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THE DIFFERENCE IN DIAMETRAL TENSILE STRENGTH OF NANOHYBRID COMPOSITE RESIN WITH THE ADDITION OF *Donax canniformis* 10%, 15%, AND 20%

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ABSTRACT
***Background**: Diametral tensile strength is an important factor in determining the durability of composite resin materials. A reduction in diametral tensile strength increases the risk of fracture and cracking. The incorporation of natural fibers as fiber-reinforced composites (FRC) has been reported to improve the mechanical properties of composite resins. Bemban fiber (Donax canniformis), a plant native to South Kalimantan, contains cellulose and lignin that may enhance the strength of composite resin. **Objective**: To determine the differences in diametral tensile strength of nanohybrid composite resin reinforced with 10%, 15%, and 20% bemban fiber by volume weight. **Method**: This true experimental study employed a posttest-only design. Thirty-five samples were divided into five groups: composite resin without fiber reinforcement (negative control), composite resin reinforced with 10%, 15%, and 20% bemban fiber, and composite resin reinforced with polyethylene synthetic fiber (positive control) (n=7 per group). Diametral tensile strength was measured using a Universal Testing Machine. Data were analyzed using normality, homogeneity, One-Way ANOVA, and Bonferroni post hoc tests. **Results:** Differences in diametral tensile strength were observed among the groups. The highest mean value was found in the 15% bemban fiber group. A significant difference was identified between the 15% bemban fiber group and the group without bemban fiber reinforcement, while differences among the other groups were not statistically significant. **Conclusion:** There was a difference in the diametral tensile strength of nanohybrid composite resin with the addition of bemban fiber, with the optimal value observed in the 15% bemban fiber group.*

***Keywords:** Bemban fiber, Diametral tensile strength, Donax canniformis, fiber reinforced composite, nanohybrid composite resin.*
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INTRODUCTION

One of the most commonly used restorative materials is nanohybrid composite resin. The matrix of nanohybrid composite resin is hydrophilic, enabling it to absorb water. This property allows saliva and other oral fluids to be absorbed and retained at the interfaces among the constituents of composite resin, potentially triggering the degradation process of the material.[1] Consequently, the polymer network within the resin matrix becomes less stable and increasingly vulnerable to deterioration. Such degradation may negatively influence the material's mechanical characteristics, resulting in decreased mechanical performance.[1,2]

One of the important mechanical properties of composite resin is diametral tensile strength (DTS). Diametral tensile strength serves as an indirect method for assessing the tensile behavior of brittle materials.[3] The DTS test is performed by applying a compressive load along the diametral axis of a cylindrical specimen rather than a direct tensile force.[4] The DTS test is used to assess the ability of composite resin to withstand masticatory forces within the oral cavity. Composite resin with insufficient diametral tensile strength may be more susceptible to cracking or fracture during clinical service.[3]

Consideration of the mechanical characteristics of resin based composite materials is essential to decrease the possibility of structural failure. Due to certain limitations of this restorative material, numerous studies have explored the addition of synthetic and natural fibers to improve its mechanical behavior. Synthetic fibers, however, present several disadvantages, including poor environmental sustainability, resistance to natural degradation, and non-biodegradability by microorganisms, leading to their accumulation in the environment and potential ecological concerns.[5] In addition, synthetic fibers are often less accessible in developing countries because of their high production costs and market prices. Consequently, the development of natural fibers as an alternative to synthetic fibers remains an important area of research.[6]

One natural fiber with potential application as a reinforcing material is bemban fiber, which originates from South Kalimantan, Indonesia. Bemban (*Donax canniformis*) is a plant species commonly found in the wetlands of South Kalimantan.[7] Although bemban is abundantly available, its utilization remains limited and requires further development.[8] As a natural fiber, bemban offers several advantages, including environmental friendliness, biodegradability, low energy requirements during production, cost-effectiveness, and ease of recycling.[9] The bemban stem, which serves as the source of the fiber, contains water (2.36%), cellulose (22.52%), and lignin (1.33%).[10] Cellulose provides structural strength to the fiber itself and exhibits resistance to both chemical and mechanical degradation.[11] In addition, the cell walls of bemban contain lignin, which contributes to strength and resistance against external environmental factors.[10]

A study by Febriyanto (2019) demonstrated that the addition of natural fibers at 10% by volume weight increased the hardness of composite materials compared with composites without fiber reinforcement, while fiber additions of 15% and 20% resulted in higher hardness values than those reinforced with fiberglass. The study reported that the hardness of nettle fiber reinforced composites increased with increasing fiber weight fraction.[12] This result agrees with the notion that increasing the fiber volume fraction improves composite strength through a more even transfer of applied stress from the matrix to the reinforcing fibers. Incorporating fibers at specific weight fractions may contribute to improved tensile behavior of resin based restorative composites.[13] However, no previous study has compared the effects of different bemban fiber volume fractions on diametral tensile strength.

This study aimed to determine the differences in diametral tensile strength of nanohybrid composite resin following the incorporation of bemban (*Donax canniformis*) fiber at volume fractions of 10%, 15%, and 20%, considering the promising reinforcing potential of this natural fiber.[13,14]

MATERIALS AND METHODS

Materials

The materials involved in this research included a nanohybrid-type composite resin (3M™ Filtek™ Z250 XT Nano Hybrid Universal), Dental adhesive (3M™ Single Bond Universal Adhesive), Natural bemban fibers (Donax canniformis), Synthetic polyethylene fibers (Infibra®), Cylindrical specimen molds with a diameter of 6 mm and a thickness of 3 mm were prepared according to ADA Specification No. 27 (1993), Glass plate, Filling instrument, Dental tweezers, Fine tweezers, Celluloid strip, Microbrush, Scissors, Light-curing LED, Plastic containers, Universal Testing Machine Shimadzu-Japan Model AG-5kN, Sandpaper and Oven. This study received ethical approval under reference number 039/KEPKG-FKGULM/EC/II/2025.

Methods

This study employed a true experimental design with a posttest-only approach. This study aimed to determine the differences in the diametral tensile strength of nanohybrid composite resin reinforced with bemban fiber (*Donax canniformis*) at volume weight fractions of 10%, 15%, and 20%. Bemban fibers were obtained from the stems of *Donax canniformis* collected from Sungai Bakung

Village, located in Sungai Tabuk District, Banjar Regency, South Kalimantan, Indonesia. Plant identification was conducted immediately after collection at the Faculty of Mathematics and Natural Sciences Laboratory, Lambung Mangkurat University, Banjarbaru. Specimen fabrication and diametral tensile strength testing were carried out at the Wet Laboratory and Dental Materials Laboratory, Faculty of Dentistry, Lambung Mangkurat University.

Preparation of Bemban fiber

Bemban stems were selected based on a diameter criterion of 4–5 cm to ensure uniform fiber dimensions. The selected stems were cleaned, cut into segments approximately 20 cm in length, and longitudinally split into two halves. Subsequently, the stems were boiled for approximately 60 minutes. The fibers were then combed using a wire brush to remove the corky outer layer adhering to the fibers and to ensure fiber homogeneity. After extraction, the fibers were separated individually into fine strands and dried using an oven maintained at 70°C for 3 hours to reduce their moisture content. The prepared bemban fibers were subsequently arranged individually on a glass plate and coated with a dental bonding agent prior to specimen fabrication.[15,16]

Sample Preparation Based on Groups

Group 1:

A cylindrical mold lined with a celluloid strip at its base was placed on a digital balance, and the balance was subsequently tared to zero. The nanohybrid composite resin (3M™ Filtek™ Z250 XT Nano Hybrid Universal) was then incrementally packed into the mold to a height of 3 mm. The material was condensed using a condenser, and a celluloid matrix strip was positioned on the top surface of the mold. The weight of the composite resin obtained from this group was used as the reference weight for specimens without fiber reinforcement. The specimens were polymerized with an LED light-curing device for 20 s, with the curing tip placed as near as possible to the specimen. Light curing was carried out on both sides of the composite resin specimen to ensure adequate polymerization. After polymerization, the specimens were polished with sandpaper to reduce surface unevenness and produce a smooth, uniform surface before being removed from the mold.[17]

Group 2, 3 & 4:

The weight of the composite resin obtained from Group 1 was used in the calculation formula according to the operational definition to determine the proportions of composite resin and fiber for each experimental group. The nanohybrid composite resin (3M™ Filtek™ Z250 XT Nano Hybrid Universal) was weighed according to the calculated values, consisting of 90% composite resin and 10% fiber for Group 2, 85% composite resin and 15% fiber for Group 3, and 80% composite resin and 20% fiber for Group 4. The composite resin was subsequently divided into two equal portions corresponding to the first and second layers. The first layer of composite resin was placed into the mold to half of its height (1.5 mm), condensed using a condenser, and polymerized with an LED light-curing unit. Bemban fibers were cut to the appropriate specimen dimensions and weighed according to the predetermined calculations. The prepared fibers were placed on a glass plate and coated with a bonding agent using a microbrush. The bonding-treated fibers were then positioned horizontally on top of the first composite resin layer using tweezers. The fibers were oriented perpendicular to the direction of the applied load. Subsequently, the fiber layer was covered with the second layer of composite resin until the mold was completely filled to a total thickness of 3 mm. The material was condensed using a condenser, and both the upper and lower surfaces of the mold were covered with celluloid strips. Polymerization was performed using an LED light-curing unit positioned perpendicular to the specimen surface for 20 s, with the light tip placed as close as possible to the specimen. After curing, the specimens were polished with sandpaper to create a smooth and uniform surface before demolding.[17–19]

Group 5:

The nanohybrid composite resin (3M™ Filtek™ Z250 XT Nano Hybrid Universal) was placed into the mold to approximately half of its height (1.5 mm) and subsequently polymerized using an LED light-curing unit. Polyethylene fibers were sectioned to match the dimensions of the specimen mold. The prepared fibers were placed on a glass lab and treated with a bonding agent. After bonding application, the fibers were carefully positioned horizontally over the initial layer of composite resin using tweezers. Their alignment was arranged perpendicular to the anticipated loading direction. A second layer of composite resin was subsequently applied to cover the fibers, and the mold was filled completely until a final specimen thickness of 3 mm was achieved. The material was condensed using a condenser, and the upper and lower surfaces of the mold were covered with celluloid strips. Polymerization was performed using an LED light-curing unit positioned perpendicular to the specimen surface for 20 s, with the light tip placed as close as possible to the specimen. The cured specimens were smoothed with sandpaper to improve surface uniformity and eliminate imperfections before being separated from the mold.[17–19]

Diametral Tensile Strength Test:

The specimens were tested using a Universal Testing Machine. During testing, each specimen was positioned centrally between two loading plates and aligned with the guide needle before a vertical compressive load was applied. Mechanical testing was performed using a testing machine with a 5 kN load capacity and a crosshead speed of 0.5 mm/min. The maximum force required to induce specimen failure was recorded from the machine display in Newtons (N). The diametral tensile strength (DTS) value was subsequently calculated using the following formula and expressed in megapascals (MPa).

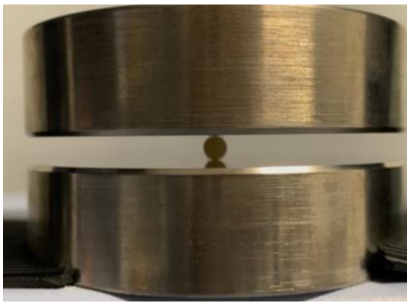

Figure 1. Specimen During DTS Test

RESULTS

Table 1 summarizes the average diametral tensile strength of the different nanohybrid composite resin groups.

Table 1. Diametral Tensile Strength Measurement Results

Nanohybrid Composite Resin	Mean ± Standard Deviatian (Mpa)
No fiber	35,61 ± 8,71
Bemban fiber 10%	40,68 ± 3,86
Bemban fiber 15%	46,74 ± 7,55
Serat Bemban 20%	44,71 ± 4,33
Polyethylene fiber	46,13 ± 7,14

Based on the data presented in Table 1, specimens reinforced with 15% bemban fiber achieved the highest average diametral tensile strength of 46,74 MPa. Conversely, the lowest average value of 35,61 MPa was observed in the group lacking fiber reinforcement. These findings demonstrate that different fiber contents resulted in variations in the mechanical performance of the nanohybrid composite resin.

The Shapiro–Wilk test showed that the data were normally distributed ($p > 0.05$), and Levene's test indicated that the data were homogeneous ($p = 0.217$). Therefore, the data met the requirements for parametric statistical analysis. A one-way ANOVA was then performed at a 95% confidence level. The results showed a statistically significant difference among the groups ($p = 0.019$), indicating that at least two groups differed significantly. To identify which groups showed significant differences, a Post Hoc Bonferroni test was conducted. The results of the Post Hoc Bonferroni test are presented in Table 2.

Table 2. Statistical Significance of Diametral Tensile Strength in Nanohybrid Composite Resin

Perlakuan	1	2	3	4	5
1		1,000	0,036*	0,150	0,056
2			0,963	1,000	1,000
3				1,000	1,000
4					1,000
5					

According to the Bonferroni post hoc test presented in Table 2, the group with 15% bemban fiber exhibited a significant difference compared with the group that did not receive fiber reinforcement.

DISCUSSION

Reinforcement with bemban fiber has been shown to improve the diametral tensile strength of nanohybrid composite resin. This enhancement may be influenced by several factors, including the material type, fiber orientation, adhesive bonding between the resin matrix and the fiber, and the fiber volume fraction.[12,20,21] The diametral tensile strength of composite resin is also affected by the fiber volume fraction. Theoretically, higher fiber volume fractions contribute to increased composite strength, while lower fractions are associated with decreased strength.[22]

Specimens in the control group, which did not contain bemban fiber reinforcement, demonstrated the lowest diametral tensile strength at 35,61 MPa. This outcome may be explained by the absence of reinforcing structures capable of distributing and resisting tensile loads within the composite matrix. As a result, fracture occurred more easily, producing lower strength values compared with the reinforced groups.[23]

The group reinforced with 10% bemban fiber exhibited higher diametral tensile strength than the unreinforced group 40,68 MPa. This finding may be attributed to the presence of bemban fibers, which functioned as reinforcing agents by bearing tensile stresses transferred from the resin matrix. Consequently, the fiber-reinforced composite demonstrated greater resistance to tensile loading than the composite without fiber addition.[23]

The highest value of diametral tensile strength observed in the group reinforced with 15% bemban fiber 46,74 MPa. This finding may be attributed to the greater amount of reinforcing fiber, which enabled more efficient stress transfer from the resin matrix to the fibers and enhanced fiber–matrix interactions. At a fiber volume fraction of 15%, the bemban fibers appeared to be optimally distributed throughout the resin matrix, resulting in a more compact and homogeneous composite structure. This concentration may represent the optimal fiber content for reinforcing the composite resin, as it improves mechanical performance without inducing fiber agglomeration or void formation that could compromise the structural integrity and homogeneity of the material.[23–25]

The group reinforced with 20% bemban fiber exhibited lower diametral tensile strength than the 15% bemban fiber group, with a value of 44,71 MPa. This finding contrasts with the results reported by Darmansyah (2018), who showed that the tensile strength of composite materials exhibited a linear increase with higher fiber content.[13] The decrease in diametral tensile strength observed in this study may be associated with the reduced amount of resin matrix caused by the higher fiber content, which affected stress distribution within the composite. Although increasing the fiber volume fraction can enhance tensile strength up to an optimal level, excessive fiber incorporation may lead to a decline in mechanical performance due to an imbalance between the fiber and matrix components. At higher fiber concentrations, achieving uniform fiber–matrix integration becomes more challenging because the densely packed fibers hinder adequate resin penetration between fiber bundles. Consequently, voids may form within the composite structure, reducing interfacial bonding and preventing complete wetting of the fibers by the resin matrix. The presence of these defects can promote stress accumulation within the material, resulting in lower diametral tensile strength values.[23,26]

A group reinforced with synthetic polyethylene fiber was designated as the positive control. The group reinforced with polyethylene fiber exhibited a higher mean diametral tensile strength than the group reinforced with 20% bemban fiber, with a value of 46,13 MPa. The superior performance of polyethylene fiber may be attributed to its favorable mechanical properties. Polyethylene is a carbon-rich material, containing approximately 92% carbon, and is recognized as a carbon-based reinforcing material. In addition, polyethylene fibers possess high tensile strength, elastic modulus, and density, as well as excellent fracture toughness, making them effective reinforcement materials for composite resins.[27,28]

The present study demonstrated that the 15% bemban fiber-reinforced group exhibited a higher mean diametral tensile strength 46,74 MPa than the positive control group reinforced with polyethylene fiber 46,13 MPa. This finding suggests that bemban fiber has considerable potential to enhance the mechanical performance of composite resin and may even outperform standardized commercial reinforcing fibers. The comparable or superior performance observed in this study indicates that bemban fiber could serve as a promising alternative material for fiber reinforced composites (FRC). In addition to its reinforcing capability, bemban fiber offers several advantages, including environmental friendliness, biodegradability, low energy requirements during production, cost-effectiveness, and recyclability.[9] Furthermore, bemban has the potential for domestication and large-scale cultivation, allowing its sustainable utilization in future industrial applications, including dental material development.[29,30] Therefore, these findings indicate that bemban fiber may be considered a promising natural reinforcement material for composite resins, with potential applications in the development of sustainable dental materials.

CONCLUSION

The diametral tensile strength values differed among the groups, with the highest value observed in the 15% bemban fiber group. A significant difference was found between the 15% bemban fiber group and the group without fiber addition, while no significant differences were observed among the other treatment groups.

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