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A Comparative Study to Evaluate The Effect of Polyethylene And Polypropylene Fibers Reinforcement on The Flexural Strength of Denture Base Resin - An *in vitro* Study

Dr. Keshav Mundra E-3, Senior MIG-7, Arera Colony , Bhopal 462016, Madhya Pradesh

Gunjan Chouksey E-3, Senior MIG-7, Arera Colony , Bhopal 462016, Madhya Pradesh

ABSTRACT

Background and Objectives: Reinforcement of denture base resin may offer significant advantages in clinical performance of the material, especially fracture toughness. Fiber reinforcement has been used to overcome the mechanical limitations of denture base polymers. Reinforcement with various fiber types should strengthen acrylic denture bases. The objective of this study was to evaluate and compare the effect polyethylene and polypropylene fiber reinforcement on the flexural strength of denture base resin.

Materials and Methods: Samples were divided into 3 groups, Control group (A) made of conventional heat cure denture base resin and the Test Groups B made of Conventional heat cure denture base resin reinforced with 2% by weight of Polyethylene fibre and Test Group C made of Conventional heat cure denture base resin reinforced with 2% by weight of Polypropylene fibre. The fibers were immersed in a beaker with monomer liquid for better adhesion with the resin matrix. Mixing was done incrementally for thorough dispersion of fibers. Once the mix reached the dough consistency, it was kneaded by hand to increase its homogeneity and integrity and then packed in the mold space prepared by using metal die with dimensions of 65mm x 10mm x 3mm. All the samples were processed by the curing cycle as recommended by the manufacturer. All the samples were stored in water at 37±1 0C for 50±2 hours prior to testing. The fracture tests were carried out using a Universal testing machine.

One-way ANOVA test was used for multiple group comparison followed by Tukey's Post Hoc test for pair-wise comparison during statistical analysis.

Results: Incorporation of Polyethylene and Polypropylene fibers significantly reduce the flexural strength of Denture base resin.

Interpretation and Conclusion: Incorporation of Polyethylene and Polypropylene fibers failed to assist in strength of conventional denture base resin.

KEYWORDS : Conventional heat-cure denture base resin, Polyethylene fibers, Polypropylene fibers, Flexural strength, Reinforcement.

INTRODUCTION:

Poly methyl-methacrylate is commonly used for denture fabrication because of its ease of processing, favourable working characteristics, accurate fit, stability in oral environment, superior aesthetics, use with inexpensive equipments and adequate mechanical properties.[1]

One of the disadvantages of this material is breakage resulting from impact fracture, as an accidental dropping of the denture during cleaning or from fatigue fracture, which is often seen in complete maxillary denture, where continual flexing of the denture base during function leads to crack development.[2]

It is generally recognized that the impact strength and fatigue strength of Poly methyl-methacrylate denture base polymer is not entirely satisfactory. [3,4] Strength of the denture base material can be improved by substituting by nylon, polycarbonates and polyamides, chemical modification through the addition of rubber in the form of butadiene styrene or incorporation of fibres like Carbon fibres, Glass fibres, Polyethylene fibres and Kevlar fibres.[5]

Carbon fibres have restricted use in dentistry as the black colour of the carbon fibres imparted to the resin is unacceptable to some denture wearers , it has difficult handling characteristics and there is a possibility of toxicity.[6] Various forms of glass fibres have been tried including woven, loose and continuous such as roving or fibre bundles. [5] Polyethylene fibers are biocompatible, are of low density and high modulus, esthetically satisfactory and have been successfully incorporated into acrylic denture base with reported improvement in the mechanical properties of the resin. [7]

A polypropylene fibre has natural colour and good mechanical properties. Because of its excellent biocompatibility it has been used in general surgery for closure of abdominal wounds and in oral and maxillofacial surgery. To date, very few studies have been reported in the dental literature using polypropylene fiber for reinforcement in denture base. [8]

AIM & OBJECTIVE:

The aim of this study was to compare the effect of polyethylene and polypropylene fibre reinforcement on the flexural strength of denture base resin.

The objective of the study was to evaluate the effect on flexural strength by reinforcing heat cure acrylic resin with polyethylene fibers and polypropylene fibers and to compare the effect on flexural strength by reinforcing heat cure acrylic resin with polyethylene, polypropylene fibers and control group.

METHODOLOGY:

Preparation of mould (Figure 1, 2)

Figure 1: Metal moulds invested in flask.

Figure 2: Mould space after removal of metal moulds

Dental stone moulds were prepared in dental flask, each containing 2 rectangular dies (each 65mm x 10mm x 3mm) 32. The dies were coated with a thin layer of petroleum jelly before being invested. The flask base was prepared using Type II gypsum product and the dies were invested. A new coat of petroleum jelly was applied before final pouring of Type III dental stone was done. After complete setting of stone, flask was opened to obtain mold space of uniform thickness. The mold space thus obtained was used for the preparation of acrylic samples that were divided into three groups:

Group A – Control group (Conventional denture base resin)

Group B – Conventional denture base resin (Trevalon) reinforced with polyethylene fibers.

Group C - Conventional denture base resin (Trevalon) reinforced with polypropylene fibers.

Preparation of test samples (Figure 3)

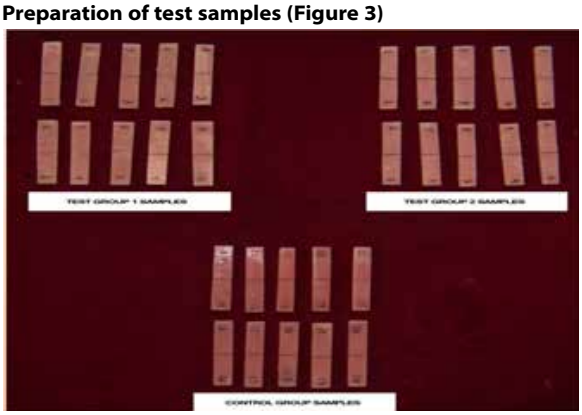

Figure 3: Finished specimens.

Group A (Control Group): Conventional heat cure denture base material (Trevalon) was taken in a powder-liquid form. Alginate separating media was applied on the dental stone mould with the help of brush and dried. The specimen was fabricated using standard techniques with mixture of monomer and polymer in ratio of 1: 2.4 by weight. When the mixture reached the dough stage, it was kneaded and packed into the mould. The flasks were clamped and closure was done under pressure of 20 KN and kept for 30 min to allow for proper penetration of monomer into polymer and even flow of material. The flasks were immersed in an acrylizer for curing. The temperature was raised slowly to 74^{0}C and held for 2 hours, and then raised to 100^{0}C and was maintained for 1 hour.33 After the completion of the curing cycle, the flasks were allowed to bench cool to room temperature. After overnight bench cooling, cured samples were carefully removed from the mold and excess was trimmed and finished. The samples were finally finished with silicone carbide paper, 80-200 grits size.

Group B (Test Group): Conventional heat cured denture base material (Trevalon) reinforced with 2% polyethylene fibers was used to prepare 10 samples. For each sample to be made, 100 gm of polymer powder was used with appropriate amount of monomer liquid. 2 gm of polyethylene fiber was weighed using electronic measuring balance to be used for each sample. This measured quantity of fibers was immersed in a beaker for 10 min with the minimum amount of monomer that was compatible for thorough wetting12. The fibers were removed from the monomer and allowed to dry. These fibers were then mixed thoroughly with polymer. Polymer and monomer was mixed in the ratio of 1:2.4 by weight. After the material reached the dough stage, it was kneaded and packed into the mold. The samples were polymerized, recovered, finished and polished as stated for control group.

Group C (Test group): Conventional heat cured denture base material (Trevalon) reinforced with 2% polypropylene fibers was used to prepare 10 samples. For each sample to be made, 100 gm of polymer powder was used with appropriate amount of monomer liquid. 2 gm of polyethylene fiber was weighed using electronic measuring balance to be used for each sample. This measured quantity of fibers was immersed in a beaker for 10 min with the minimum amount of monomer that was compatible for thorough wetting. The fibers were removed from the monomer and allowed to dry. These fibers were then mixed thoroughly with polymer. Polymer and monomer was mixed in the ratio of 1:2.4 b weight. After the material reached the dough stage, it was kneaded and packed into the mold. The samples were polymerized, recovered, finished and polished as stated for control group. All the samples were stored in water for 50±2 hours at 37^{0}C prior to fracture test.32

Mechanical Strength Test (Figure 4, 5)

Figure 4:Samples in Universal Testing Machine

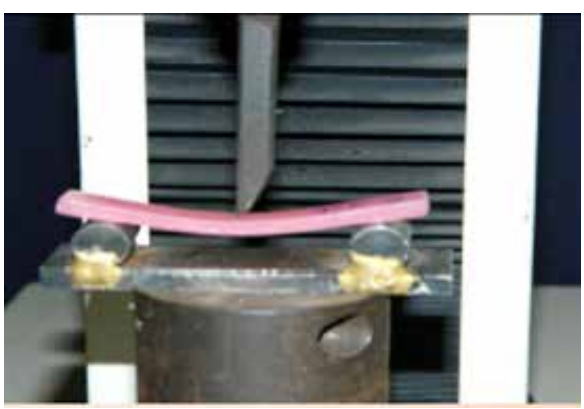

Figure 5: Flexion of test specimen during testing

Mechanical strength test was carried out in the textile department, BIET, Davangere. The mechanical strength of each sample was tested on Hounsfield universal testing machine under 3 – point loading with a cross head speed of 0.5cm/min. A transverse testing jig, which consisted of 2 parallel stainless steel rods that supported the specimen was used to apply load centrally. The span of this 3- point deflection test was 50mm.

Transverse strength were calculated with the formula S = 3 LP/ 2 WT2

P = Fracture load, L = Distance between the support (50 mm), W = Width of specimen (10 mm), T = Specimen thickness (3mm)

RESULT:

The aim of this study was to do comparative evaluation of the effect of Polyethylene and Polypropylene fibres reinforcement on the flexural strength of denture base resin.

Ten samples were made of each group (control and test) and fracture tests were carried out using Universal testing machine and checked for flexural strength. Control specimens that were not reinforced with fibres broke cleanly into two pieces. While specimens reinforced with fibres exhibited "greenstick" fractures in which observable fracture had occurred. **(Figure 6)**

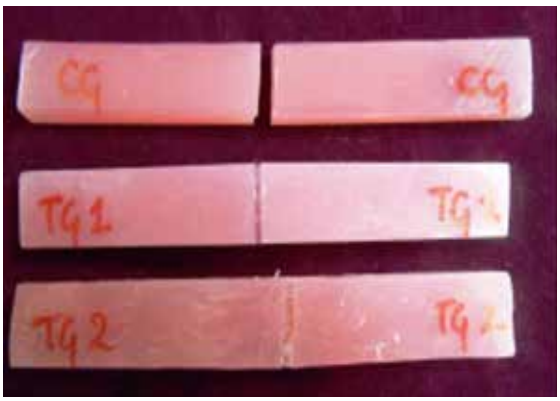

Figure 6:Broken specimens (CG: Control Group, TG1: Test Group 1, TG2: Test Group 2)

Table I shows the flexural strength of 3 study groups with 10 samples each. Mean and standard deviation were calculated. Highest mean strength was recorded from control group followed by group B and Group C.

Table II describes comparison between the flexural strength of each of the test group with control group. One way ANOVA statistical test was done to know whether any statistical difference exists between the groups. Significance (p) value was set at $p<0.001$ to be considered as highly significant.

Table III shows final results after statistical analysis using Tukey's Post Hoc test. When compared to Group A (control), Group B and Group C gave significant decrease in flexural strength. When compared to Group B, Group C gave significant decrease in flexural strength.

DISCUSSION:

Polymethyl methacrylate polymers were introduced as denture base materials in 1937.[9] However, the fracture of dentures made from acrylic resin (Polymethyl methacrylate) is an unresolved problem. The modes of failure are flexural fatigue failures caused by occlusal biting force and impact force failures caused by dropping of denture.

In polymer-fibre composites, fibres are embedded in polymer matrix, which bind the fibres and forms a continuous phase surrounding the fibres thus improving the mechanical property. The polymer matrix transfers loads to the fibres, which are stronger component. The stiffness of fibres is an important property for reinforcement of brittle materials, such as denture base resins. Thus, ordinary textile fibres, though they may have high tensile strength, are not stiff enough to reinforce PMMA. The adhesion between fibres and polymer matrix plays an important role in transferring stress from the matrix to the fibres. Studies have shown that the area of the interface bond between polymer and fibres increases by treating ultra-high modulus polyethylene (UHMPE) fibre surface with plasma. Therefore, plasma treated UHMPE fibres should enhance the mechanical properties more than untreated fibres. [10]

Another important factor affecting the strength is impregnation of fibres with the polymers i.e. voids should not be present in the structure. Effective impregnation allows the resin matrix to come into contact with the surface of every fibre.

The two fibres used in the study were Polyethylene and Polypropylene fibres which are the most common member of olefin family. These fibres are very light weight, have high strength and modulus, resistance to deterioration by chemicals, abrasion resistant, resistant to moisture absorption, resilient and not brittle.

In this in-vitro study, samples were divided were divided into 3 groups, Control group or Group A made of conventional heat cure denture base resin and the Test Groups i.e., Group B made of conventional heat cure denture base resin reinforced with 2% by weight of Polyethylene fibre and Group C made of conventional heat cure denture base resin reinforced with 2% by weight of Polypropylene fibre.

Since any increase in fibre incorporation beyond 3% by weight will affect the flow of dough. Hence, a standard 2% by weight of each type of fibre was added to each specimen in this study.[11]

The control group (n=10) consisting of conventional denture base resin had flexural strength ranging from minimum of 92.69 MPa to maximum of 105.74 MPa, with the mean value of 98.92 MPa. Group B (n=10) consisting of conventional denture base resin reinforced with polyethylene fibres had flexural strength ranging from minimum of 83.8 MPa to maximum of 94.65 MPa with the mean value of 87.72 MPa. Group C (n=10) consisting of conventional denture base resin reinforced with polypropylene fibres had flexural strength ranging from minimum of 74.23 MPa to maximum of 89.75 MPa with the mean value of 78.14 MPa.

When compared to control group, the flexural strength of test groups containing polyethylene and polypropylene fibres was found to be significantly lesser ($p< 0.01$). This indicates that inclusion of polyethylene and polypropylene fibres has no effect on the transverse strength.

In this study, multiple group comparison was done by using one way ANOVA test followed by pair wise comparison done using Tukey's Post hoc test. Significant difference was observed in mean flexural strength values when comparing control group with Group A, control group with group B and also between Group B and Group C.

Similar results were found by Gutteridge who concluded that inclusion of UHMPE fibre has no marked effect on the transverse strength. Inclusion of 1% untreated UHMPE fibre reduces the transverse strength, although result is not highly significant. [12] The results are in correlation with another study done by Uzun et al who concluded that fibre reinforcement had no significant effect on transverse strength. Specimens containing polyethylene fibres slightly decreased the transverse strength of acrylic resin.[8] On the contrary Braden et al carried out flexural strength testing of Trevalon resin reinforced with longitudinally oriented UHMPE fibre, both untreated and plasma etched, and found that the plasma etch fibre improved this value by one third.[10]

Result of present study showed that inclusion of untreated polyethylene and polypropylene fibres reduces the flexural strength of denture base resin, reason for which may be that untreated fibres could act as inclusion bodies in the acrylic resin mixture and instead of strengthening actually weakens the resin by breaking up the homogenous matrix.[13]

LIMITATIONS OF THE STUDY:

In this study specimens were prepared in accordance with ISO 1567 (1999) specification. Though the study was carried out with utmost accuracy, it has certain limitations which are enlisted below.

1) In spite of the following the standard and uniform protocol for preparing , curing and finishing of all specimens , the homogeneity of mix , presence of internal porosities and release of stress during finishing and polishing procedures could not be controlled.

2) In the oral cavity, denture bases are subjected to forces of varying magnitudes acting in different directions. The same situation could not be simulated in this in vitro study.

3) In clinical situations, a uniform thickness of denture base resin may not be 3mm, as used in this study.

CONCLUSION:

Within the limitations of the study, the following conclusions were drawn:

- Reinforcement with 2% polyethylene fibres decreases the flexural strength of conventional heat cure denture base resin
- Reinforcement with 2% polypropylene fibres decreases the flexural strength of conventional heat cure denture base resin

SUMMARY:

Mechanical strength of denture base resins is of great concern, and many approaches have been used to strengthen acrylic resin dentures. Generally there are three routes which have been investigated to improve the properties of PMMA:

a. Development of an alternative material of PMMA.
b. The chemical modification of PMMA such as by addition of rubber graft copolymer.
c. Reinforcement of PMMA with other materials such as carbon fibres, glass fibres and ultra-high modulus polyethylene fibres.

This in-vitro study was done to compare the flexural strength of denture base resin made of conventional heat cure acrylic resin reinforced with 2% polyethylene and 2% polypropylene fibres with that of conventional denture base resin. Acrylic resin specimens 65x10x3 mm were fabricated using customized metal mould. A total of 30 standardized specimens were fabricated and stored in distilled water for 50±2 hours at 370C. In this in-vitro study, samples were divided into 3 groups, Control group or Group A made of conventional heat cure denture base resin and the Test Group i.e. Group B made of conventional heat cure denture base resin reinforced with 2% Polyethylene fibres and Group C made of conventional heat cure denture base resin

reinforced with 2% Polypropylene fibres. Flexural strength was assessed using Universal Testing Machine. One-way ANOVA was used for multiple group comparison followed by Tukey's Post-Hoc test for pair-wise comparisons during statistical analysis. When compared to the control group, the samples made by reinforcing conventional heat cure denture base resin with Polyethylene and Polypropylene fibres showed significant decrease in flexural strength. When compared to the samples made by reinforcing conventional heat cure denture base resin with Polyethylene fibres, samples reinforced with Polypropylene fibres showed significant decrease in flexural strength.

Table 1: FLEXURAL STRENGTH OF INDIVIDUAL SAMPLES IN VARIOUS GROUPS

	Conventional heat cure denture base resin	Group A reinforced with Polyethylene fibers	Group A reinforced with Polypropylene fibers
SAMPLE NO	GROUP A	GROUP B	GROUP C
1.	99.38	85.66	76.11
2.	102.81	83.38	74.23
3.	100.27	91.38	89.75
4.	92.69	89.26	75.21
5.	105.74	90.23	80.68
6.	93.26	84.36	77.50
7.	100.61	88.38	75.21
8.	99.86	94.65	77.17
9.	96.27	83.38	81.25
10.	98.40	86.56	74.31
Mean	98.92	87.72	78.14
Standard deviation	4.02	3.72	4.75

Table 2: DESCRIPTIVES INFORMATION ON MECHANICAL STRENGTH

					95% Confidence Interval for Mean	
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound
A	10	98.929000	4.0215930	1.2717394	96.052126	101.805874
B	10	87.724000	3.7279372	1.1788772	85.057194	90.390806
C	10	78.142000	4.7552773	1.5037507	74.740280	81.543720
Total	**30**	**88.265000**	**9.5394599**	**1.7416591**	**84.702907**	**91.827093**

	Minimum	Maximum
A	92.6900	105.7400
B	83.3800	94.6500
C	74.2300	89.7500
Total	**74.2300**	**105.7400**

One way ANOVA test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2164.887	2	1082.444	61.639	.000
Within Groups	474.150	27	17.561		
Total	**2639.038**	**29**			

Table 3: COMPARISON OF MECHANICAL STRENGTH BETWEEN VARIOUS GROUPS

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
A	B	11.2050000*	1.8740933	.000	6.558340	15.851660
	C	20.7870000*	1.8740933	.000	16.140340	25.433660
B	A	-11.2050000*	1.8740933	.000	-15.851660	-6.558340
	C	9.5820000*	1.8740933	.000	4.935340	14.228660
C	A	-20.7870000*	1.8740933	.000	-25.433660	-16.140340
	B	-9.5820000*	1.8740933	.000	-14.228660	-4.935340

*. The mean difference is significant at the 0.05 level.

HOMOGENOUS SUBSETS

		Subset for alpha = 0.05		
groups	N	1	2	3
3	10	78.142000		
2	10		87.724000	
1	10			98.929000
Sig.		1.000	1.000	1.000

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