

Research

Effect of Kenaf Fiber Reinforcement on the Flexural Strength of Pmma-Based Temporary Crown and Bridge Material: An in-vitro Study

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Abstract:

Purpose: To evaluate the effect of kenaf (*Hibiscus cannabinus* L.) fiber reinforcement on the flexural strength and yield behavior of polymethyl methacrylate (PMMA)-based temporary crown and bridge material. **Materials and Methods:** Pretreated kenaf fibers (6 mm length) were incorporated at 2 wt% into a self-cure PMMA provisional material (DPI Self-Cure Tooth Moulding Material, DPI, Mumbai, India). Rectangular specimens (65 × 10 × 3 mm; n = 10 per group) conforming to ADA Specification No. 12 were fabricated for two groups: Group A (unmodified PMMA control) and Group B (kenaf-reinforced PMMA). Three-point flexural testing (span 32.5 mm, crosshead speed 2 mm/min) was performed on a universal testing machine. Flexural strength and 0.2% offset yield stress were calculated and compared using an independent t-test ($\alpha = 0.05$). **Results:** The kenaf-reinforced group exhibited marginally lower mean flexural strength (70.04 ± 6.60 MPa) compared to the control (71.99 ± 11.06 MPa), with no statistically significant difference ($p = 0.638$). The 0.2% offset yield stress for Group B (59.35 ± 10.83 MPa) was marginally higher than Group A (58.02 ± 5.75 MPa), but this difference was also not statistically significant ($p = 0.760$). **Conclusion:** Incorporation of 2 wt% kenaf fibers did not significantly enhance flexural strength or yield resistance of PMMA provisional material. Further investigation with optimized fiber surface treatment, concentration, and orientation is warranted to achieve clinically meaningful mechanical improvements. **Keywords:** kenaf fiber; provisional restorations; polymethyl methacrylate; flexural strength; natural fiber reinforcement; temporary crown and bridge material

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INTRODUCTION

Provisional crown and bridge restorations play an important role in fixed prosthodontic treatment, providing necessary functions: protection of prepared teeth, maintenance of occlusion, aesthetics and preservation of soft tissue

architecture. [1,2] Polymethyl methacrylate (PMMA)-based materials remain popular because of ease of use, acceptable esthetics and reasonable cost. However, brittleness and low flexural strength pose practical problems, especially with long-span provisional restorations.[3]

Unmodified PMMA possesses inadequate fracture toughness and flexural strength for long-term fixed prosthodontic restorations and is thus generally restricted to provisional use.[4] The problem of acrylic resin restoration fracture has not been resolved despite many efforts in prosthodontics.[5] Two types of forces—impact and flexural fatigue—produce fractures in provisional restorations. Although impact may fracture restorations when dropped, most intraoral fractures ultimately develop from repeated flexing during mastication.[5]

Several reinforcement approaches have been evaluated for PMMA, including addition of glass, carbon, polyethylene, polypropylene fibers and nanoparticulate fillers.[6-8] In denture base PMMA, heat-polymerized resins have been significantly reinforced by addition of synthetic fibers, although results strongly depend on fiber characteristics and processing conditions.[9] Synthetic fibers have demonstrated improved flexural strength, modulus and impact resistance when appropriately added to PMMA matrices.[9,10] In provisional materials, fiber meshes and particulate fillers enhance fracture resistance but at some risk of increased cost and complicated chairside handling.[11,12]

Sustainable reinforcement alternatives include natural fibers such as flax, jute, bamboo, and kenaf because of their relatively low density, adequate specific strength, renewability and possible biocompatibility. Kenaf (*Hibiscus cannabinus* L.) is a lignocellulosic bast fiber with excellent stiffness-to-weight ratio that has gained attention as reinforcement in PMMA denture base materials and hybrid dental composites.

However, natural fibers are hydrophilic because of their cellulose, hemicellulose, and lignin content, whereas PMMA is hydrophobic; this leads to poor fiber-matrix bonding when not properly treated and may limit mechanical property improvement.[13] Works using PMMA modified by short vegetable fibers reported that poor interfacial adhesion, moisture uptake, and fiber agglomeration may induce voids and microcracks that act as stress concentrators and negate theoretical strength advantages.[13,14]

There is limited information about the influence of kenaf fiber on PMMA-based provisional crown and bridge materials, which encounter different loading configurations during clinical service compared to denture bases.[4] Therefore, the purpose of this in vitro study was to investigate the effect of reinforcing a self-cure PMMA temporary crown and bridge material with kenaf fiber on the flexural strength and yield behavior.

MATERIALS AND METHODS

Study design: In vitro experimental study.

Materials

- Base material: DPI Self-Cure Tooth Moulding Material (PMMA; DPI, Mumbai, India)
- Reinforcement fiber: Kenaf fibers (*Hibiscus cannabinus* L.), pretreated by washing with ethanol and ultrasonication for 30 min
- Fiber length: 6 mm
- Fiber concentration: 2 wt% relative to PMMA powder

The choice of short fibers (approximately 3-10 mm) at low concentrations was based on previous works dealing with fiber-reinforced PMMA denture and provisional materials, balancing reinforcement efficiency with workability.[9,11]

Specimen Fabrication

According to ADA Specification No. 12, rectangular bar specimens (65 × 10 × 3 mm) were fabricated using a custom mold.

Group A (Control - Unmodified PMMA):

PMMA powder and monomer were proportioned according to manufacturer recommendations and mixed to dough stage. Material was packed into the mold. Flasking, trial closure, and self-cure polymerization were performed according to manufacturer protocol.

Group B (Kenaf-reinforced PMMA):

Kenaf fibers were weighed to 2 wt% relative to PMMA powder and mixed with powder until visually uniform. Monomer was then added and spatulated to dough stage before packing into mold.

Processing protocol (both groups):

1. Wax pattern fabrication
2. Flasking and dewaxing
3. Packing during dough stage (kenaf-modified mixture for Group B)
4. Polymerization according to manufacturer protocol
5. Deflasking and finishing with silicon carbide abrasive papers
6. Storage in distilled water at 37°C for 24 h before testing to simulate oral moisture exposure and allow post-polymerization stabilization[12]

Flexural Strength Testing

Three-point bending tests were performed in accordance with ISO-type methods applicable to PMMA denture base and provisional materials on a universal testing machine equipped with a 3-point bend fixture (Model AC-05-01B3, BISS, India).[9,10]

Test parameters:

- Support span: 32.5 mm
- Crosshead speed: 2 mm/min
- Testing environment: Ambient laboratory conditions

Specimens rested between two supports and were loaded at the midpoint with a central loading nose until fracture or significant deformation occurred. Flexural strength (FS, in MPa) was calculated using the formula:

$$FS = 3PL / 2bt^2$$

Where:

- P = maximum load (N)
- L = span length (mm)
- b = specimen width (mm)
- t = specimen thickness (mm)

The 0.2% offset yield stress was determined from the load-deflection curve as the stress corresponding to 0.2% plastic strain, obtained graphically by constructing a line parallel to the elastic region of the curve offset by 0.2% strain.

Statistical Analysis

Mean flexural strength and 0.2% offset yield stress were calculated for each group.

Comparisons between groups were made using an independent t-test ($\alpha = 0.05$). All statistical analyses were performed using SPSS software (version 29, IBM Corp., Armonk, NY, USA).

Ethical considerations

Ethical approval was not required as this was an in vitro study with no human or animal subjects.

RESULTS

Flexural Strength

The mean flexural strength of the kenaf-reinforced group (Group B) was 70.04 ± 6.60 MPa, marginally lower than the control group (Group A) at 71.99 ± 11.06 MPa. The independent t-test revealed no statistically significant difference between the two groups ($t = 0.478$, $p = 0.638$). Kenaf fiber reinforcement at 2 wt% and 6 mm length did not improve the ultimate load-carrying ability of the PMMA provisional material under three-point bending. (Table 1)

0.2% Offset Yield Stress

The offset yield stress at 0.2% could only be determined for specimens that showed a clear plastic deformation region before failure. Specimens that failed suddenly without a plastic region in the load-deflection diagram did not permit the determination of a yield point and were thus not considered for yield stress analysis. The number of samples considered for yield stress determination was thus reduced to $n = 8$ for Group A and $n = 9$ for Group B. The 0.2% offset yield stress of Group B (kenaf-reinforced) was marginally higher (59.35 ± 10.83 MPa) compared to Group A (control, 58.02 ± 5.75 MPa). However, the independent t-test showed no statistically significant difference between groups ($t = -0.311$, $p = 0.760$). This indicates that resistance to onset of plastic deformation due to kenaf reinforcement was not statistically significant. (Table 2)

In summary, incorporation of kenaf fiber at 2 wt% did not significantly improve either the ultimate flexural strength or the 0.2% offset yield stress of the PMMA provisional material under the test conditions employed.

Table 1: Comparison of flexural strength between groups

Parameter	Group A (Control)	Group B (Kenaf)	t-value	p-value
Mean \pm SD (MPa)	71.99 \pm 11.06	70.04 \pm 6.60	0.478	0.638 (NS)
n	10	10	—	—

NS = Not significant ($p > 0.05$)

Table 2: Comparison of 0.2% offset yield stress between groups

Parameter	Group A (Control)	Group B (Kenaf)	t-value	p-value
Mean \pm SD (MPa)	58.02 \pm 5.75	59.35 \pm 10.83	-0.311	0.760 (NS)
n	8	9	—	—

NS = Not significant ($p > 0.05$)



Figure 1



Figure 2



Figure 3

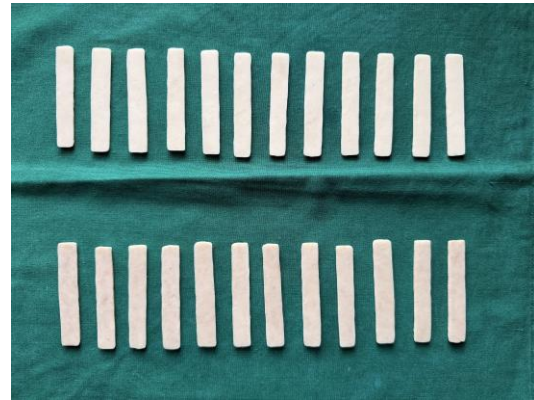


Figure 4



Figure 5

DISCUSSION

The results of the current study revealed that addition of 2 wt% kenaf fibers to a self-cure PMMA based provisional material did not significantly improve the flexural strength and

0.2% offset yield stress. This result is important for the current interest in sustainable reinforcement approaches in prosthodontic materials.

Flexural strength and stiffness are important factors in determining the success of provisional crown and bridge materials, which are subjected to functional loading and must retain their integrity throughout the treatment phase. [1,2] Fiber reinforcement of PMMA has been widely explored to improve the flexural strength and fracture resistance of denture base and provisional restorative materials. [3-5]

Several studies have shown that the addition of synthetic fibers (glass, carbon, polyethylene, polypropylene) to denture base and provisional materials resulted in a significant improvement in flexural strength and stiffness, mainly due to the improved mechanical properties and good bonding between the fibers and the PMMA matrix.[6-9] However, the current study showed that the addition of 2 wt% kenaf fibers did not significantly improve the flexural strength and yield stress, which is in line with the observations in other natural fiber-reinforced PMMA systems, where the improvement in mechanical properties has been less significant compared to synthetic fibers.[10,11]

Flexural strength measurements have been shown to be of clinical relevance in assessing the performance of provisional restorative materials, which simulate the actual bending forces experienced by the material during mastication.[4] The lack of significant improvement in flexural strength indicates that the kenaf fibers, at the tested concentration and length, were ineffective in reinforcing the PMMA matrix under three-point bending conditions. [10,11]

The quality of the fiber/matrix interface is a key factor that determines the behavior of natural fiber-reinforced PMMA. [10] Natural fibers, like kenaf, are hydrophilic in nature due to the cellulose, hemicellulose, and lignin present in them, whereas PMMA is hydrophobic. This incompatibility reduces the bonding quality between the fibers and the matrix when the fibers are incorporated without any surface modification

or coupling agents. This reduces the efficiency of stress transfer from the matrix to the fibers. Poor bonding quality can cause fiber pull-out, voids, micro-cracks and stress concentrations, which are micro-structural flaws that may initiate crack propagation and negate any strengthening effects. [10,11]

Other fiber-related factors influencing mechanical response include type, surface treatment, length, aspect ratio, concentration, and orientation.[3,5,8] Short, randomly oriented fibers are convenient for manual mixing and laboratory handling but offer less effective crack-bridging than unidirectional or strategically aligned fibers positioned in regions of tensile stress.[3,5,8] In this study, only one length of the fibers (6 mm) and one concentration (2 wt%) with random orientation due to manual mixing were used. Literature suggests that optimization of these parameters, especially through alkali treatment or silanization of fibers and systematic variation of concentration, may improve the reinforcement efficiency of kenaf. [11,12]

Complementary scanning electron microscopic evaluation of fracture surfaces—as performed in other investigations of fiber-reinforced PMMA—would have been useful for characterizing fiber dispersion, interfacial defects, and modes of failure, providing direct microstructural support for the limited reinforcement observed.[8] This represents a limitation of the present study.

From a clinical perspective, provisional restorations should maintain marginal integrity, occlusal contacts, and morphology under functional loading conditions during the provisional phase. The absence of statistically significant differences in flexural strength and yield stress values indicates that kenaf at 2 wt% concentration does not offer any mechanical advantage over unmodified PMMA under the current study conditions, and thus cannot be recommended as a better alternative for enhancing the structural performance of provisional restorations.[11]

However, kenaf still has the potential to be developed as a reinforcement material because of its renewable origin, low density and potential cost-effectiveness. With optimal surface

treatment, dispersion and interfacial bonding; kenaf-based materials can potentially be developed as sustainable reinforcement materials that meet the increasing demand for eco-friendly prosthodontic materials without compromising the mechanical integrity. [11,12]

The limitations of this study include the fact that only one length, concentration, and surface treatment method of the fibers were tested. Future studies should include investigations of the effects of fiber surface treatment (alkali treatment, silanization), varying concentrations (1-5 wt%), different lengths (3-15 mm) and controlled fiber orientation. Long-term water sorption, fracture toughness, and fatigue resistance studies would also give a more thorough assessment of the clinical suitability of the materials.

CONCLUSION

Within the limitations of this in vitro study, addition of 2 wt% kenaf fiber to a self-cure PMMA temporary crown and bridge material did not significantly improve flexural strength ($p = 0.638$) or 0.2% offset yield stress ($p = 0.760$) compared to unmodified PMMA. Kenaf is still a promising sustainable reinforcement material candidate for prosthodontic applications from an environmental point of view. However, fiber surface treatment (alkali treatment, silanization), concentration optimization and dispersion methods need to be further improved to produce clinically significant mechanical properties. The results provide a basis for further studies on natural fiber reinforcement of provisional materials and suggest that optimized fiber parameters and surface chemistry modifications are necessary before kenaf-reinforced materials can be recommended as mechanically superior alternatives to conventional PMMA for clinical provisional restorations.

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Conflicts of interest:

There are no conflicts of interest.

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