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Flexural Strength of Poly Propylene Fiber Reinforced PMMA

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Abstract: *Poly Methyl Methacrylate based restorations are widely accepted in dental and medical field due to the excellent biocompatibility and easy fabrication, however these restorations exhibit inferior mechanical properties. Therefore, the present study conducted to enhance the flexural strength of PMMA based material by reinforcing conventional PMMA with poly propylene fiber. 10 different test groups were prepared by varying the weight percentage (2.5, 5 & 10 Wt %) and aspect ratio (3mm/220µm, 6mm/220µm & 12mm/220µm) of the poly propylene fibers. Results obtained were statistically analyzed using One – Way Anova followed by Tukey Kramer multiple comparison test. All fiber reinforced test groups showed improved flexural strength and 6mm long fiber in 2.5 Wt% showed the highest flexural strength among the fiber reinforced test groups.*
Keywords*: PMMA, Poly propylene fiber, Flexural Strength*

I. Introduction

Synthetic resins are employed in a variety of dental and medical applications such as contact and intraocular lens, bone cements in orthopedics, filler for bone cavities and skull defects, vertebrae stabilization in osteoporosis patients, dentures, cavity filling, sealants, maxillofacial reconstructive materials, impression materials, orthodontic appliances, equipments etc. [1,2]. Among the synthetic resins, poly (methyl methacrylate) is considered as the most suitable biomaterial due to its favorable properties such as biocompatibility, chemical inertness, dimensional stability, ease in processing and other such advantages [3]. However, PMMA based restorations cannot withstand higher rate of loading due to the inferior flexural strength. Therefore, the present study aimed to improve the flexural strength of conventional PMMA by preparing the PMMA/ poly propylene fiber composite.
AIM: The Aim of the study is to prepare a modified PMMA composite which can resist flexural loading.

II. Objectives

1. Preparation of PMMA polymer composite by reinforcing it with poly propylene fiber of varying lengths and weight percentages
2. Determination of the flexural strength of the prepare polymer composite.
3. Comparison of the results and determine the optimum fiber weight percentage and fiber length

III. Materials

Heat activated acrylic resin considered as the matrix material for the present study, obtained from DPI (Dental products of India) was in powder- liquid form. The pink shaded PMMA powder obtained in plastic container and the colorless methyl methacrylate monomer liquid obtained in amber colored glass bottle to avoid accidental polymerization during storage and transportation. Pure poly propylene fiber yarns obtained from Walter Enterprises, Mumbai. India. Other materials used for the preparation of the mould for the fabrication of the acrylic samples include, Type II and type III gypsum products, Modelling wax for the preparation of the wax pattern supplied by Hindustan Pvt. Ltd, Cold Mould seal as the separating medium supplied by DPI.

IV. Methods

1. Characterization of the fibers obtained:

Characterization of the fibers obtained from the manufacturers, performed using SEM. The SEM used was JOEL analytical Scanning Electron Microscope, JSM 6380 LA model. The diameter of the fibers obtained verified using SEM.

2. Preparation of the wax pattern

The specimens for characterization and flexural strength assessment were made with the help of wax patterns. The pattern had the profile of the standard specimens under consideration.

3. Preparation of the mould

Wax pattern was prepared (modeling wax cut into desired dimension for rectangular form) and invested in the dental flask using type II & III gypsum products. Invested dental flask was kept for dewaxing after one hour and the mould obtained was cleaned using soap solution. Thin layer of cold mould seal was then applied over the mould as separating the medium and allowed to dry.

4. Preparations of the samples

Heat cure polymer powder and liquid (2.4gm: 1ml) mixed in a porcelain jar and allowed to reach dough consistency for control group. For the reinforced groups, poly propylene fiber (220 µm diameter) of varying lengths (3mm, 6mm, 12mm) and weight percentages (2.5Wt%, 5 Wt%, 10Wt%) were taken and impregnated in the monomer liquid for 5 minutes, and then the polymer powder mixed and allowed to reach the dough consistency. The dough was then kneaded and packed into the mould, the closed flask was kept in a hydraulic press apparatus and pressure of 1400 Psi was given for 30 minutes to dissipate the entire monomer into the polymer allows bench curing. Flask with clamp was then transferred in to the water bath in the acrylizer unit. The temperature was elevated to 72°C, and maintained for 90 minutes. Then the temperature was elevated to 100°C and maintained for 60 minutes. This allowed complete polymerization of the samples and then the flask was permitted to cool in same water bath to room temperature, the acrylic resin specimens were retrieved after deflasking. The specimens obtained were cleaned from stone particles and polished using sand paper 80, 120, 150 grits. Each specimen visually inspected calibrated, polished using pumice.

5. Measurement of Flexural Strength

All the prepared samples were tested for flexural strength using Instron 3366, universal testing machine. Specimens were placed in a position where its two edges supported from the lower side and the load was given in the middle of the specimen from an upper side (3 points bending). Using the digital micrometer attached to the machine, the specimen dimension was measured and recorded into the computer. Test carried out at room temperature using a cross head speed of 1mm/min. the loading was continued up to failure of the test sample. Flexural strength values were recorded directly from the computer connected to it. Six rectangular specimens (62mm X 10mm X 2.5mm) were tested for each test groups and the mean value for each test group is reported.

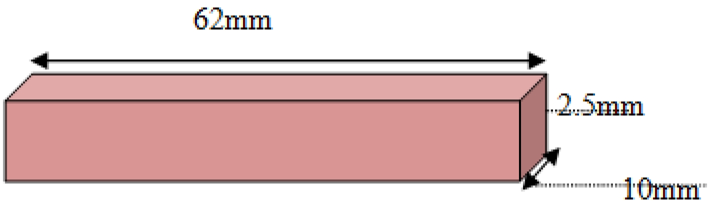


Figure 1: Schematic diagram of the sample profile for flexural strength analysis

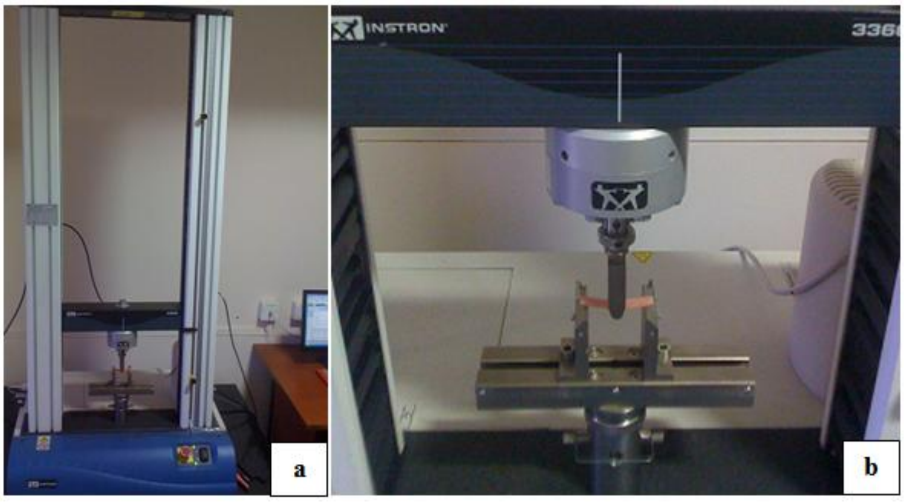


Figure2: Flexural strength analysis using Instron
a: three -point bend set up using Instron, b: sample kept in position and load applied close view.

V. Results

1. All fiber reinforced test groups showed improved flexural strength value compared with control group having no fiber reinforcement. (see Table 1)
2. Among the fiber reinforced test group, 6mm long fiber reinforced in 2.5 Wt% resulted in best flexural strength value. (see Table 1)

***Table1:** Flexural strength of untreated poly propylene fiber reinforced PMMA*

	control	3mm long fiber			6mm long fiber			12mm long fiber		
		2.5 Wt%	5 Wt%	10 Wt%	2.5 Wt%	5 Wt%	10 Wt%	2.5 Wt%	5 Wt%	10 Wt%
1	91.43	124.64	156.89	180.28	188.44	180.76	177.81	191.91	181.21	172.06
2	94.74	125.04	160.26	182.20	197.12	179.04	176.80	192.34	184.42	171.68
3	91.02	126.78	168.12	186.16	196.46	177.57	178.07	189.07	178.9	167.08
4	94.83	122.01	166.49	189.98	189.06	179.03	175.98	190.04	176.63	166.84
5	92.07	123.45	164.22	187.06	188.06	182.52	172.88	187.79	178.46	168.1
6	91.08	121.14	165.63	185.42	189.32	184.09	179.6	193.12	177.12	170.02
Mean	92.52	123.84	163.60	185.18	191.41	180.50	176.85	190.71	179.45	169.29

VI. Discussion

The present study utilized three-point bending test to measure the flexural strength of the prepared polymer composite. The flexural strength analysis is an important parameter for the dental prosthetic materials as flexural loading imitates clinical situations in which they undergo in the oral environment [4]. Rodrigues SA et al reported that three point bending is preferred over biaxial flexural test or similar flexural test, as this test gives lower standard deviation, lower coefficient of variation and less complex crack distribution; all these results in easy flexural strength calculations. In addition to all these, flexural strength analysis is widely used for comparative purposes because the specimen fabrication and the load application are quite simple [5].

poly propylene fiber reinforced PMMA polymer composite exhibited higher flexural strength value in all selected fiber weight percentage and aspect ratio compared to control group having no fiber reinforcement suggested that, the fiber reinforcement in the PMMA resin matrix could transfer the load effectively from resin to the fiber, when the polymer composite stressed [6].

Figure 3 to 5 represents the flexural strength of 2.5 Wt%, 5 Wt%, and 10 Wt% poly propylene fiber reinforced PMMA. 2.5 Wt% and 5 Wt% of polypropylene fibers when incorporated to the PMMA resin matrix to prepare the polymer composite, there was significant increase in the flexural strength value, when the fiber length increased from 3 to 6mm ($p<0.001$), and there was no significant increase in the flexural strength as the fiber length increases from 6 to 12mm ($p >0.05$).Thisagrees with the study that, after a critical length, the increase in the fiber length has no effect in the flexural strength value [7]. 10Wt% of polypropylene fibers when used to reinforce the PMMA polymer, there was a significant decrease in the flexural strength value with increasing fiber lengths. This support the various researchers that the amount of fibers incorporated play a major role in flexural behavior of a polymer composite [8, 9, 10]. At higher fiber weight percentages, the effective interaction between fiber and the matrix fails and led to delamination or inter-laminar fracture of the polymer composite [11].Figure 6 to 8 represents the relationship between the fiber length and the fiber weight percentage.3mm long polypropylene fiber when incorporated, there was a direct proportion to weight percentage of fiber addition and flexural strength ($p<0.001$), but the 6mm and 12mm long fibers resulted in an inversely related proportion to weight percentage and flexural strength value.This may because, the fiber length and weight percentage when increases, the fiber and the matrix interaction could be restricted and the load could not transferred from the matrix to the fiber, resulted in the fracture of the specimen and led to less flexural strength value than in lower fiber lengths and weight percentages [6,12].

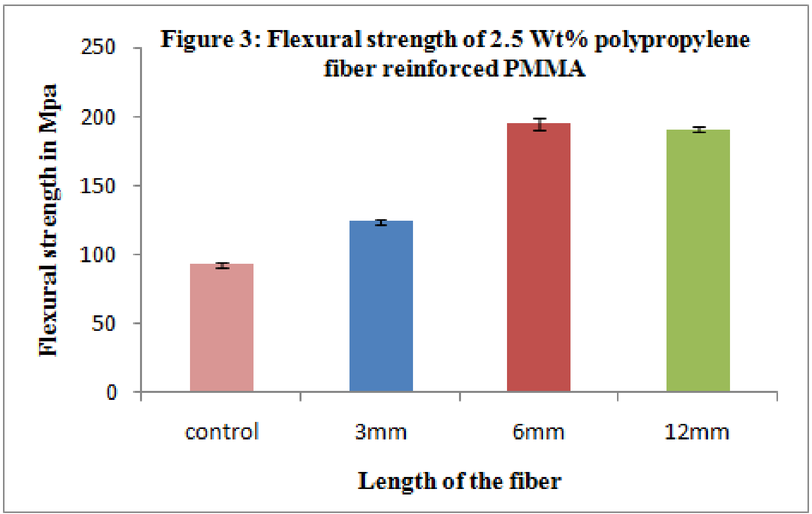


Figure 4: Flexural strength of 5 Wt% poly propylene fiber reinforced PMMA

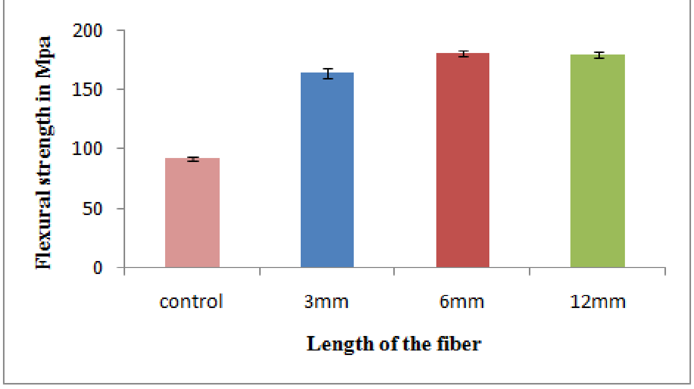


Figure 5: Flexural strength of 10 Wt% poly propylene fiber reinforced PMMA

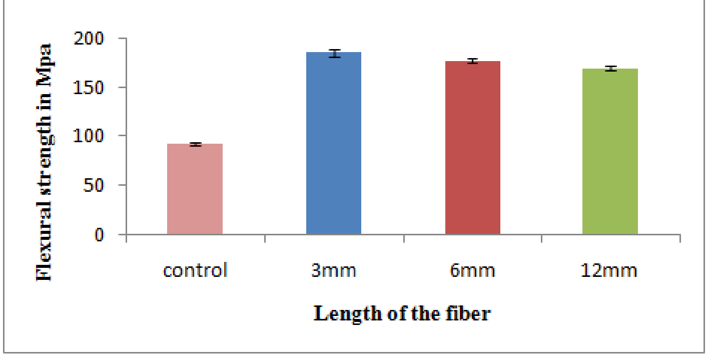


Figure 6:Flexural strength of the 3mm long poly propylene fiber reinforced PMMA

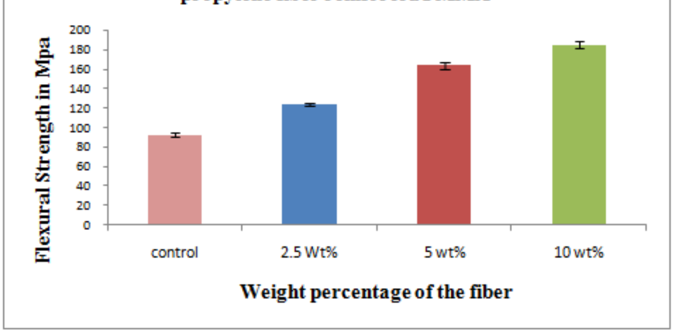
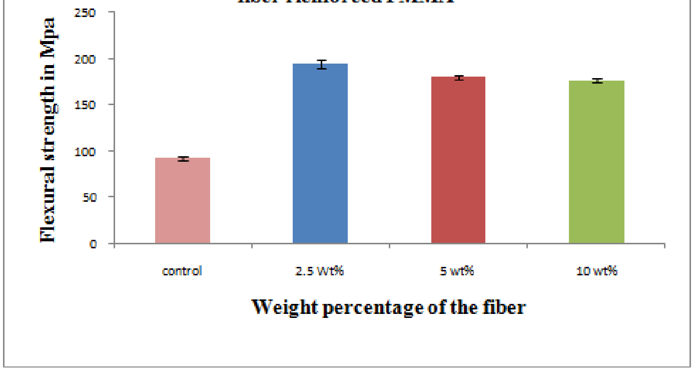
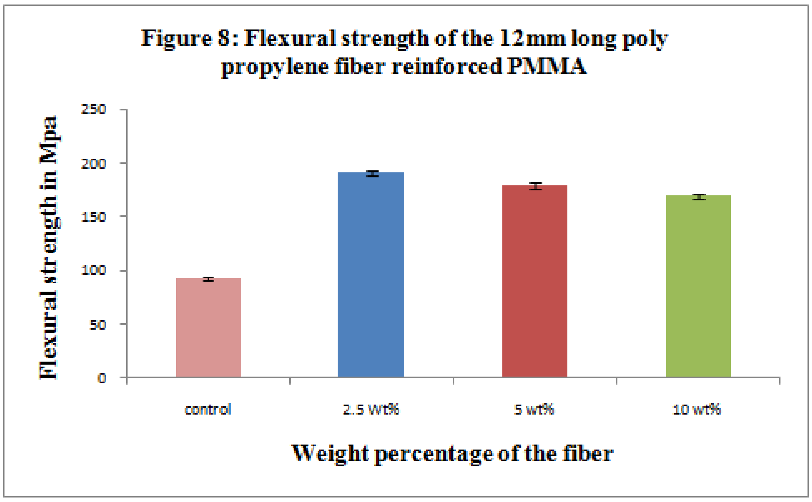


Figure 7: Flexural strength of the 6mm long poly propylene fiber rienforced PMMA





VII. Conclusion

Poly propylene fiber reinforcement resulted in an improved flexural strength characteristic in PMMA based material; Fiber weight percentage, length and diameter played a significant role in altering the flexural resistance of the poly propylene fiber reinforced PMMA composites.

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