ORIGINAL RESEARCH PAPER

Volume-9 | Issue-4 | April-2020 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

EFFECT OF FIBER REINFORCEMENT ON THE COMPRESSIVE STRENGTH OF HEAT CURE ACRYLIC RESINS- AN INVITRO STUDY.

Prosthodontics

Dr. N. Divya	Post graduate Student, Department of Prosthodontics & Crown and Bridge & Implantology, GITAM Dental College.
Dr. G. Sravani Seshanka	Post graduate Student, Department of Prosthodontics & Crown and Bridge & Implantology, GITAM Dental College.
Dr. K. Srinivas	MDS, Professor, Department of Prosthodontics & Crown and Bridge & Implantology, GITAM Dental College.
Dr. M. Hari Krishna	MDS, Reader, Department of Prosthodontics & Crown and Bridge & Implantology, GITAM Dental College.
Dr. Y. Ravi Shankar*	MDS, Professor & Head of the Department, Department of Prosthodontics & Crown and Bridge & Implantology, GITAM Dental College. *Corresponding Author
Dr. T. Satyendra Kumar	MDS, Reader, Department of Prosthodontics & Crown and Bridge & Implantology, GITAM Dental College.

ABSTRACT

Purpose: The main aim of this study is to evaluate the effects of adding 1%, 3%, and 5% glass, carbon, and aramid fibers on the compressive strength of a conventional heat polymerized acrylic resin.

Materials and Methods: Conventional heat cure acrylic resin with the incorporation of 1%, 3%, and 5% of glass, carbon and aramid fibers was studied. A standard die was used to fabricate 200 samples and compressive strength was measured with Universal Testing Machine.

Results: The highest values for compressive strength were found in PMMA with 3% glass fibers with mean of 45.20 ± 1.17 Mpa, 1% carbon fibers with a mean of 42.76 ± 4.85 Mpa and 5% aramid fibers with a mean of 48.55 ± 1.21Mpa.

Conclusion: Aramid fibers have shown a significant increase in 1%, 3%, and 5% of incorporated fibers.

KEYWORDS

Aramid fibers, Carbon fibers, Glass fibers, Compressive strength.

INTRODUCTION:

The clinical performance and success of PMMA resin is dependent upon the mechanical and physical properties of the material. [1] However, the primary concern is the denture's poor strength characteristics, which are the low compressive strength and impact strength. [2, 3]Attempts have been made to improve the mechanical properties of acrylic resin by reinforcement with different fibers in the form of powder, whiskers, and meshes. [4-8] This study was done to evaluate the effect of glass, aramid, and carbon fiber reinforcement on the compressive strength of heat cure acrylic resins.

Materials and Methodology:

The present study was conducted in vitro, and the total sample size taken was 200. The specimens were divided into four different groups in which one group was a control group with 20 samples and the other three groups with sixty samples, each of which was subdivided into three groups of 20 samples in each subgroup.

Grouping of samples: Group I: Unmodified PMMA (control group) (Figure:1)

Group II: Sixty PMMA samples reinforced with glass fibers (Figure:2) in three concentrations by random distribution which were subdivided into

IIa- 1% glass fibers
IIb- 3% glass fibers
IIc- 5% glass fibers

Group III: Sixty PMMA samples reinforced with carbon fibers (Figure: 3) in three different concentrations by random distribution which was subdivided into

IIIa- 1% carbon fibers
IIIb- 3% carbon fibers
IIIc- 5% carbon fibers

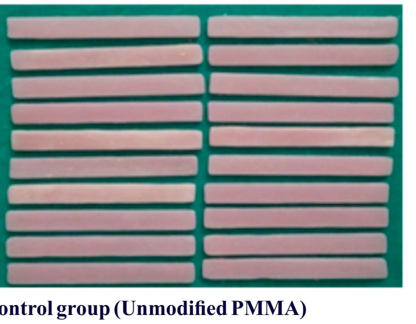


Figure:1Control group (Unmodified PMMA)

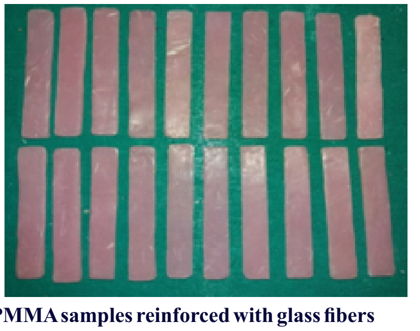


Figure:2PMMA samples reinforced with glass fibers

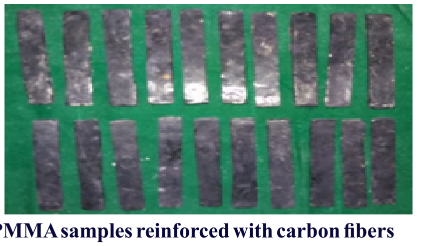


Figure:3PMMA samples reinforced with carbon fibers

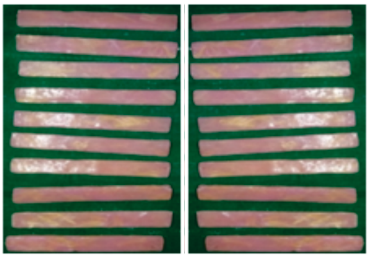


Figure 4: PMMA samples reinforced with aramid fibers

Group **IV**: Sixty PMMA samples reinforced with polyaramid fibers (Figure: 4) in three different concentrations by random distribution which was subdivided into

IVa- 1% aramid fibers

IVb- 3% aramid fibers

IVc- 5% aramid fibers

Preparation of control group test specimens:

The control group test specimens were made with commercially available PMMA (DPI, India). 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 the manufacturer's recommendation and packed in the mold. Acrylization was carried out in a water bath of cold water, which is heated gradually for 1 hour. After 30 minutes of bench curing, PMMA specimens were removed from the flask and finished. Twenty samples were hence made.

Preparation of Fiber-reinforced PMMA test specimens:

The amount of glass, carbon and aramid fibers incorporated into PMMA (DPI, India) was 1%, 3%, 5% by weight in each group. They were distributed randomly in the heat cure acrylic resin.

Random Distribution

The three experimental groups consisted of PMMA resin specimens of the same dimensions reinforced with E-glass (Owens corning advantex, Bombay, India) Polyaramid (Twaron aramid, Tejim, India) and Carbon (Toray T 700, Japan) fibers. These fibers had a thickness of 10 to 15 µm and were cut into 5 mm length. The cut fibers of glass, carbon, and aramid were soaked in a silane coupling agent (Monobond N, Ivoclar, India) for at least half an hour for better bonding with the acrylic resin; after that, the fibers were dried. The resin and fibers (1%, 3%, and 5%) were mixed thoroughly to disperse the fibers. On reaching the dough stage, the mixture was then kneaded and carefully packed into the mold space. The specimens were acrylised and retrieved in the same manner as the control group. After deflasking, if the samples revealed exposed fibers at the peripheral border, diamond burs were used to trim them. All samples were then stored in water at room temperature for one week before testing. Specimens were labeled on each end before testing so that the fractured pieces could be reunited and examined after testing. All samples were tested for compressive strength with a universal testing machine (Figure: 5&6) at a crosshead speed of 3 mm/min. A load was applied until each specimen reaches its breakpoint.

The compressive strength was calculated by using the formula:

CS= L/A

Where CS is compressive strength, L is the load applied load Applied and A is the area of each specimen.

The area of each specimen in this study is Area= length X width= 10X3 = 30mm^2

Figure:5 Universal testing machine

Figure 6: Sample testing under UTM

RESULTS:

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

From table 1, on comparison of compressive strength of 1%, 3%, and 5% of glass, carbon and aramid fibers, the significance value (p-value-0.08) shows that there was no statistical significance when 1% of glass, carbon and aramid fibers were compared. Among 1%, the compressive strength was highest for the control group with a mean value of 47.10, followed by the glass with a mean of 44.49, aramid with a mean of 44.46, and carbon fiberswith a mean of 42.76.

The significance value (p value<0.01) shows that there was a statistical significance when 3% of glass, carbon, and aramid fibers were compared. Among 3%, the compressive strength was highest for the control group with a mean value of 47.10, followed by aramid with a mean of 46.36, glass with a mean of 45.20, and carbon fiberswith a mean of 41.82.

The significance value (p value<0.01) shows that there was a statistical significance when 5% of glass, carbon, and aramid fibers were compared. Among 5%, the compressive strength was highest for the control group with a mean value of 47.10, followed by aramid with a mean of 48.55, carbon with a mean of 39.46, and glass fiberswith a mean of 38.59.

From table 2, on the intragroup comparison of aramid, carbon, and glass fibers. The significance value (p-value <0.01) shows that there was statistical significance when 1%, 3%, 5% of aramid fibers were compared and among them, 5% has shown highest compressive strength with a mean value of 48.55, followed by 3% with a mean of 46.36 and 1% with a mean of 44.46.

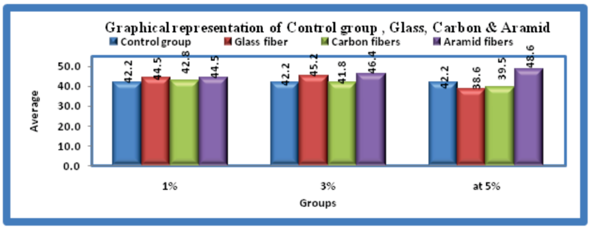
The significance value (p-value <0.01) shows that there was statistical significance when 1%, 3%, 5% of carbon fibers were compared and among them, 1% has shown highest compressive strength with a mean value of 42.76, followed by 3% with a mean of 41.82 and 5% with a mean of 39.46.

The significance value (p-value <0.01) shows that there was statistical significance when 1%, 3%, 5% of glass fibers were compared and among them, 3% has shown highest compressive strength with a mean value of 45.20, followed by 1% with a mean of 44.29 and 5% with a mean of 38.59.

Table 1: Comparison of compressive strength between mean values of the control group, Glass, Carbon & Aramid fibers.

Percentage	Group	Minimum	Maximum	Mean	SD	P-value
1%	**Control group**	41.90	47.10	42.16	1.29	0.08
	Glass fiber	44.20	49.30	44.49	4.60	
	Carbon fibers	46.66	51.00	42.76	4.85	
	Aramid fibers	33.33	46.80	44.46	1.63	
3%	**Control group**	41.90	47.10	42.16	1.29	<0.01*
	Glass fiber	37.90	47.10	45.20	1.17	
	Carbon fibers	33.30	44.00	41.82	2.89	
	Aramid fibers	40.00	43.50	46.36	1.64	
5%	**Control group**	41.90	47.10	42.16	1.29	<0.01*
	Glass fiber	35.90	50.00	38.59	6.19	
	Carbon fibers	42.90	46.80	39.46	3.90	
	Aramid fibers	30.00	50.40	48.55	1.21	

Graph 1: Graphical representation Compressive strength of Control group, Glass, Carbon & Aramid fibers

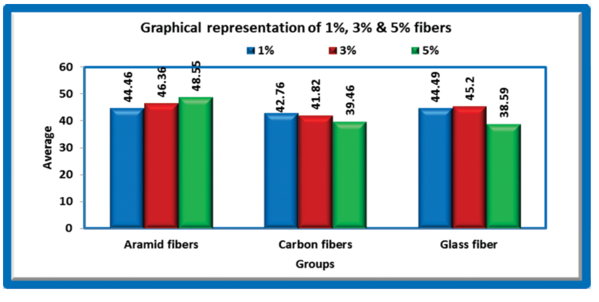


From graph 1, it was found that compressive strength,
In 1% of fibers: Glass fibers> Aramid Fibers > Carbon fibers
In 3% of fibers: Aramid fibers> Glass Fibers > Carbon fibers
In 5% of fibers: Aramid fibers> Carbon Fibers > Glass fibers

Table 2: Comparison of compressive strength between mean values of 1%, 3%, and 5% of each fiber.

Group	%	Minimum	Maximum	Mean	SD	P- value
Aramid fibers	1%	41.90	47.10	44.46	1.63	<0.01*
	3%	44.20	49.30	46.36	1.64	
	5%	46.66	51.00	48.55	1.21	
Carbon fibers	1%	33.33	46.80	42.76	4.85	<0.05*
	3%	37.90	47.10	41.82	2.89	
	5%	33.30	44.00	39.46	3.90	
Glass fiber	1%	35.90	50.00	44.49	4.60	<0.01*
	3%	42.90	46.80	45.20	1.17	
	5%	30.00	50.40	38.59	1.21	

Graph 2: Graphical representation of Control group, Glass, Carbon & Aramid fibers.



From graph 2, it was found that the compressive strength within the groups of
Aramid fibers: 5% >3% >1%
Carbon fibers: 1% >3% >5%
Glass fibers: 3% >1% >5%

DISCUSSION:

Polymethyl methacrylate has been established as principal material in denture base construction due to its good overall processing as well as user-friendly properties. The denture base is subjected to load during function as well as parafunction.[9] Factors that contribute to the stress concentrations will enable the initiation and propagation of the cracks, thereby influencing the rate of failure. [10]

Compressive strength is the stress required to rupture a specimen under the compression load. Compression failure in acrylic material depended on the properties of reinforced materials such as volume fraction, interface, shape, and size. [11]

Reinforcement of acrylic resin with different fibers has been shown to enhance the flexural strength, impact strength, and also fatigue resistance of the resin. [12]E- Glass, Aramid and Carbon fibers were selected in this study is 1%, 3%, and 5%.

Glass fiber reinforcement has been found to significantly increase the flexural strength, impact strength, toughness, and Vickers hardness of acrylic resin.Also, a significant reduction in deformation of the denture base to less than 1% deformation was found. [13]Moreover, a recent study found that the actual positioning of glass fibers within the acrylic denture base alters its flexural properties. Enhancement of flexural strength, toughness, and flexural modulus was obtained by placing the glass fibers closer to the surface of the acrylic denture base on its tensile stress side. When glass fiber was placed in a neutral stress area, only flexural toughness was improved, and when placed in the compressive side, the surface flexural modulus was increased. [14]

Aramid fiber-reinforced acrylic denture base was found biocompatible, and additionally, its flexural strength and flexural modulus were increased. [15]However, the hardness of the acrylic resin decreased with increasing fiber concentration. Also, its yellow color is considered a major drawback.

The addition of 1% of carbon fibers to acrylic was found to enhance the impact and flexural strength of the acrylic significantly, but its hardness was decreased. [16]Conversely, one study reported an insignificant effect of adding carbon fibers on the flexural strength of PMMA along with its blackish discoloration. [17]

The values of compression strength increased with increasing the percentage concentrations in aramid fiber group up to 5% and glass fiber group up to 3%. This is due to the strengthening mechanism and the nature of bonding. The adhesion between fibers and polymer matrix played an essential role in transferring the stress from the matrix to fibers, which is coinciding with the study conducted by Pekka K. Vallittu. [18]

But in the glass fiber group of 5% and the carbon fiber group, the values of compressive strength decreased as the percentage concentration of fibers was increased.It may be due to tendency of fibers to clump together when mixed with the polymer and resulted in porosity due to formation of void spaces in the resin matrix which is correlating with the study done by Stipho et al. [1]

Carbon fibers had difficult handling techniques, problems with polishing [9], poor esthetics due to the black color of the fibers [19], and potential toxicity. [20,21]Aramid fibers with their yellow hue and exposed fibers at the surface of the resin results in a rough surface, which made it difficult to polish. [9] Better esthetics was found with E- glass fibers and also good adhesion due to the silane coupling agent. [22,23]

CONCLUSION:

Within the limitations of the study, it was concluded that

1. In 1% of all the fibers, glass fibers have shown the highest strength, and carbon fibers have shown the least strength when compared to the control group.
2. In 3% and 5% of all the fibers, aramid fibers have shown the highest strength, and carbon fibers have shown the least strength.
3. From all the fibers, aramid fibers have shown a significant increase in all the concentrations.
4. In 1% of fibers of glass, carbon, and aramid, although the strength has increased, it is not significant.

Despite producing successful reinforcement, the black color of carbon fibers and the yellow color of aramid fibers imparted to the resin can be unacceptable to the denture wearers.

Hence the aramid fibers which are of more strength but unesthetic can be incorporated in the areas of dentures where fracture seems to happen commonly, i.e., in the mid palatal region of maxilla and the midline of the mandible.The areas in the dentures which are esthetic can be reinforced with 3% glass fibers as it was found to be better when compared to aramid and carbon fibers, although it gives some pale appearance.

REFERENCES:

1. Stipho HD. Effect of glass fiber reinforcement on some mechanical properties of autopolymerizing polymethyl methacrylate. Journal of Prosthetic Dentistry 1998; 79: 580- 584.
2. Lung CYK, El-Sheikh MA, Al-Zahrani BS. Causes of denture fracture: A survey. Saudi Dental Journal, 2006; 18: 149-154.
3. T. J. D. Kama, M. Zortuk and S. Eskimez, "Flexural Properties of Glass Fibre Reinforced Acrylic Resin Polymers," Australian Dental Journal, Vol. 51, No. 1, 2006, pp. 52-56
4. Ekstrand K, Ruyter UE, Wellendorf H. Carbon/graphite fiber-reinforced poly(methylmethacrylate): Properties under dry and wet conditions. Journal of Biomedical Material Research 1987; 21: 1065-1080.
5. Ladizesky NH, Ho CF, Chow TW. Reinforcement of complete denture bases with continuous high-performance polyethylene fibers. Journal of Prosthetic Dentistry 1992; 68: 934-939.
6. Valittu PK. A review of fiber-reinforced denture base resins. Journal of Prosthodontics 1996; 5: 270-276.
7. Valittu PK. Comparison of the in vitro fatigue resistance of an acrylic resin removable partial denture reinforced with continuous glass fibers or metals wires. Journal of Prosthodontics 1996; 5: 115-121.
8. Gautam V S Kumar, Anupama Nigam, Ahmed Naeem, Abhishek Gaur. 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.
9. D. C. Jagger, A. Harrison, and K. D. Jandt, "The Reinforcement of Dentures," Journal of Oral Rehabilitation, Vol. 26, No. 3, 1999, pp. 185-194.
10. Mathew E, Wain E A. Stresses in denture bases. Br. Dent J 1956; 100: 167.
11. Sihama Issa Salih, Jawad Kadhum Oleiwi, Qahtan Adnan Hamad. Investigation of Fatigue and Compression Strength for the PMMA Reinforced by Different System for Denture Applications. International Journal of Biomedical Materials Research. Vol. 3, No. 1, 2015, pp. 5-13.
12. Alla R, Sajjan S, Alluri V, Ginjupalli K, Padhya NU. Influence of fiber reinforcement on the properties of denture base resins. J Biomat Nano-Biotechnol. 2013; 4:91–97.
13. Moreno MV, Acosta-Torres LS, Barcel O-Santana FH, Vanegas-Lanc RD, Plata-Rodrıguez ME, Casta VM. Fiber-reinforced nano-pigmented poly (methyl methacrylate) as an improved denture base. J Appl Polym Sci. 2012; 126:289–296.
14. Agha H, Flinton R, Vaidyanathan T. Optimization of fracture resistance and stiffness of heat-polymerized high impact acrylic resin with local¬ized e-glass fiber reinforcement at different stress points. J Prosthodont. 2016; 25(8):647–655.
15. Yu SH, Ahn DH, Park JS, et al. Comparison of denture base resin reinforced with polyaromatic polyamide fibers of different orientations. Dental Mater J. 2013; 32:332–340.
16. Mahmood WS. The effect of incorporating carbon fibers on impact, transverse strength, hardness, and roughness to high impact denture base material. J Bagh Coll Dent. 2015; 27: 96–99.
17. Qasim SB, Al Kheraif A, Ramakrishaniah R. An investigation into the impact and flexural strength of light cure denture resin reinforced with carbon fibers. World Appl Sci J. 2012;18:808–812.
18. P. K. Vallittu, "The Effect of Void Space and Polymerization Time on Transverse Strength of Acrylic-Glass Fiber Composite," Journal of Oral Rehabilitation, Vol. 22, No. 4, 1995, pp. 257-261.
19. S. Y. Chen, W. M. Liang, and P. S. Yen, "Reinforcement of Acrylic Denture Base Resin by Incorporation of Various Fibres," Journal of Biomedical Materials Research, Vol. 58, No. 2, 2001, pp. 203-208
20. A. J. Bowman and T. R. Manley, "The Elimination of Breakages in Upper Dentures by Reinforcement with Carbon Fibre," British Dental Journal, Vol. 156, 1984.
21. N. Yazdanie and M. Mahood, "Carbon Fiber Acrylic Resin Composite: An Investigation of Transverse Strength," Journal of Prosthetic Dentistry, Vol. 54, No. 4, 1985, pp. 543-547.
22. P. K. Vallittu, "Curing of a Silane Coupling Agent and Its Effect on the Transverse Strength of Autopolymerizing Polymethylmetactylate-Glass Fibre Composite," Journal of Orthopaedic Research, Vol. 24, No. 2, 1997, pp. 124– 130.
23. P. Hari, A. Kalavathy, and H. S. Mohammed, "Effect of Glass Fiber and Silane Treated Glass Fiber Reinforcement on Impact Strength of Maxillary Complete Denture," Annals and Essences of Dentistry, Vol. 3, No. 4, 2011, pp. 7-12.