10.5005/jp-journals-10024-1960

ORIGINAL RESEARCH

Reinforcing Heat-cured Poly-methyl-methacrylate Resins using Fibers of Glass, Polyaramid, and Nylon: An *in vitro* Study

[1]Gautam VS Kumar, [2]Anupama Nigam, [3]Ahmad Naeem, [4]Abhishek Gaur, [5]Kaushik Kumar Pandey, [6]Abhimanyu Deora

ABSTRACT

Introduction: As civilization has progressed, there has been continued refinement of materials available for dental practice. The applications of resins have been extended to increased practical uses in numerous areas of prosthetic and restorative dentistry. Certain significant alterations in the technique of manipulation and nature of the dental product have influenced the range of application in dentistry. The present study was done to measure and compare the fracture strength of heat polymerized poly-methyl-methacrylate (PMMA) resin reinforced with fibers of glass, polyaramid, and nylon.

Materials and methods: The present study was conducted *in vitro* on 40 PMMA denture base resin specimens. Specimens were divided into four subgroups with ten specimens each and tested for transverse strength using universal testing machine.

Results: In group I, the transverse strength mean value was 67.82 MPa. In group II, the transverse strength mean value was 59.47 MPa. In group III, the transverse strength mean value was 66.87 MPa, while in group IV, the transverse strength mean value was 66.47 MPa.

Conclusion: Incorporation of 4% weight glass fibers in loose form significantly increased the transverse strength of denture base PMMA, while 4% of polyaramid fiber in random distribution significantly increased the transverse strength of denture base PMMA.

Keywords: Carbon, Glass, Poly-methyl-methacrylate, Polyaramid, Resin.

[1]Department of Prosthodontics, Saraswati Dental College Lucknow, Uttar Pradesh, India

[2]Department of Prosthodontics, Chandra Dental College and Hospital, Barabanki, Uttar Pradesh, India

[3-6]Department of Prosthodontics, Career Post Graduate Institute of Dental Sciences and Hospital, Lucknow, Uttar Pradesh, India

Corresponding Author: Gautam VS Kumar, Reader Department of Prosthodontics, Saraswati Dental College Lucknow, Uttar Pradesh, India, e-mail: drgautamsaxena@gmail.com

How to cite this article: Kumar VSG, Nigam A, Naeem A, Gaur A, Pandey KK, Deora A. Reinforcing Heat-cured Poly-methyl-methacrylate Resins using Fibers of Glass, Polyaramid, and Nylon: An *in vitro* Study. J Contemp Dent Pract 2016; 17(11):948-952.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

The loss of teeth by accident or disease has plagued mankind through ages. In order to restore a degree of function, it has been necessary to opt for contemporary materials to dental practice. The material must be biologically compatible, readily available, reasonably inexpensive, and simple to manipulate with a readily controlled technical procedure. A resin is a broad term used to describe a natural and synthetic substance that forms into a plastic material after polymerization.[1]

Methyl-methacrylate resin was first introduced to National Society of Denture Prosthesis at Atlantic City in July 1937 by Dr Walter H Wright.[2] It is presently the most widely used denture base material, but has many inherent disadvantages.

Fractures may occur owing to its unsatisfactory transverse strength, impact strength, or fatigue resistance. Acrylic resin also exhibits notch sensitivity; a problem with the labial frenum that can initiate midline fractures. Occlusal imbalance also predispose to fractures.

Attempts have been made to improve the mechanical properties of acrylic resin by either chemical modification with incorporation of butadiene styrene to produce high-impact resins or by giving either maximum bulk to the material, copolymerization, crosslinking and reinforcement with kinds of fibers like glass fibers, aluminum and sapphire whiskers, polycarbonates, carbon fibers or

metal strengtheners in the form of powder, whiskers, and meshes.[3]

Incorporation of metal fillers into poly-methyl-methacrylate (PMMA) is difficult and technique-sensitive, with risk of toxicity. Fibers, on the contrary, are easier to incorporate in resin matrix and exhibit good bonding if treated with a coupling agent. Fibers reinforcement is dependent on many variables like type of fibers, percentage in matrix, modulus and distribution of fibers, length, orientation, and form (chopped, continuous, unidirectional, or bidirectional).[3]

Carbon fibers increase the resistance to flexural fatigue and prevent breakages in complete dentures, fixed, and removal of partial dentures.[4] Glass fibers are used for reinforcing polymers in prosthetic dentistry due to its superior esthetics and excellent mechanical properties. Kevlar fibers increase the impact strength of PMMA resin. It has superior wettability to carbon fibers and does not require treatment with a coupling agent.[5] Nylon fibers are polyamide fibers and show resistance to shock and repeated stressing. It has improved bonding to resin polymer upon treatment with silane coupling agent. The untreated fibers, however, act as inclusion bodies and weaken the resin.[6-11]

Chopped fibers allow only a small portion of reinforcement to be directed perpendicular to applied stress. However, unidirectional-oriented fibers perpendicular to the expected stress permit maximum resistance with minimum reinforcement.

MATERIALS AND METHODS

The present study was conducted *in vitro* on 40 PMMA denture base resin specimens. Specimens were divided into four subgroups with ten specimens each and tested for transverse strength using universal testing machine.
Group I: PMMA reinforced with glass fibers in random distribution (Fig. 1).
Group II: PMMA reinforced with nylon fibers in random distribution (Fig. 2).
Group III: PMMA Lucitone 199 (Fig. 3) and
Group IV: PMMA reinforced with polyaramid fibers in random distribution (Fig. 4).

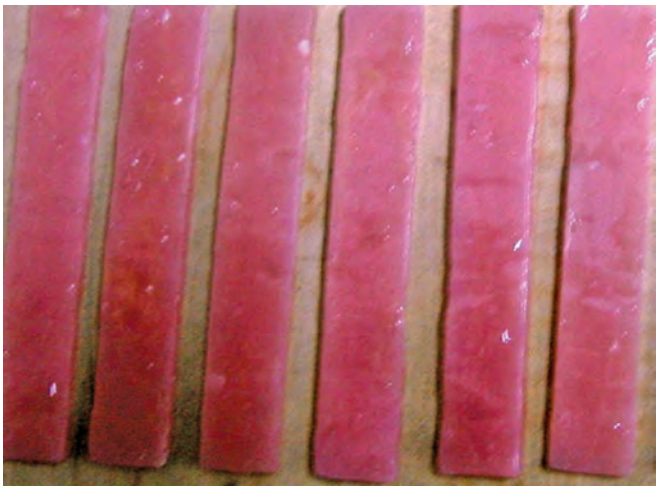

Fig. 1: Glass sample

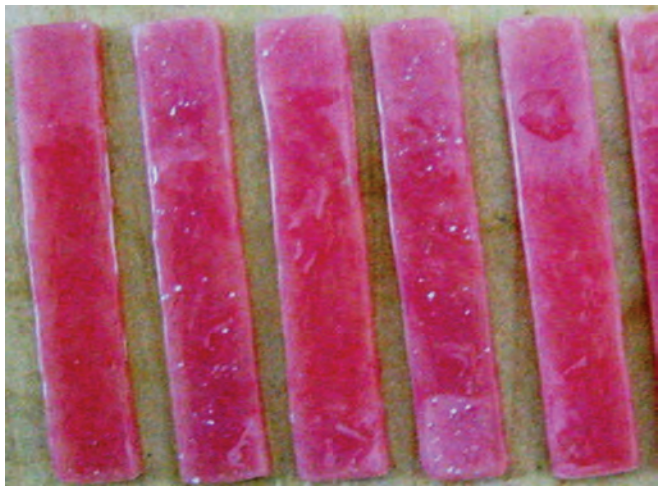

Fig. 2: Nylon sample

Fig. 3: Lucitone sample

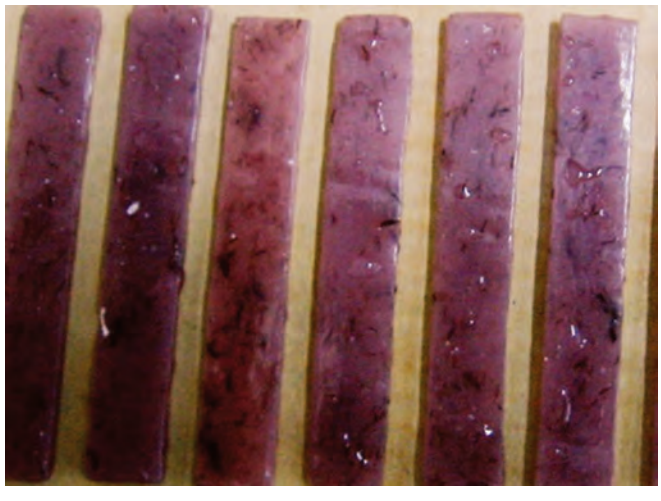

Fig. 4: Polyaramid sample

Preparation of PMMA Test Specimens (Control Group)

The control group test specimens were made with commercially available PMMA (Lucitone 199). Stainless steel blanks of size 65 × 10 × 2.5 mm were flasked in dental stone to form mold.

Poly-methyl-methacrylate powder and liquid were mixed as per manufacturer's recommendation (DPI, India) and packed in the mold. After trial closure, the flask was closed, ensuring metal-to-metal contact.

Polymerization was carried out in a thermostatically controlled Acrylizer; Confident India Ltd.

After 30 minutes of bench curing, PMMA specimens were removed from the flask and finished. Ten specimens were hence made.

Preparation of Fiber-reinforced PMMA Test Specimens

The amount of glass fibers incorporated into PMMA (DPI, India) was 4% by weight in each case in random distribution.

Random Distribution

The three experimental groups consisted of PMMA resin specimens of the same dimensions reinforced with glass, polyaramid (Kevlar), and nylon (Ceat Ltd, Calcutta, India) fibers.

These fibers had a thickness of 10 to 15 µm and were cut to 5 mm length. The cut fibers were soaked in monomer for 10 minutes for better bonding with the acrylic resin; after the fibers were removed from the monomer, excess liquid was allowed to dry. The resin and fibers (4% by weight) were mixed thoroughly to disperse the fibers. On reaching dough stage, the mixture was kneaded and packed into the prepared mold. The specimens were polymerized and recovered in the same manner as the control group. After deflasking, if the specimens revealed exposed fibers at the peripheral border, trimming was performed with diamond burs to avoid delamination of the reinforcement (Figs 1 to 4).

All specimens were stored in water at room temperature for 1 week before testing. Specimens were labeled on each end before testing so that the fractured pieces could be reunited and examined subsequent to testing.

All samples were tested for flexural strength with a three-point bending test with a universal testing machine at a crosshead speed of 2 mm/min. A load was applied by a centrally located rod until fracture occurred (Fig. 5).

The flexural strength was calculated with the following formula:

$$FS = 3/2 \ X \ PL / BD^2$$

Where FS is flexural strength, p is the peak load applied, l is the span length, b is the sample width, and d is the sample thickness.

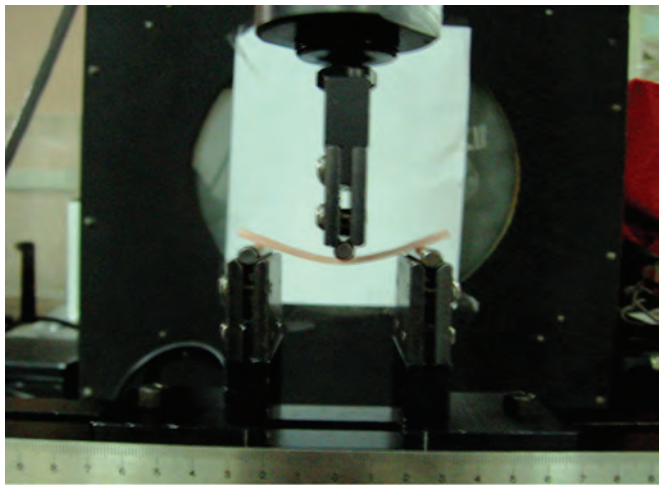

Fig. 5: Sample under three-point bend test

The results were analyzed with a one-way analysis of variance (ANOVA).

RESULTS

The present study was conducted at the Department of Prosthodontics, Private Dental College, Lucknow and IIT Kanpur to test the transverse strength of different fiber-reinforced denture base resins (Table 1).

In group I, the transverse strength ranged from 62.03 to 71.72 MPa with a mean value of 67.82 and a standard deviation of 2.83 MPa. No outlying or extreme value was observed. Evaluation of normalcy of data by using Kolmogorov–Smirnov test was found to be normal ($p = 0.704$) (Table 2).

In group II, the transverse strength ranged from 52.93 to 63.74 MPa with a mean value of 59.47 and a standard deviation of 3.42 MPa. Only one value (i.e., value no. 14)

Table 1: Group-wise distribution of samples

Sl. no.	*Groups*	*Fibers*	*No. of sample*	*Percentage*
1	I	Glass fiber	10	25
2	II	Nylon	10	25
3	III	Lucitone	10	25
4	IV	Kevlar	10	25

Table 2: Transverse strength in group I

Specimen no.	*Transverse strength (MPa)*
1	69.50
2	66.37
3	62.03
4	67.49
5	71.72
6	69.41
7	66.37
8	69.36
9	65.59
10	70.34

Table 3: Transverse strength in group II

Specimen no.	*Transverse strength (MPa)*
1	61.14
2	58.80
3	59.20
4	52.93
5	62.34
6	55.06
7	59.60
8	63.74
9	63.06
10	58.80

Table 4: Transverse strength in study group III

Specimen no.	*Transverse strength (MPa)*
1	62.51
2	64.36
3	60.20
4	59.90
5	69.60
6	69.30
7	63.44
8	76.80
9	69.70
10	72.84

Table 5: Transverse strength in group IV

Specimen no.	*Transverse strength (MPa)*
1	69.82
2	69.23
3	60.00
4	62.33
5	61.93
6	65.89
7	73.14
8	72.64
9	63.44
10	66.28

is shown as outlying value. Leaving this value apart, the range of distribution was 55.06 to 63.74 MPa. The distribution was normal (p = 0.704) (Table 3).

In group III, the transverse strength ranged from 59.90 to 76.80 MPa with a mean value of 66.87 and a standard deviation of 5.63 MPa. None of the values were outliers. The distribution was normal (p = 0.930) (Table 4).

In group IV, the transverse strength ranged from 60.00 to 73.14 MPa with a mean value of 66.47 and a standard deviation of 4.60 MPa. None of the values were outliers. The distribution was normal (p = 0.985) (Table 5).

Based on above observations, the following order of transverse strength in different groups was observed:

Group II < Group IV < Group III < Group I

Statistical Analysis

The statistical analysis was done using Statistical Package for the Social Sciences (SPSS) version 15.0, the statistical analysis software. The values were represented in number (%) and mean ± SD.

DISCUSSION

Oral appliances made of acrylic resin are prone to fracture during service due to repeated masticatory loading or accidental dropping. To overcome these shortcomings, one of the modalities suggested is reinforcement of acrylic resin with different types of fibers. Effective fiber reinforcement is dependent on many variables, including the type of fibers, the percentage of fibers in the matrix, the modulus and distribution of the fibers, fiber length, orientation, forms, and interfacial bond.[13-21]

In the present original research thesis work, 4% concentration of fiber reinforcement was done, which is in accordance with the findings of Gutteridge[12] who used 1%, 3% concentration of ultrahigh molecular weight polyethylene fibers, and reported that if fiber concentration was greater than 4% by weight, manipulation becomes difficult. Ladizesky et al[22] also found that more than 4% concentration of fiber increased impact strength, but had no effect on transverse strength.

In the present study, PMMA resin samples were compression molded for testing the transverse strength, which is in accordance with the findings of Karacer,[23] who noted that when glass fiber concentration was increased to 5%, the impact strength decreased while transverse strength was not clear in compression molded samples.

Stipho[24] found that the glass-reinforced specimens exhibited better flexural strength than the other specimen groups, which is in accordance with the present study findings. It might be due to the fact that as the modulus of elasticity of glass fibers is very high, hence most of the stresses are being received by them without deformation. Ozdemir and Polat[25] also observed an increase in transverse strength by addition of glass fiber.

In the present study, the values of transverse strength obtained were 59.90 to 76.80 MPa for PMMA and 62.03 to 71.72 MPa when glass fibers were added 4% by weight. These values were not in accordance with the findings found by Jacob et al[26] who reported a strength value of 624.6 to 825.4 MPa for PMMA and 825.4 to 1084.5MPa when glass fibers were added 2% by weight.

Baryaktar et al[27] stated that glass fiber reinforcement of denture base polymers is also clinically acceptable as residual monomer content does not exceed 1% level, which is within biological limits of safety. In the present study, glass fiber reinforcement of PMMA resin gave

maximum transverse strength. Hence it can be used as a safe option for denture reinforcement.

In the present study, use of aramid fiber reinforcement demonstrated a lower transverse strength compared to specimens reinforced with glass fibers. It can be due to the fact that aramid fibers have a plated structure, i.e., molecules are radially arranged in the form of sheets, making it weak.

Mullarky[5] and Berrong[28] stated that reinforcement with polyaramid fiber increased the transverse strength of PMMA resin, which is not in agreement with the findings of present study.

In the present study, nylon fiber reinforcement of PMMA resin decreased the transverse strength compared to unreinforced conventional PMMA resin, which is in agreement with the findings of Berrong.[28]

CONCLUSION

Within the limitations of this study, it was concluded that incorporation of 4% wt. of glass fibers in loose form significantly increased the transverse strength of denture base PMMA and incorporation of 4% wt. of polyaramid fibers in random distribution also significantly increased the transverse strength of denture base PMMA.

REFERENCES

1. Abraction E. Glossary of prosthodontic terms. Academy of Prosthodontics.
2. Tylman SD, Peyton FA. Acrylic and other synthetic resins used in dentistry. 2nd ed. Philadelphia: JB Lippincott Company; 1946. p. 1-5, 26-30.
3. Uzun G, Hersek N, Tincer T. Effect of five woven fiber reinforcement on the impact and transverse strength of a denture base resin. J Prosthet Dent 1999 May;81(5):616-620.
4. Schreiber CK. The clinical applications of carbo fiber/polymer denture bases. Br Dent J 1974 Jul;137(1):21-22.
5. Mullarky RH. Aramid fiber reinforcement of acrylic appliance. J Clin Ortho 1985 Sep;19(9):655-658.
6. Solnit GS. The effect of methyl methacrylate reinforcement with silicone – treated and untreated glass fibers. J Prosthet Dent 1991 Sep;66(3):310-314.
7. Schreiber CK. PMMA reinforced with carbon fiber. Br Dent J 1971 Jan;130(1):29-30.
8. Woelfel JB. Newer materials and techniques in prosthetic resin materials. Dent Clin North Am 1971 Jan;15(1):67-79.
9. Manley T, Bowman A, Cook M. Denture bases reinforced with carbon fibers. Br Dent J 1979 Jan;146(1):25.
10. Bowman AJ, Manley TR. The elimination of breakage in upper denture by reinforcement with carbon fibers. Br Dent J 1984 Feb;156(3):87-89.
11. Ladizesky NH, Chow TW. The effect of interface adhesion, water immersion and anatomical notches on the mechanical properties of denture base resins reinforced with continuous high performance polyethylene fibers. Aust Dent J 1992 Aug;37(4):277-289.
12. Gutteridge DL. Reinforcement of poly (methylmethacrylate) with ultrahigh modulus polyethylene fibers. J Dent 1992 Feb;20(1):50-54.
13. Chow TW, Ladizesky NH, Clarke DA. Acrylic resin reinforced with woven highly drawn linear polyethylene fibers. 2 water sorption and clinical trials. Aust Dent J 1992 Dec;37(6): 433-438.
14. Ramos V, Runyan DA, Christensen LC. The effect of plasma treated polyethylene fiber on the fracture strength of PMMA. J Prosthet Dent 1996 Jul;76(1):94-96.
15. Vallittu PK, Narva K. Impact strength of a modified continuous glass fiber poly (methyl methacrylate). Int J Prosthodont 1997 Mar-Apr;10(2):142-148.
16. Miettinen VM, Vallittu PK. Water sorption and solubility of glass fiber reinforced denture polymethylmethacrylate resin. J Prosthet Dent 1997 May;77(5):531-534.
17. Marei MK. Reinforcement of denture base resin with glass fillers. J Prosthodont 1999 Mar;8(1):18-26.
18. Waltimo T, Tanner J, Vallittu PK, Haapasalo M. Adherence of candida albicans to the surface of PMMA – E glass composite used in denture. Int J Prosthodont 1999 Jan-Feb;12(1): 83-86.
19. Foo SH, Lindquist TJ, Aquilino SA, Schneider RL, Williamson DL, Boyer DB. Effect of polyaramid fiber reinforcement on the strength of three denture base polymethylmethacrylate resin. J Prosthodont 2001 Sep;10(3):148-153.
20. Chen SY, Liang WM, Yen PS. Reinforcement of acrylic denture base resin by incorporation of various fibers. J Biomed Mater Res. 2001;58(2):203-208.
21. Kim SH, Watts DC. The effect of reinforcement with Woven E-glass fibers on the impact strength of complete dentures fabricated with high impact acrylic resin. J Prosthet Dent 2004 Mar;91(3):274-280.
22. Ladizesky NH, Pang MKM, Chow TW, Ward IM. Acrylic resin reinforced with woven highly drawn linear polyethylene fibers. 3-mechanical properties and further aspect of denture construction. Aust Dent J 1993 Feb;38(1):28-38.
23. Karacer O, Polat TN, Tezvergil A, Lassilla LVJ, Vallittu PK. The effect of length and concentration of glass fibres on the mechanical properties of an injection and compression molded denture base polymer. J Prosthet Dent 2003 Oct;90(4): 385-393.
24. Stipho HD. Repair of acrylic resin denture base reinforced with glass fiber. J Prosthet Dent 1998 Nov;80(5):546-550.
25. Ozdemir AK, Polat NT. The effect of glass fiber distribution on the transverse strength and surface smoothness of two denture resins. Dent Mater J 2003 Dec;22(4):600-609.
26. Jacob J, Gangadhar SA, Shah I. Flexural strength of heat polymerized PMMA denture resin reinforced with glass, aramid and nylon fibres. J Prosthet Dent 2001 Oct;86(4):424-427.
27. Baryaktar G, Duran O, Guvener B. Effects of water storage of E-glass fiber reinforced denture base polymers on residual methyl methacrylate content. J Biomed Mater Res B Appl Biomater 2004 Jul;70(1):161-166.
28. Berrong JM, Weed RM, Young JM. Fracture resistance of Kevlar reinforced poly (methyl methacrylate) resin-A preliminary study. Int J Prosthodont 1990 Jul-Aug;3(4):391-395.