Original Article

Comparison of Flexural Strength of Kevlar, Glass, and Nylon Fibers Reinforced Denture Base Resins With Heat Polymerized Denture Base Resins

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Introduction: Polymethyl methacrylate (PMMA) has been widely accepted and used in dentistry owing to its working characteristics, aesthetics and stability in the oral environment, ease in manipulation, and inexpensive processing methods and equipment. Aim and Objectives: The aim of this study was to evaluate the flexural strength of a high-impact PMMA denture base resin material and flexural strength of a commonly available heat cure PMMA denture base material with Kevlar, glass, and nylon fibers. Materials and Methods: The test samples were studied under two groups. The Group I (control group) comprised pre-reinforced PMMA (Lucitone 199; Dentsply Sirona Prosthetics, York, Pennsylvania, USA) consisting of 12 samples and second group comprised regular PMMA (DPI, Mumbai, India) reinforced with different fibers. The second test group was further divided into three subgroups as Group 2, Group 3, and Group 4 comprising 12 samples each designated by the letters a–l. All the samples were marked on both ends. A total of 48 samples were tested. Results were analyzed and any P value ≤0.05 was considered as statistically significant (t test). Results: All the 48 specimens were subjected to a 3-point bending test on a universal testing machine (MultiTest 10-i, Sterling, VA, USA) at a cross-head rate of 2 mm/min. A load was applied on each specimen by a centrally located rod until fracture occurred; span length taken was 50 mm. Flexural strength was then calculated. Conclusion: Reinforcement of conventional denture base resin with nylon and glass fibers showed statistical significance in the flexural strength values when compared to unreinforced high impact of denture base resin.

Keywords: Denture base resin, glass fibers, Kevlar fibers, nylon fibers, polymethyl methacrylate

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INTRODUCTION

Complete denture has been an integral part of dental practice ever since man has been practicing dentistry. Dr. Walter Wright introduced polymethyl methacrylate (PMMA) as a denture base in 1932 which has been quite a popular material in dentistry. A proper denture base should have sufficient mechanical properties and should be suitable for the oral environment. Therefore, there is a need for the improvement of the denture base material and denture base resins.
methacrylate (PMMA) in 1937 as a denture base material.\textsuperscript{[1]} Reinforcements range from incorporation of wire to modifying the resin, by introducing a rubber phase in reinforcing the polymer. Special fibers such as polyethylene, carbon, Kevlar, and glass fibers have been used. It has been seen that glass and Kevlar fibers may be best suited for this purpose.\textsuperscript{[2]}

**MATERIALS AND METHODS**

**Grouping of samples**

The test samples were studied under two groups. The Group I (control group) comprised pre-reinforced PMMA (Lucitone 199; Dentsply Sirona Prosthetics, York, Pennsylvania, USA) consisting of 12 samples and the second group comprised regular PMMA (DPI, Mumbai, India) reinforced with different fibers. The second test group was further divided into three subgroups as Group 2, Group 3, and Group 4 comprising 12 samples each designated by the letters a–l. All the samples were marked on both ends. A total of 48 samples were tested.

- **Group I:** Control group (high-impact denture base resin Lucitone 199—no fiber reinforcement [G1a–G1l])
- **Group II:** Study group (DPI heat cure resin)

**Subgroups**

- **Group 2:** DPI heat cure denture base resin reinforced with Kevlar fibers (G2a–G2l)
- **Group 3:** DPI heat cure resin reinforced with glass fibers (G3a–G3l)
- **Group 4:** DPI heat cure resin reinforced with nylon fibers (G4a–G4l)

**Fabrication of control group specimens**

Group I (control group) test specimens were fabricated using high-impact denture base resin Lucitone 199. Monomer to polymer ratio of 2 ml:5 g by weight was measured using a disposable syringe and precision balance, respectively and mixed to reach the dough stage, then placed in the mold cavity. Trial closure was performed with hydraulic pressure at 100 psi pressure and flash was removed. The flask was clamped and left overnight for bench curing. Next day the flasks were submerged in water in an acrylizer at room temperature. The temperature was raised at a slow speed to 73°C and conserved for half an hour. After cessation of the polymerization cycle, the flask was allowed to cool in the water bath to room temperature before deflasking. The fibers had a thickness of about 10–15 µm. They were soaked in monomer and excess liquid was allowed to dry for 40 min. Only for glass fibers (Group 3), it was pre-impregnated with silane coupling agent for 1 min and then soaked in monomer for 10 min. Silanized glass fibers provide a higher surface energy and help in better impregnation, resulting in better adhesion to polymer matrix [Image 1].

**Weighing of fibers and resin**

The fibers 2% by weight and the resin were measured and mixed. The fibers were weighed separately on a precision balance so as to achieve 2% of the weight of fibers. That is, 0.1 g of fibers was incorporated into 4.9 g of polymer and manipulated with 2 ml of monomer. The combined weight of polymer and fibers together is 5 g, which is the same as the control group polymer to monomer ratio. The 0.1 g of fiber in 4.9 g of polymer ensures that 2% by weight of fibers have been incorporated per specimen. The monomer (2 ml) was dispensed in all the four silicon mixing jars. The pre-weighed mixture of fiber and polymer wasdispensed into the jars containing monomer at a time. Mixing was started simultaneously for all the four samples and packed in dough stage. Material from each mixing jar was packed into each individual mold cavity one by one separately, and acrylization procedure was carried on as performed for control group [Image 1].

**RESULTS**

All the 48 specimens were subjected to a 3-point bending test on a universal testing machine (MultiTest 10-i, Sterling, Virginia, USA) at a cross-head rate of 2 mm/ min [Image 2]. A load was applied on each specimen from the monomer and excess liquid was allowed to dry for 40 min. Only for glass fibers (Group 3), it was pre-impregnated with silane coupling agent for 1 min and then soaked in monomer for 10 min. Silanized glass fibers provide a higher surface energy and help in better impregnation, resulting in better adhesion to polymer matrix [Image 1].

**Image 1:** Control group and study group
by a centrally located rod until fracture occurred; span length taken was 50 mm. The flexural strength was calculated by using formula:

\[ FS = \frac{3pI}{2bd^2} \]

where FS is flexural strength, \( p \) is the peak load applied, \( I \) is the length of the sample, \( b \) is the width of the sample, and \( d \) is the thickness of the sample. Results were analyzed with \( t \) test and one-way analysis of variance (ANOVA). Total of four groups were studied. For easy specimen identification and tabulation of flexural strength values, the subgroups’ names were written on either ends of the specimen. The association between the strengths (in Newton) of Group 1 and Group 3, and Group 1 and Group 4 were statistically significant \( (P = 0.045, P = 0.001; \text{[Tables 1 and 2]}) \). Results obtained showed that there was no statistical significance in comparison with control group and with specimens reinforced with Kevlar fibers. In comparison between control group and specimens fortified with glass and nylon fibers, there was statistical significance \( (P < 0.05) \).

**Discussion**

The popularity of PMMA in dentistry is due to its ease in processing, less cost, light weight, aesthetic characteristics, less water sorption, and solubility.\(^2\)\(^-\)\(^4\) Other properties such as inferior mechanical strength, low thermal conductivity, brittleness, and high coefficient of thermal expansion make the material more prone to be failure during clinical service.\(^3\) Therefore, many attempts have been made to improve the strength properties of acrylic denture bases. Reinforcing technique is the use of metal wire embedded in the prosthesis but this results in poor adhesion between the resin and wire.\(^5\)-\(^7\) Various fibers such as polyethylene, carbon, glass, and Kevlar have been used as reinforcement materials to increase the strength of conventional heat cure PMMA resin.\(^4\),\(^8\),\(^9\) The dark color of carbon fibers makes it undesirable and unaesthetic.\(^4\),\(^6\) Studies conducted by Yazdanie and Mahood showed that cytotoxicity of carbon fibers is considered to be a problem and there is skin irritation on handling carbon-reinforced denture.

### Table 1: Association between the strengths (in Newton) of Group 1 and Group 3

| Test 2 | N  | Mean  | Std. deviation | Std. error mean |
|--------|----|-------|----------------|-----------------|
| Control | 1.00 | 12 | 96.8358 | 9.25793 | 2.67253 |
|        | 2.00 | 12 | 87.5583 | 11.98821 | 3.46070 |

**Independent samples test**

| Test 2 | \( t \) | \( df \) | Sig. (two-tailed) | Mean difference |
|--------|-------|--------|------------------|-----------------|
| Control equal variances assumed | 2.122 | 22 | 0.045 | 9.27750 |
| Equal variances not assumed | 2.122 | 20.678 | 0.046 | 9.27750 |

**Independent samples test**

| Test 2 | Std. error difference | 95% confidence interval of the difference |
|--------|-----------------------|----------------------------------------|
|        | Lower | Upper |
| Equal variances assumed | 4.37251 | 0.20946 | 18.34554 |
| Equal variances not assumed | 4.37251 | 0.17573 | 18.37927 |
base specimens. To overcome this problem, more aesthetic and appropriate strengtheners are needed. Glass, Kevlar, and nylon fibers might be materials aesthetically better suited for this purpose. In this study, Kevlar, glass, and nylon fibers were used to reinforce conventional heat cure denture base resin and compared the flexural strength of the specimens reinforced with fiber to that of a high-impact resin. These fibers are chemically resistant and thermally stable, and have a high mechanical stability, melting point, and glass transition temperature. This in vitro study was conducted to compare the effect of reinforcement on the flexural strength of conventional heat cure denture base resin by reinforcing with Kevlar fibers, glass fibers, and nylon fibers and comparing it with a high-impact resin. Four groups of specimens (n = 12) were fabricated for flexural strength testing with dimensions 65 × 10 × 3 mm. The flexural strength was tested with a 3-point bending test on a universal testing machine. Statistical analysis was performed with t-test, and for multiple group and pair-wise comparison, one-way ANOVA was performed. The reinforcement significantly increased the flexural strength of the specimens reinforced with glass and nylon fibers. Highest impact strength values were exhibited by Kevlar fibers followed by glass and nylon fibers [Figure 1].

**CONCLUSION**

Reinforcement of conventional denture base resin with glass and nylon fibers showed statistical significance in the flexural strength values when compared to unreinforced high-impact denture base resin (control group). Glass fibers pretreated with silane coupling agent and monomer liquid reinforced with conventional heat cure denture base resin improved the flexural strength, and nylon fibers pretreated with monomer liquid reinforced with conventional heat cure resin also showed improved flexural strength values. Glass and nylon fiber reinforcement can be used to improve the flexural strength of conventional heat cure denture base resins. Further studies are required on nylon fiber reinforcement.

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**Conflicts of interest**

There are no conflicts of interest.

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