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Comparative Evaluation Of The Flexural Strength Of Heat Cure Acrylic Resin With Two Different Types Of Woven Fiber Reinforcements: An Invitro Study.

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ABSTRACT
Purpose: Conventional heat cure denture bases made of heat cure PMMA are the most used denture base material. It is aesthetically pleasing, economic, easily fabricated, repaired and is dimensionally stable in the oral conditions. Fracture of denture base made of PMMA is one of the most common problems. Strengthening by fiber reinforcements in the denture base material is based on the principle that polymer matrix is fully capable of transferring an applied load to fibres via shear forces at the interface. The purpose of this study was to evaluate and compare the flexural strength of woven carbon fiber reinforced and woven glass fiber reinforced heat cure pmma with that of the conventional pmma
Methods*: A total of 60 specimens were fabricated for flexural strength testing with dimensions of 64mm x 10mm x 3.3 mm and were divided into twenty specimens each of conventional group, woven carbon fiber reinforced group, and woven glass fiber reinforced group. These specimens were subjected to a three-point bending test in a universal testing machine. Statistical analysis was done using One-way ANOVA for comparison of mean values between the groups. Multiple comparison of mean differences in the values between the groups was performed using Tukey's Post hoc Analysis. Level of significance was set at P=0.05.*
Results: woven carbon fiber reinforced group exhibited the highest flexural strength followed by woven glass fiber reinforced group than the conventional group.
Conclusion: The study concluded that the woven fiber reinforced heat cure denture bases are promising materials with better flexural strength than the conventional heat cure denture base resin.

Key words: *complete denture; polymethyl methacrylate; woven fiber reinforced; carbon fiber; glass fiber*

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I. Introduction:

Excellent look, ease of processing and ease of repair are the three features that have contributed the most to the success of polymethyl methacrylate as a denture base material.[1] An acrylic resin denture has the potential to fracture intra orally, due to the repeated masticatory forces causing fatigue fracture, and extra orally due to the high impact forces which can occur as a result of the prosthesis being dropped, resulting in denture fracture.

Attempts had previously been undertaken to enhance the acrylic resin's mechanical qualities, with an emphasis on impact and flexural strength. These included copolymerizing resin with rubber and reinforcing with various fibres such as polycarbonate fibres, carbon fibres, glass fibres, and the addition of metal strengtheners.[2] Incorporating a rubber phase into the bead polymer is one way to improve impact strength. Rubber methacrylate graft copolymers generated through chemical modification are high impact resins. Another option is to use fibres to reinforce acrylic resin dentures. To increase the physical and mechanical qualities of acrylic resin dentures, different fibre kinds have been used.[3] Integrating multiple fibres with various fibre designs into the denture base polymer can improve the physical and mechanical qualities of removable prostheses. Graphite/carbon, glass and organic fibres with high molecular weight, such as aramide and polyethylene fibres with high molecular weight, are utilised to strengthen the flexural and impact strength of denture base polymer.[4] Edison was the first to commercialize carbon fibres by carbonizing thin bamboo shoots and cotton fibres in the late 1800s.

Polyacrylonitrile is used to make the bulk of carbon fiber, which is heated in an inert environment at 1200°C after being heated in air at 200°C to 250°C. Carbon fibres are formed when H2, N2 and O2 are removed from a chain of carbon atoms. Carbon fibres may be woven or knitted into a variety of materials. Carbon fibres have low density, excellent tensile strength, high thermal and chemical stability.

The inclusion of surface-treated carbon fibres by Schreiber improved the impact and transverse strength of polymethyl methacrylate. Skirvin et al. demonstrated that incorporating randomly oriented carbon fibres coated with a silane coupling agent into the resin prior to processing increased fatigue resistance from 42% to 100%. [5]

The most acceptable fibres for dental base resins reinforcements are glass fibres, because of their good aesthetics and good bonding with polymers via silane coupling agents. They are simple to manipulate, aesthetically pleasing, enhances the mechanical qualities of denture base polymers and provide a metal-free solution with no additional bulk added to the prosthesis. E-glass fibres often known as electrical glass is a good electrical insulator is the most commonly preferred type of glass fibers in dentistry.[6,7] Hence, a comparative evaluation of the flexural strength of heat cure acrylic resin with two different types of woven fiber reinforcements (carbon fiber (WCF) and glass fiber (WGF)) is carried out to determine whether the woven fiber reinforcements could enhance the mechanical properties of acrylic dentures. The null hypothesis states that there is no significant difference between the flexural strength of conventional and woven carbon fiber and woven glass fiber.

II. Methodology

This in-vitro study was conducted in the Department of Prosthodontics, The Oxford Dental College, Bangalore, and the analysis of the flexural strength of heat cured denture base material reinforced with WCF and WGF was done using Universal Testing Machine at the Indian Institute of Science, Bangalore. A total of 60 samples measuring 64mm x 10mm x 3.3mm (ISO 1567: 1999) were used in this study. The samples were further divided into three main groups (Group A, Group B, Group C) consisting of 20 samples each. ➢ GROUP A (Control group) — Twenty specimens without reinforcements

➢ ***GROUP B***- Twenty specimens with glass fiber reinforcement.

➢ ***GROUP C***- Twenty specimens with carbon fiber reinforcements. Heat activated polymethyl methacrylate (HC-PMMA) resin (DPI), Glass fiber (Fiber region), carbon fiber (Ruthinium fibra), Resina base (Ruthinium fibra), Catalizzatore (Ruthinium fibra) were used in the study.

FIGURE1: armamentarium used in the study

Group A: Heat polymerized acrylic resin:

HC-PMMA (DPI) polymer and monomer were combined in a porcelain jar at a volume-to-weight ratio of 3:1 and packed into the mold cavities during the dough stage of the setting reaction. The flask was secured with a clamp, then bench-cured for 30 minutes. The flask was submerged in the acrylizer for a long curing cycle (8 hours at 74^0C). Following which, the flask was subjected to bench cooling overnight and samples were finished and polished according to standard protocol. For best strength, these samples were kept in distilled water for a week.

GROUP B: Heat polymerized acrylic resin reinforced with WGF:

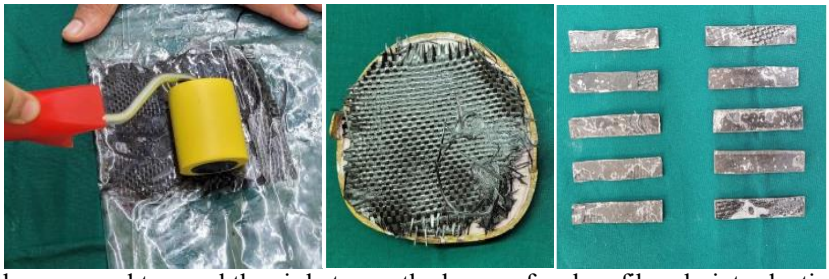
The WGF was cut into 55 mm and 10 mm length pieces. For better bonding, these cut fibers were soaked in monomer for 10 minutes, and any extra liquid was then allowed to dry. HC-PMMA (DPI) polymer and monomer were mixed in the ratio 3:1 by volume (2:1 by weight) in porcelain jar and was packed into the mold spaces during the dough stage of setting reaction with the pre-soaked WGF. The flask was set for bench curing and long cycle curing similar to group A specimens.

 a

2) Adaptation of the pre-soaked e-glass fiber into the mould space along with heat-cure PMMA

GROUP C: Heat polymerized acrylic resin reinforced with WCF:

The carbon fiber was first fabricated according to the manufacturers instructions and then was introduced with HC-MMA for curing to fabricate the group c specimens. According to the manufacturer's instructions the Resina Base (Ruthinium fibra) and Catalizzatore (Ruthinium fibra) were mixed in a ratio of 3:1 by weight and the WCF sheet was impregnated with resin. The outer edge bordered by the paper adhesive tape were trimmed. The sheet was cut into rectangles according to a template prepared according to the required dimensions. Three of the cut rectangle sheets were overlapped and a roller was used to expel the air between the layers. The template was placed on the sheets and the edges were trimmed. The mould was then inserted with the impregnated fibers and placed inside a food grade vacuum bag and sealed after vacuuming. The vacuum sealed mould was put in water at room temperature and the water was brought to 80^0 C and the temperature was maintained at that temperature for 2½hours. Post curing cycle, the product was removed, allowed to cool and then finished.

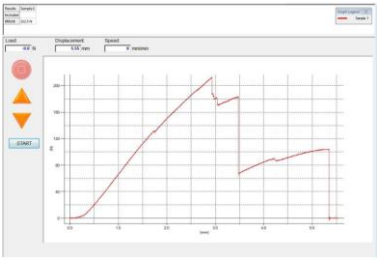


Figures: a: a roller was used to expel the air between the layers of carbon fiber; b: introduction of carbon fiber into the prefabricated mould; c: the processed carbon fiber in the predetermined dimensions

HC-PMMA (DPI) polymer and monomer were mixed in the ratio 3:1 by volume (2:1 by weight) in porcelain jar and was packed into the mold spaces during the dough stage of setting reaction with the cured WCF. The flask was set for bench curing and long cycle curing similar to group A specimens.

Testing specimen for Flexural strength:

The measurements of all samples were standardized using digital calliper. Flexural strength test was performed according to ISO 1567: 1999. The evaluation of the flexural strength was carried out in a Universal Testing Machine (Mecmesin, Multitest 10i) under three-point bending test at a cross head speed of 5mm/min. This device consisted of a central loading plunger band with two polished cylindrical supports. The distance between the centers of the support was 50mm. The load was applied perpendicular to the center of the samples until the deviation of the load deflection curve and fracture of samples occurred. Flexural strength was calculated using the formula: FS = 3 FL/(2bd) Where, FS is flexural strength (MPa), F is the load or force at break (N), L is span of specimen between the supports (50 mm) b the width (10 mm), d the thickness (3.3 mm).
Load-deflection curve and load at break of specimen of Group C subjected to three-point bend test.



III. Results

Load at break for each specimen was procured from the load-deflection curve that was obtained for each specimen from three-point load test in an UTM. The flexural strength values of every specimen in the group were used to compute the mean. Comparison of mean flexural strength among the three fiber types (groups) namely, Conventional Fiber (Control Group), Glass Fiber (Experimental Group 1) and Carbon Fiber (Experimental Group 2) was done using the statistical tool one way Analysis of Variance (ANOVA) test. The results obtained proved a statistically significant difference among the three groups ($P<0.05$).

Multiple comparison of mean difference in flexural strength between the groups was performed using Tukey's Post hoc Analysis to know which pair of groups is significantly different. The Post hoc test demonstrated that all three groups in the study are significantly different from each other in the flexural strengths ($P<0.05$). The mean difference between Conventional and Woven Carbon fiber group is maximum (51.3888) followed by the difference between Glass fiber and Carbon fiber (29.972). The minimum mean difference is between Glass fiber and Carbon fiber groups, which also show statistically significant difference in the mean flexural strength.

From the results obtained through this study, one can infer that woven carbon fiber reinforced heat cure PMMA samples has the highest mean flexural strength (160.42 MPa), followed by woven glass fiber reinforced heat cure PMMA (130.44 MPa) and the conventional heat cure PMMA resin samples (109.03 MPa). Hence the null hypothesis can be rejected as there is significant difference between the flexural strength of the conventional and woven carbon fiber and woven glass fiber reinforced acrylic samples.

I Groups	J Groups	Mean Difference (I-J)	95% Confidence interval for the difference		P- Value
			Lower	Upper	
Conventional Fiber	Glass Fiber	-21.416*	-36.560	-6.2725	0.003
	Carbon Fiber	-51.388*	-66.532	-36.2445	0.000
Glass Fiber	Carbon Fiber	-29.972*	-45.116	-14.8285	0.000
P<0.05 – Statistically Significant					

IV. Discussion:

The primary intraoral and extraoral causes of denture fractures, respectively are flexural fatigue brought on by repetitive masticatory stresses and high-impact forces brought on by dropping the prosthesis. Repeated flexing causes flexural fatigue, which is characterised by the formation and spread of microcracks in the stress concentration zones.[8]

Flexural strength is the ability of materials to resist bending deflection when energy is applied to the structure. Flexural strength which is also called as transverse strength and modulus of rupture is a strength test of a bar supported at each end under a static load.[9] When an object flexes under load, the length of the surface towards which the bending occurs increases, and the principal stresses on this surface are compressive stresses. On the other hand, the length of the surface that the bending occurs away from decreases, and the main forces on this surface are compressive stresses. On the object's supported ends, shear stress is also observable, but it has no effect on the way the object fractures.

The results in the present study was similar to a study conducted by Isa et al. where they studied and compared the flexural properties of denture bases reinforced with carbon, aramid, and glass fibers, which were arranged in long axis of the specimen and it was found to be the flexural strength of denture base polymers reinforced with carbon fibres were more than the other fibers studied.[10]

N. Yazdanie, et al in 1985 conducted a study where he concluded that carbon fiber reinforced acrylic resins are stronger and stiffer than the unfilled acrylic resin.[6] PMMA resin has been reinforced with a variety of fibre types, including carbon, glass, and E-glass fibres. Significant investigations have been made in this subject with an improvement to the mechanical properties. However, fibre's capacity to strengthen the denture base was discovered to depend on the unique characteristics of the fibres and resin matrix; the fibres are impregnated with resin; fibre volume; and fibre's adherence to the matrix, the fibre's orientation within the composite matrix; and

fibre placement within the prosthesis. Carbon fibers were used to improve the mechanical property of the acrylics; however, it was found that dry carbon fibers were difficult to handle hence wetting of the carbon fiber with monomer had to be done to be used with heat-cure acrylic. Silane coupling agents impregnated carbon fibers showed better flexural, impact strength.

According to D. C. Jagger et al the different orientations of carbon fibers when placed perpendicular to the applied force showed increased resistance to the stress which significantly improved the flexural fatigue of the fiber reinforced acrylics. This study full-filled the essential requirements for obtaining carbon reinforced polymers as described by Chow (1996) i) The reinforcement must have strong adhesion to the matrix, which is a requirement for the reinforcement to ultimately withstand external loads. ii) Good wettability to the matrix in order to maximise molecular interaction between the two phases. The reinforcement should be positioned to maximise its function at the stress-bearing phase in order to provide maximum adhesion and prevent voids that could create potential locations for crack initiation and propagation. [11] Similarly in the present study a combination of the base and a catalyst were mixed in a ratio of 3:1 by weight and the woven carbon fiber was impregnated with it and a roller was used to remove the air entrapped between the different layers which were overlapped at different angulations to enable distribution of the forces in the acrylic. Hence the improved flexural strength of the woven carbon fiber reinforced heat cure acrylic denture bases would mainly attribute to the resin base used for wetting of the carbon fibers.

According to a study conducted by John J et al the flexural strength of the glass fiber reinforced specimens ranged from 825.4 to 1048.5 MPa, with a mean of 979.2 MPa, the highest among all groups while the conventional group had a range of 624.6 to 825.4 MPa, with a mean of 696 MPa. Thus, proving that the glass fiber reinforced denture base resins are better. Glass fibres can withstand the majority of loads without deforming due to their extremely high modulus of elasticity.12 According to a study by L. Goguta et al the incorporation of multiple unidirectional or woven glass fibers improves the mechanical property of the reinforced heat cure acrylic resins.13 A strong adhesion between the glass fibers and the acrylic resin matrix improves the mechanical properties. Hence silane treated E- glass fiber which is pre-soaked in monomer for 15mins is used in this study.

For the purpose of employing fibres to reinforce denture bases, Vallittu (1997) put forward the total fibre reinforcement (TFR) and partial fibre reinforcement (PFR) concepts. While PFR typically includes placing the reinforcing agent at the weakest area of the prosthesis, TFR entails uniformly dispersing the reinforcing agent throughout the matrix material. With fibres aligned in one direction, fibre composites can achieve their maximum strength. TFR, which come in multidirectional weave or mat form, are stronger than PFR, which are unidirectional. Multidirectional fibres can cause tissue irritation when they protrude from the denture surface, which is one of its main drawbacks. [14]

V. Limitations of the study:

The present in-vitro study had some limitations.

¬ Thermocycling used to simulate oral environment was not carried out in this in vitro study.

¬ Specimens were fabricated in cuboid shape according to ISO standards, hence the effect of denture base fabricated according to residual ridge anatomy could not be evaluated.

¬ Only one physical property that is Flexural Strength has been checked in this study.

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