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An In Vitro Study to Evaluate the Flexural Strength of Three Different Commercially Available Denture Base Resins Reinforced with Polyethylene Fibers

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ABSTRACT

Background: Poly(methylmethacrylate) has been used as a denture base material from last 60 years. Besides all the advantages of this material, denture fracture still poses a great problem to the patient. Flexural failure of the denture base material is the prime mode of failure. Various methods have been tried to improve the flexural strength of the material. Fiber reinforcement is one of the methods to improve the flexural strength of denture base resins. The purpose of this study was to evaluate the flexural strength of three different denture base materials with and without reinforcement with polyethylene fibers.

Materials and Methods: Twenty specimens of standard dimensions were prepared for each of the six experimental groups; Trevalon heat cure resin, Acralyn –H & Vertex Rapid Simplified with and without reinforcement with Polyethylene fibers. All samples were then subjected to a 3-point bending test and flexural strength was calculated. Statistical analysis was carried out using 1-way analysis of variance (ANOVA) and Duncan's Post Hoc test. **C**

Discussion: Incorporation of Polyethylene fibers increased the flexural strength of Trevalon and Vertex Rapid Simplified resin. But there was no statistically significant difference in the flexural strength of Acralyn –H heat cure denture base resin with fiber reinforcement.

Keywords: Flexural Strength, Poly-Methyl Methacrylate, Polyethylene Fibers, Denture Fracture.

INTRODUCTION

The loss of teeth by accident or disease has affected mankind throughout the ages. As civilization has progressed there has been continued refinement of the materials available for dental practice. With development of biological, chemical and physical sciences, there occurred a slow but steady increase in both the quantity and quality of useful materials available for dental prosthesis. Denture base materials have always been a matter of research in the field of dental materials. In 1937, Dr Walter Wright introduced Poly methyl methacrylate and Harold Vernon first introduced the use of this material in the form of a powder and liquid to be used as a denture base material. Since then use of Poly methyl methacrylate in denture construction has advanced by leaps and bounds[11]. Denture

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fracture in clinical use may result from a large transitory force caused by an accident or a small force during repeated chewing. Flexural failure of denture base materials is considered to be the primary mode of clinical failure and has been explained by the development of microscopic cracks in the areas of stress concentration. The ease with which acrylic dentures may fracture is of importance to the denture wearer, as this makes them vulnerable to the embarrassment and inconvenience of being suddenly deprived of their dentures.

Flexural strength test is thought to be relevant, since it reflects the load arrangement in the clinical situation and it also gives an indication of the rigidity which is useful in comparing the denture base materials under stress. It is defined as a force per unit area at the point of fracture of a test specimen subjected to flexural loading. Fracture of the dentures can be reduced by increasing the strength of the poly methyl methacrylate (PMMA) resin which is commonly used as a base material[9].

The modes to improve the strength of the denture base has been addressed in 3 ways-

a) Introduction of various substitutes for PMMA such as nylon, polycarbonates and polyamides

b) The chemical modification of PMMA through the addition of rubber in the form of butadiene styrene

c) Incorporation of fiber inserts or beads.

This study was aimed to compare the flexural strength of three different commercially available denture base resins with and without reinforcement with polyethylene fibers and whether the incorporation of fibers would have any effect on the strength of the denture base resins.

MATERIALS AND METHODS

The materials used in this study are Trevalon heat cure acrylic resin (Dentsply, India Pvt. Ld.), Acralyn – H heat cure acrylic resin (Asian Acrylates, Mumbai, India) , Vertex Rapid Simplified (Vertex Dental, The Netherlands) and Polyethylene fibers (DVA Reinforcement Fibers, California). (figure 3)

Three commercially available heat cure denture base resins were selected as control group and were then reinforced with polyethylene fibers which were used for comparison. The fiber content was determined as 3% by weight for trial groups. The amount of fibers added was based only on the premixed, measured resin powder weight and not on the combined powder and liquid or mixed resin weight. Samples were divided into following groups, each group consisting of 20 samples.

Group A: Samples of Trevalon.
Group B: Samples of Acralyn- ‘H’.
Group C: Samples of Vertex Rapid Simplified.
Group D: Samples of Trevalon, heat cure resin reinforced with polyethylene fiber.
Group E: Samples of Acralyn- ‘H’ reinforced with polyethylene fiber.
Group F: Samples of Vertex Rapid Simplified reinforced with polyethylene fiber.

PREPARATION OF THE MOULD

For standardization of the acrylic samples a stainless steel die was fabricated. The dimension of the die was 70x25x2mm and rectangular in shape(fig 1). This stainless steel die was invested in denture flask for preparation of mould. Separating medium was applied and dental plaster (Dentex, Prevest Denpro Ltd.) was poured to cover the flask. After half an hour, flask was opened and die in the lower base of the flask was removed carefully. Thus, the mould was obtained for packing with the denture base acrylic resin for the preparation of test samples. Ten such moulds were prepared(figure 2).

PREPARATION OF THE DENTURE BASE RESIN SAMPLES

Control group samples (group A , B, C) were made using conventional flasking and acrylization technique. After completion of polymerization cycle, the flasks were allowed to cool in water bath to room temperature before deflasking. The samples were then retrieved, finished and polished. Samples with fiber reinforcement (group D, E, F) were made by placing fibers longitudinally in half filled mould with acrylic resin. Length of the fibers was kept 68mm, i.e 1mm short from both the ends. After placing fibers mould was completely filled with acrylic resin and cured in conventional manner using manufacturer's instructions. After curing samples were retrieved, finished and polished

FLEXURAL STRENGTH TESTING

All samples were tested for flexural strength with 3 point bending test with a universal testing machine at a cross head speed of 2 mm/min. The sample was placed on the rollers which were attached to the lower jaw of the universal testing machine having it in such a way that the centre of the sample coincide with the centre of the distance between the two rollers(Figure 4). A load was applied by a centrally located rod until fracture occurred. In this manner 3 point bending test was carried for each sample. The flexural strength (Fs) was calculated using the following formulas:

$Fs = 3Fl/2bh^2$

where F = the maximum load,

l = the span length,

b = the width of the test specimen,

h = the thickness of the test specimen

STATISTICAL ANALYSIS

After the collection of data, mean values and standard deviations were calculated. The results were subjected to the statistical analysis by applying one-way ANOVA (Analysis of Variance) and Duncan's Post Hoc test (for multiple comparisons) and graphs were plotted. Level of statistical significance was taken as p value < 0.001.

RESULTS

The mean flexural strength of groups without fiber reinforcement has shown to be highest for Group C (Vertex Rapid Simplified) i.e 104.6945 N/mm^2, followed by Group A (Trevalon) i.e 83.6015 N/mm^2 and Group B (Acralyn-'H') i.e 79.0715 N/mm^2 respectively. The mean flexural strength of groups with fiber reinforcement has shown to be highest for Group F (Vertex Rapid Simplified) i.e 109.6160 N/mm^2, followed by Group D (Trevalon) i.e 96.0645 N/mm^2 and Group E (Acralyn-'H') i.e 82.7440 N/mm^2. On applying One-Way ANOVA a statistically significant difference in flexural strength was seen within groups and between groups i.e $p<0.001$.

Duncan's Post Hoc test was applied to make multiple comparisons between different groups. At 0.05 level, statistically significant mean difference values were seen between following groups- A and D, C and F.

Table 1: Mean flexural strength (n/mm^2) in different groups.

Group	N	Mean	Std. Deviation	Std. Error of Mean	Range	
					Minimum	Maximum
Group A	20	83.6015	10.88884	2.43482	60.68	100.03
Group B	20	79.0715	12.74456	2.84977	55.90	105.45
Group C	20	104.6945	15.56343	3.48009	70.45	126.80
Group D	20	96.0645	16.03685	3.58595	73.36	121.48
Group E	20	82.7440	21.46759	4.80030	44.44	120.19
Group F	20	109.6160	16.25171	3.63399	83.11	146.39

Table 2: One way ANOVA

	Sum of Squares	df	Mean Square	F	P value
Between Groups	16179.012	5	3235.802	12.897	<0.001 Highly significant
Within Groups	28601.970	114	250.894		
Total	44780.983	119			

Table 3: Duncan's Post-Hoc Test.

Group	Mean Values
Group B	79.0715 A
Group E	82.7440 A
Group A	83.6015 A
Group D	96.0645 B
Group C	104.6945 BC
Group F	109.6160 C

Same Superscript letters show Not Significant Differences at p < 0.05.

Fig 1: Prepared mould in the dental flask.

Fig 2: prepared poly-methylmethacrylate samples for testing.

Fig 3: polyethylene fibres.

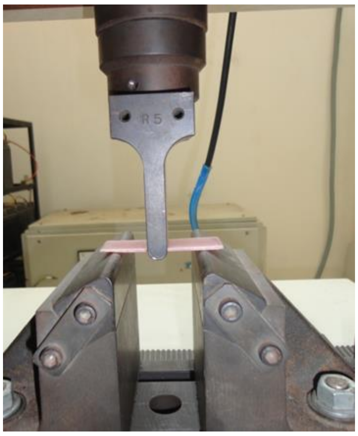
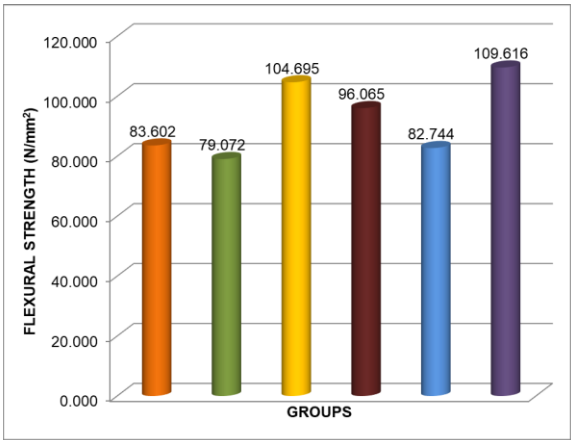


Fig 4: Sample testing using universal testing machine.



Graph 1: Comparison of flexural strength in different groups.

DISCUSSION

Denture fracture is still encountered by patients despite many attempts to solve this problem. Many modifications in denture base resins have been done to increase its strength. These include plasticization, copolymerization, cross-linking and reinforcement[6]. Interest has moved towards incorporation of fibers to denture base resins in order to improve its strength. The effectiveness of these modifiers and fillers in the denture base resins and performance of different products can be investigated and compared using various mechanical tests. In literature, most commonly used method is to predict the fracture resistance i.e. the flexural strength[2]. For the present study, this property that is flexural strength was chosen because of its influence on the selection of denture base resin material. The sample preparation followed in this study is in accordance with the study conducted by dogan and associates in 2008. In this study stainless steel die was used for the preparation of the mould.

The dimension of the die was (70x25x2mm) standardized as specified by ASTM D790M-92 for flexural test[9]. A three point bending test was carried out using universal testing machine with predictability. The transverse strength of material is a combination of compressive, tensile and shear strengths. As the tensile and compressive strength increases the force required to fracture the material also increases13. Polyethylene fibers amongst the many types of fibers used for reinforcement have been tested in various studies and were found to be suitable for use in dentures[8]. The groups were as follows.

Group A: Samples made from Trevalon, heat cure resin.
Group B: Samples made from Acralyn- 'H'.
Group C: Samples made from Vertex Rapid Simplified.
Group D: Samples made from Trevalon, heat cure resin reinforced with polyethylene fiber.
Group E: Samples made from Acralyn- 'H' reinforced with polyethylene fiber.
Group F: Samples made from Vertex Rapid Simplified reinforced with polyethylene fiber.

Twenty samples were made for each group. To measure the Flexural strength, 3 point bending test was done for each sample by universal testing machine using crosshead speed of 2mm/min.. Break load and break stress was calculated. The results were subjected to the statistical analysis by applying one-way ANOVA (Analysis of Variance) and Duncan's Post Hoc test (for multiple comparisons).

The mean flexural strength of groups without fiber reinforcement has shown to be highest for Group C (Vertex Rapid Simplified) i.e 104.6945 N/mm^2, followed by Group A (Trevalon) i.e 83.6015 N/mm^2 and Group B (Acralyn-'H') i.e 79.0715 N/mm^2. The mean flexural strength of groups with fiber reinforcement has shown to be highest for Group F (Vertex Rapid Simplified) i.e 109.6160 N/mm^2, followed by Group D (Trevalon) i.e 96.0645 N/mm^2 and Group E (Acralyn-'H') i.e 82.7440 N/mm^2.

A statistically significant difference in flexural strength was observed within groups and between groups i.e $p<0.001$. Duncan's Post Hoc test was applied to make multiple comparisons between different groups. At 0.05 level, statistically significant mean difference values were seen between following groups- A & D, C & F.

The effect of reinforcement fibers on the mean flexural strength of Trevalon & Vertex Rapid Simplified denture base resin was increased significantly, which was not significant for Acralyn – 'H' denture base resin.

Cheng et al (1999) reported that polyethylene fibers are neutral in colour, low density, chemically inert, resistant to solvents and are biocompatible. The fibers were added into resin at 3% concentration by weight. **Gutteridge (1988)** reported that if the fiber concentration were higher than 4%, it would become difficult to manipulate. Before addition of fibers into the resin, they were treated with monomer to enhance the bonding of fibers**. Solnit (1991)** reported that untreated fibers acts as inclusion bodies in the acrylic resin mixture and weakens the resin. Fibers may break up the homogenous matrix. **Uzun et al (1999)** studied that Polyethylene and glass reinforced specimens appeared to be more resistant to impact strength. Polyethylene-reinforced specimens underwent permanent deformation before fracture compared with other fibers. Polyethylene-reinforced specimens had least deformation before fracture.

Polyethylene-reinforced specimens showed the highest modulus of elasticity values. The effect of reinforcement fibers on the mean transverse strengths of Trevalon denture base resin was a slight increase, which was not significant for glass, carbon, and thick Kevlar. Thin Kevlar increased the transverse strength of the resin significantly and polyethylene fibers slightly weakened the test specimens. However, the weakening was not statistically significant of the resin of the polyethylene fibers. **Ladizesky et al (1993) and Braden et al(1988),** reported that polyethylene fibers in woven form are more effective than carbon fibers in enhancing impact strength and flexural strength. **Dixon & Breeding (1992)** studied different acrylic resins reinforced with polyethylene fibers and reported that transverse strength of heat polymerised resin was not significantly increased. **Gutteridge et al (1988)**, the addition of fibers in chopped form in higher amounts results in decreased strength. Because fibers are used to strengthen a polymer material, optimal adhesion between the polymer matrix and fibers is essential. **Larson et al (1991).** Polyethylene fibers are virtually invisible once incorporated into PMMA resin.

Polymethylmethacrylate denture base resin fracture is a common clinical problem. Accidental dropping of the denture while cleaning, insertion and removal was the most common cause for lower denture fracture. Reinforcement of denture base resin with various fibers is believed to improve flexural strength as crack would occur on the tension side but would not propagate through to the compression point. The embedded fiber could not be stretched enough for the crack in the resin to continue. The fiber appeared to hold the two pieces together. Because a fracture failure is usually related to the initiation of a crack and its subsequent propagation until displacement, a complete failure with the embedded fiber may not occur. If a fracture occurs in the resin with the plasma-treated PE reinforcement, the repair would be simpler because the fractured joint could easily be approximated and repaired.

CONCLUSION

In the present study to evaluate the flexural strength of 3 commercially available denture base resins reinforced with polyethylene fibers following conclusions were drawn;

1. The flexural strength of heat polymerised Vertex Rapid Simplified was more as compared to Trevalon and Acralyn- H without reinforcement of polyethylene fibers.

2. Polyethylene fibers reinforced denture base resin samples showed significant increase in flexural strength as compared to samples without reinforcement for Trevalon and Vertex Rapid Simplified.

3. There was no significant increase in flexural strength of samples of Acralyn-H with reinforcement of polyethylene fibers.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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