Comparative Evaluation of Flexural Strength of Heat Polymerized Denture Base Resin after Reinforcement with Glass Fibers, Nylon Fibers, Carbon Fibers and Polyaramid Fibers: An In-Vitro Study

Manju Choudhary[1], Harikesh Rao[2]

[1]MDS, Prosthodontics, Jaipur Dental College, MVGU (Raj.), India

[2]Professor & Head, Department of Prosthodontics, Jaipur Dental College, MVGU (Raj.), India

Abstract: ***Introduction**: Fracture of denture is of important concern in areas of heavy occlusal stress. This study was an in-vitro study done to evaluate and compare the flexural strength of heat polymerized poly methylmethacrylate denture base resins on reinforcement with Nylon fibers, Carbon fibers, Polyaramid fibers and Glass fibers. **Method**: A stainless steel die was used as a standard die and a total of 50 heat cured PMMA resin samples were fabricated using the same die and divided into 5 groups, having 10 samples in each group. The samples were tested on universal testing machine & three point bending test was done. Then flexural strength of each sample was calculated. Mean value of flexural strength of each group was used for statistical analysis. **Results**: Results showed that the mean flexural strength of the unreinforced PMMA samples was 55.78N/mm^2. Mean flexural strength of the reinforced PMMA (4% polyaramid fibers) was 81.38 N/mm^2, for 4% glass fiber it was 73.67 N/mm^2, for 4% nylon fibers it was 58.91N/mm^2 and for 4% carbon fibers it was 57.62N/mm^2. One-way analysis of variance showed that the fibers significantly affected the flexural strength of PMMA. **Interpretation and Conclusion**: Polyaramid fibers had a marked improvement in the flexural strength of PMMA as compared to unreinforced PMMA.*

Keywords: Reinforcement with fibers, Flexural strength, SEM microanalysis

1. Introduction

Edentulism is a debilitating and irreversible condition and is described as the “final marker of disease burden for oral health”. Edentulism can have obvious negative esthetic, functional (speech, chewing/eating) and psychological consequences. Edentulism is closely associated with socioeconomic factors and is more prevalent in poor population and in women[1,2] For edentulous patients complete denture is the standard treatment of choice in which dental implants have been deemed inappropriate by patient and/or doctor because of financial constraints, a medically compromised status that contraindicates surgery, or inevitable damage to vital structures such as maxillary sinuses, nerves, and vessels. Complete denture restores form, function and esthetics of an edentulous individual.

Poly Methyl Metacrylate (PMMA) was developed 70 years ago, and is still the major material for fabrication of denture bases due to its esthetic characteristics, high processing and polishing abilities, relining and rebasing possibility and low cost. In 1937, Dr. Walter wright[3] and Vernon Brothers in Philadelphia introduced polymethyl methacrylate (PMMA) resin (acrylic resin). Its resistance to impact and PMMA resin’s fatigue failure are somewhat poor, thus fracture of acrylic resin denture bases is a continuing problem in Prosthodontics. Predisposing factors for fracture of dentures include any areas of stress concentration (large frenal notch), dentures with thin or under extended flanges, lack of adequate relief (in case of a prominent torus palatinus), improper occlusion, previous repair of dentures, poor clinical design etc[4,5] Flexural fatigue and impact forces are the two important factors responsible for fracture of dentures. Fatigue occurs after repeated flexing of a material. Impact failures usually occur out of mouth as a result of sudden blow to denture or accidental dropping while cleaning, coughing or sneezing [5].

Fractures can be prevented by improving the strength of the PMMA. Strengthening by fiber reinforcement is based on the principle that a relatively soft ductile, polymer matrix is fully capable of transferring an applied load to fibers via shear forces at the interface [6]. Fibers will be the main load bearing constituents while the matrix forms a continuous phase to surround and hold the fibers in place. Reinforcement of PMMA with different types of fibers increases the abrasion, tensile and transverse strength, bending and elasticity modulus.

So this study is a comparative study of PMMA reinforced with four different fibers namely Glass, Nylon, Carbon and Kevlar fibers.

2. Aim & Objective

1) Whether reinforcement of PMMA denture base resin is really beneficial and advisable to enhance the flexural strength?
2) To evaluate the Flexural strength of denture base resins fabricated by reinforcement with different types of fibers

and compare it with denture base resins without reinforcement fabricated by conventional method.
3) To find out the best fibers for denture reinforcement.

3. Materials & Methodology

For the purpose of this study heat cure clear acrylic resin material DPI was taken, which was reinforced with four different types of fibers which include GLASS FIBERS, NYLON FIBERS, CARBON FIBERS AND POLYARAMID FIBERS (KEVLAR). A stainless steel die was used as a standard die and a total of 50 heat cured PMMA resin samples with dimensions (70×40×3) mm were fabricated and divided into 5 groups, having 10 samples in each group. Test groups were reinforced with 10-15 microns thick and 6mm long fibers. The samples were kept in distilled water for 7 days to get rid of unreacted monomer. The samples were tested on universal testing machine & three point bending test was done. Then flexural strength of each sample was calculated. Mean value of flexural strength of each group was used for statistical analysis. All the samples were also subjected to SEM microanalysis.

Figure 1: Stainless Steel Die

Figure 2: Wax Patterns

Figure 3: Polyaramid Fibers, Carbon Fibers, Nylon Fibers, Glass Fibers

Figure 4: Load applied on the Specimen

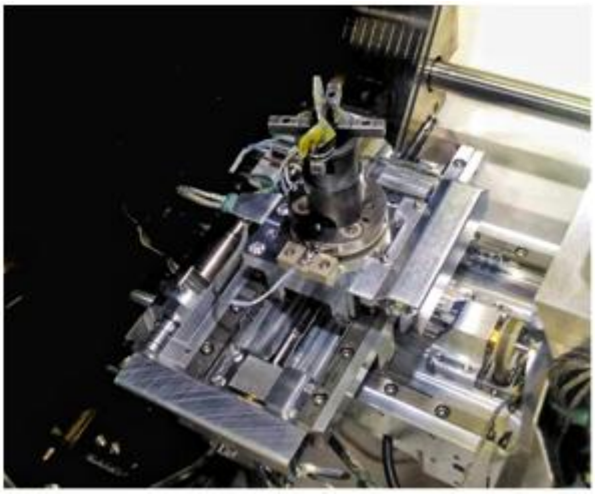

Figure 5: Sample under SEM imaging

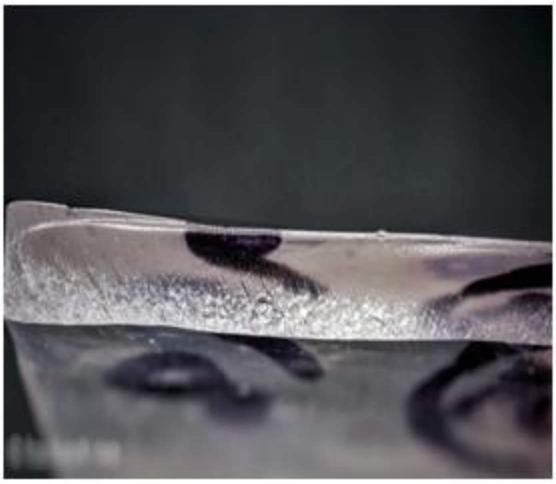

Figure 6: Macro Photograph (1:1) of unreinforced fractured PMMA specimen showing micro-cracks

Figure 7: Macro photograph (1:1)of fractured specimen of Carbon Fibers showing improper bonding of the fibers with the resin matrix

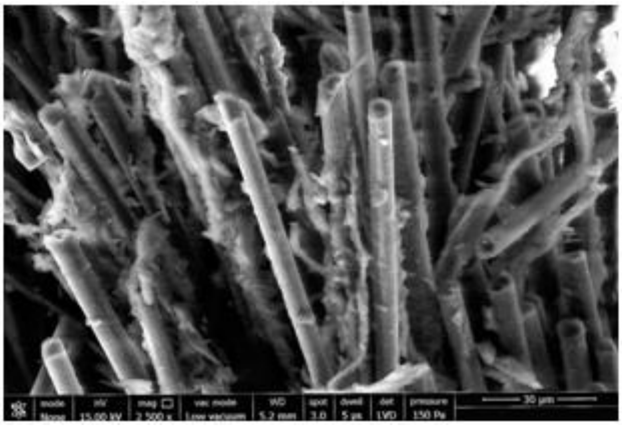

Figure 8: SEM fractograph of Carbon Fibers reinforced PMMA at 2500x magnification

Figure 9: Macro photograph (1:1) of Glass Fibers showing the projection of fibers from the fractured surface

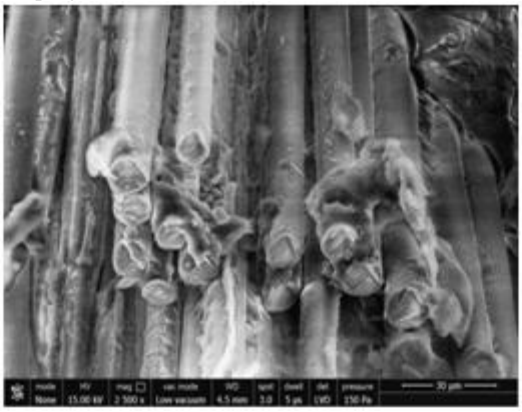

Figure 10: SEM fractograph of Glass Fibers reinforced PMMA at 2500x magnification

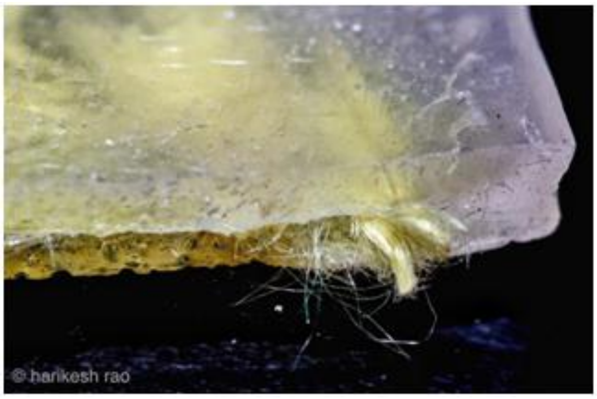

Figure 11: Macro photograph (1:1) of Polyaramid Fibers

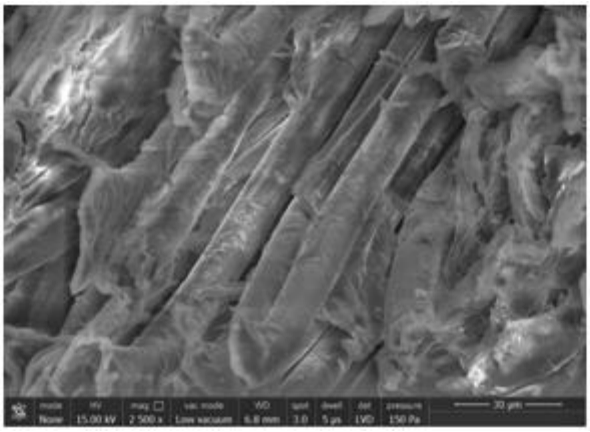

Figure 12: SEM fractograph of Polyaramid Fibers reinforced PMMA at 2500x magnification

Figure 13: Macro photograph (1:1) of fractured specimen of Nylon Fibers showing the structure of the fiber that is soft and irregular

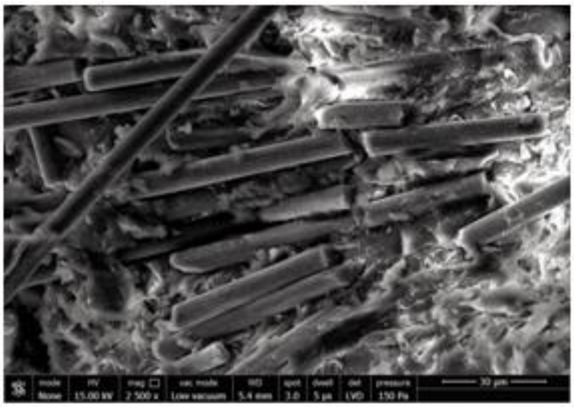

Figure 14: SEM fractograph of Nylon Fibers reinforced PMMA at 2500x magnification

4. Results

Mean of all the groups were statically evaluated and one way ANOVA was performed, 'F' ratio and 'P' value were calculated which scored 10.69 & 0.001 respectively. 'P' and 'F' ratio consideration show that at least one group among these five groups show statistically significant difference. Post hoc Tukey HSD test was done to evaluate and compare between two groups.
Group A -Control Group: Unreinforced PMMA.
Group B- PMMA denture base resin reinforced with 4% Polyaramid Fibers.
Group C- PMMA denture base resin reinforced with 4% Glass Fibers.
Group D- PMMA denture base resin reinforced with 4% Nylon Fibers.
Group E- PMMA denture base resin reinforced with 4% Carbon Fibers

Comparative Evaluation of Flexural Strength (IN N/mm^2) of Heat Polymerised Denture base Resin after Reinforcement with Polyaramid Fibers (KEVLAR), Glass Fibers, Nylon Fibers and Carbon Fibers

Groups	N	Mean	Std. Dev.	ONE WAY ANOVA		TUKEY HSD TEST*	
				'F' Ratio	'P' Value	Group Mean	'P' Value
Group A (Control)	10	55.78	2.02	10.69	<0.001 (S)	M1&M2	<0.001 (S)
Group B	10	81.38	2.20			M1&M3	<0.001 (S)
Group C	10	73.67	6.78			M1&M4	0.999
Group D	10	57.06	2.63			M1&M5	0.998
Group E	10	57.62	23.41			M2&M3	0.045 (S)
						M2&M4	<0.001 (S)
						M2&M5	<0.001 (S)
						M3&M4	0.016 (S)
						M3&M5	0.022 (S)
						M4&M5	1.000

The flexural strength has shown a increase of 25.6 N/mm^2 when the PMMA samples were reinforced with 4% polyaramid fibers when compared with control group. Values for Groups C, D and E have also shown the increase of 17.89 N/mm^2, 1.28 N/mm^2 and 1.84 N/mm^2 respectively when compared with the control group. The highest mean FS was exhibited by the Gp. B i.e. 4% PF reinforced PMMA resin samples.

5. Discussion

Whether the denture fracture occurs accidently, because of an impact or from forces due to masticatory or gliding movements, the "strength" of the denture has been inadequate in each case [7]. Therefore to overcome such disastrous eventualities many modifications in the conventional denture base resin to improve its strength were introduced [8,9,10]. This In-vitro study was therefore conducted in order to determine the flexural strength of the denture base material reinforced with four different fibers. Flexural strength was tested to get an understanding of how denture base resins hold up under function.

A pilot study was done at the beginning of this study with two different concentrations of fibers using 2% and 4% on 5 different samples, as manufacturer of the fibers did not give any instructions about the usage of the fibers. **Wright et al** (1979) used untreated randomly organized short fibers and observed 17% increase with 1% GF reinforcement, and 24% increase with 4% GF reinforcement [11]. More than 4% is not incorporated in our study as fiber concentration above

4% resulted in dry, fragile dough [12] and the resin became difficult to manipulate and was aesthetically unpleasing. **Gutteridge** (1988)[12] found that incorporated fibers could not be added over 4% weight. He found that viscosity was increased with the amount of fiber incorporated and manipulation became difficult. So it was decided to go ahead with the pilot study using the 2% and 4% fiber concentrations for reinforcement of PMMA. All the samples were subjected to flexural strength. It was seen that the samples made by incorporating 2% fibers did not withstand the flexural forces as the samples were completely fractured i.e. the fracture was of catastrophic type, but the samples made by incorporating 4% fibers withstood flexural force much better as there was a single crack line on the samples i.e. the fracture was of repairable type. So the results of pilot study showed that using 4% of fibers concentration was better as compared to 2%. So concluding the pilot study we have used 4% of each fiber for reinforcement of samples in the study. **Chen SY, Liang WM, Yen PS** observed that the transverse strength of insignificant difference by adding 2mm, 4mm and 6mm long fibers[13]. Due to the favorable results, in the present study the fibers used were in 6 mm lengths. All the specimens were made according to the manufacturer's instructions. Split dies were used to reduce the chances of water sorption and dimensional changes [14].

Long curing cycle of 8 hours at 74^0C with a terminal boiling for 1 hour was proposed for this study[15]. The flexural strength of a material is its ability to bend before it breaks[16]. Flexural strength (T) = 3pl / 2bd2 **(ADA specification No. 12, 1999)**

In our study the fibers are not impregnated in monomer as, an excess of methyl methacrylate monomer to ensure better impregnation of fibers with PMMA would increase the polymerization shrinkage and could cause dimensional changes within the denture and may input other porosities due to residual monomer [17]. The study results shows the flexural strength of polyaramid fibers more than control group (Unreinforced PMMA) and is statistically highly significant ($p<.001$) and also its flexural strength is more than that of Glass fibers, Carbon Fibers and Nylon fibers.(Significant for Glass fibers i.e. $p<.05$ and highly significant for Carbon and Nylon fibers i.e. $p<.001$).

In our study, comparative table shows that the denture base sample fabricated with reinforced polyaramid fibers has the highest mean flexural strength (81.38±2.20) whereas the denture base fabricated with reinforced nylon fibers has the lowest mean flexural strength (57.06± 2.63). SEM analysis shows that the fibers in the specimen containing Kevlar are well integrated in the matrix of acrylic resin with very little evidence of interface between the matrix and the fibers (Fig.12).. SEM study also showed that the fibers in the specimen containing glass fibers are well integrated in the matrix of acrylic resin.The prepared specimens of nylon fibers shows that at least three specimens out of ten did not have proper spread of fibers due to the difficulty in handling of the material. The SEM of the specimens containing nylon and carbon fibers showed that the fibers are protruding through the fracture surface which indicates that the fibers have not adhered to the resin matrix properly (Fig.10).

Reinforcement of PMMA with fibers is an attractive option as it does not require any new equipment outlay. Other advantage is that, if the matrix should fail catastrophically then the fractured portion is likely to remain in close proximity, held together by the fibers [18]. Reinforcement also decreases the chance of failure and may decrease patient discomfort and unscheduled appointments [17]. Unidirectional fibers enhance the strength and stiffness in one direction while randomly oriented fibers enhance mechanical properties in all directions. Thus randomly oriented fibers were used in our study. This study suggested that dentures with polyaramid fibers reinforcement might have clinical success. The difficulties which we face with the finishing and polishing of the polyaramid fibers can be overcome by sandwiching the fibers in between two layers of acrylic during processing of dentures.

6. Conclusion

Within the limitations of study, it was concluded that:

- Reinforcement of PMMA is beneficial as all the groups show higher load required to fracture the specimen as compared to control group.
- Denture base reinforced with Polyaramid fibers has higher flexural strength than the unreinforced denture base resin, and denture base resin reinforced with Glass, Carbon, and Nylon fibers consequently increasing the life span of the prosthesis during clinical use.
- The difficulties in finishing and polishing of Kevlar fibers can be overcome by sandwiching the fibers in between the two layers of acrylic resin during processing of the dentures. Glass fibers has the second highest flexural strength in our study they have a better clinical implication because of their excellent aesthetic appearance since Kevlar fiber is yellow in color which could not be sometimes acceptable by the patients.

7. Future Scope

For a better fit of denture we can also opt for Biofunctional Prosthetic System (BPS). BPS is the system designed to work with the body in a biologically harmonious way, maximizing function, and giving comfort and natural appearance to the patient.

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