in the middle showed an average of 82.54 Mpa, a value lower than the bottom group of fibers but higher than the top fibers. This study is in line with research conducted by Motaleb, where samples with added banana fiber in the middle position had an average value between the samples with fibers placed on the top and bottom of the sample.[30]… The center of the sample is often referred to as the neutral region where it is not subjected to tensile or compression stresses.[26,31]

This position does not maximize the flexural strength because the pressure is distributed at both ends of the plate.[31] The limitation of the study is focused on initial flexural strength without evaluating long-term durability, fatigue resistance, or aging effects (e.g., thermal cycling or water sorption over time), which are critical in real-world prosthodontic applications.

CONCLUSION

This study demonstrated that the position of apus bamboo fibers significantly influences the flexural strength of heat-cured acrylic resin plates. The implication of this study opens pathways for further investigations into the use of other types of natural fibers, alternative surface treatments, and long-term aging simulations to evaluate clinical durability, biocompatibility, and safety in practical prosthodontic applications.

Acknowledgement: The authors would like to thank all contributing laboratory staff, and colleagues at the Mechanical Engineering Laboratory of Universitas Padjadjaran, the Pharmaceutical Laboratory of Universitas Jenderal Ahmad Yani, and the Dental Materials Laboratory of Universitas Padjadjaran who have provided support, facilities, and guidance during the implementation of this research
Author Contributions: Conceptualization, APN & HE; methodology, TH; writing original draft preparation,APN and TH; writing review and editing, APN & HE. All authors have accepted responsibility for the entire content of this manuscript and consented to its submission to the journal, reviewed all the results and approved the final version of the manuscript..
Funding: This research received no funding
Institutional Review Board Statement: Not applicable for studies not involving humans or animals
Informed Consent Statement: This article does not contain any studies with human or animal subject that require permission from ethics committees or other institutions.

Data Availability Statement: The authors confirm that the data supporting the findings of this study are available within the article
Conflicts of Interest: The authors declare no conflict of interest

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