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Evaluating the effect on the flexural Strength of Heat Polymerized Acrylic Resin reinforced with diamond fillers-An in-vitro study

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ABSTRACT

This study investigated the effect of adding diamond powder fillers from 5% to 20% by weight on flexural strength of conventional heat polymerized acrylic resin. 72 samples of heat- polymerized acrylic resin were fabricated which were divided into three groups (n=8).The samples in different groups were reinforced with diamond powder fillers to achieve loadings of 5%, 10%, 15%, and 20% by weight. Flexural strength of the reinforced acrylic groups were found to be decreased than the unmodified acrylic resin group. It was concluded that although the flexural strength of conventional heat- polymerized acrylic resin was decreased by the addition of diamond powder fillers but large particle sized diamond powder fillers in concentration of 5% and 15% showed flexural strength comparable to the conventional heat polymerized acrylic resin.

Keywords: Heat-polymerized acrylic resin, flexural strength, polymethylmethacrylate, diamond fillers.

INTRODUCTION

The loss of teeth is a matter of great concern and their replacement by artificial substitutes, such as dentures is vital to the continuance of normal life. A wide array of materials and products are available for the dentist to aid in complete rehabilitation of lost structures.

In the 1930's, Dr. Walter H. Wright and the Vernon brothers working at the Rohm and Haas company in Philadelphia developed Polymethylmethacrylate (PMMA), a hard plastic. Although other materials were used for dental prosthesis, none could come close to PMMA and by the 1946, 95% of all dentures were made from this acrylic polymer.[1] Now acrylic resin is used almost universally for denture base construction, their distinctive properties allow a range of clinical applications not possible with other type of materials. It continues to be the material of choice for denture fabrication because of its dimensional stability, ease of processing, low water sorption, accuracy of fit, improved aesthetics and freedom from toxicity. [2]

One of the problems encountered in the provision of prosthesis is limitation of its strength to meet the functional demands of the oral cavity. It is of particular importance to have a denture-base material which resists breakage. Methyl methacrylate polymer is particularly susceptible, under stress, to rapid propagation of the initial split.[3]

Fractures in dentures result from two different types of forces, namely, flexural fatigue and impact. Flexural fatigue occurs after repeated flexing of a material and is a mode of fracture whereby a structure eventually fails after being repeatedly subjected to loads that are so small that one application apparently does nothing detrimental to the component. Thus, a denture base material should have sufficient flexural strength to resist torsional forces in function, leading to a longer clinical service life for the prostheses.

Methods to improve the inherent material properties of polymethylmethacrylate have included using alternate polymers such as polycarbonate, nylon, co-polymers and reinforcing agents including particulates (rubber particles:core-shell particles) and fibres (carbon fiber, whisker fiber, aramid fiber, polyethylene fiber and glass fiber).[4,5]

Numerous studies have been conducted on methods to improve denture base resins. Little information is available on the effect of addition of diamond powder fillers in conventional heat- polymerized acrylic resin, on its physical properties. So, this study was designed to evaluate the flexural strength of conventional heat- polymerized acrylic resin on addition of diamond powder fillers in various percentages and to conduct a comparative study between small particle and large particle size incorporation of diamond powder fillers on the flexural strength of heat- polymerized acrylic resin.

MATERIALS AND METHODS

Sample preparation

72 rectangular resin samples were fabricated. The samples were divided into three groups coded F_c, F_S and F_L. F_c was the control group [i.e., non- reinforced conventional heat- polymerized acrylic resin samples (Trevalon, Dentsply India Pvt. Ltd., New Delhi, India), F_S was the small particle size (0.1-1 micron) diamond powder (Advanced Abrasives, Venus Enterprise, Surat, India) reinforced conventional heat- polymerized acrylic resin. F_L was the large particle size (5-10 micron) diamond powder reinforced conventional heat- polymerized acrylic resin. The samples of groups F_S and F_L were reinforced with diamond powder fillers to achieve loadings of 5%, 10%, 15%, and 20% by weight **(Table 1)**.

Wax rectangles with dimensions- 64 mm length, 10 mm width and 3 mm height, were formed by pouring melted modelling wax (Modeling Wax, Dentsply India Pvt. Ltd., New Delhi, India) in the custom-made rectangular metal mold.

The wax rectangles were invested in dental stone and dewaxing was done in a dewaxing unit. The powder and liquid components of the resin were mixed in the ratio of 3:1 into a pliable mass and then loaded into the dental stone molds and pressed at 200 psi on a bench press to form the resin rectangles with cellophane sheet in between the two halves of the flasks. Flasks were then briefly opened to check proper packing of the rectangular cavities and then the flasks were pressed a final time at 4000 psi on a bench press. Samples were cured in the acrylizer for approximately 2 hours at 74^0C, followed by 1 hour at 100^0C.[10] After cooling to room temperature in water, samples were removed from the molds. Excess acrylic resin was removed and the samples were accurately measured with a vernier calliper. **(Fig.1)**

Flexural strength testing

The flexural three point bending test was carried out on Universal Testing Machine (Z010, Zwick, Germany) to determine the flexural strength. The dimension of the sample was entered into the programme for computation. The distance between the two supporting wedges was 50mm apart. The samples were centered on the device in such a way that the loading wedge, set to travel at a crosshead speed of 5mm min^{-1}, engaged the center of the upper surface of the samples . Samples were loaded until fracture occurred **(Fig.2 a-d)**. The sample was connected to the load-measuring cell, which continuously recorded the force applied to the specimen.

Flexural strength was calculated using the equation $S= 3PL / 2bd^2$ where 'S' is the flexural strength (N/mm^2 or MPa), 'P' is the load at fracture (N), 'L' is the distance between the supporting wedges (mm), 'b' is the width of the specimen (mm) and 'd' is the thickness of the sample (mm).

The data obtained were compiled, tabulated and subjected to statistical analysis.

Statistical Analysis

Descriptive statistics, including mean and standard deviation were calculated for each of the three groups. One-way ANOVA was used to determine whether significant differences existed between the means of the various groups. Students unpaired t- test was applied to determine the level of significance in the performance of three groups and to assess statistical differences in the thermal diffusivity means amongst them.

RESULTS

It was observed that the mean flexural strength of the groups II (F_S) and III (F_L) was decreased as compared to group I (F_C) as shown in **Table 2**.

The results of the one-way ANOVA revealed a statistically significant (p= 0.000) difference between the mean values of the tested groups in **Table 3**.

Table 4 showed Students unpaired t- test comparing subgroups of small and large particle sized groups which showed very highly statistically significant differences in flexural strength of subgroups of 5%, 10%, 15% and 20% concentrations (p= 0.000). Comparison of control group with subgroups of small particle sized group showed very highly statistically significant difference in flexural strength with small particle sized subgroups at different concentrations (p= 0.000). Comparison of control group with 10% subgroup of large particle sized & 20% subgroup of large particle sized group showed statistically significant (p= 0.002); & very highly statistically significant (p= 0.000) difference in flexural strength respectively.

DISCUSSION

With the introduction of PMMA resin in the year 1936,[1,6] the dental fraternity thought that this material was the final answer to its search of an ideal denture base material. The main reasons that accounts for the popularity and universal use of PMMA resin are its simple molding and processing techniques, excellent aesthetics and easy repair.[1] However with the continued use of PMMA resin it was realized that this material is still far from ideal in fulfilling the mechanical requirements of a prosthesis since it is brittle and has low strength.

A search for alternative materials to PMMA has led to the introduction of several materials which can be added to the PMMA to improve its physical and mechanical properties. **Hargreaves[7]** in a survey reported that 63% of the dentures broke within three years of their usage. **Johnson W and Mathews E[8]** estimated that a denture flexed on an average 5, 00,000 times a year. They said that the fracture problem in complete denture is related to flexural fatigue which occurs after repeated flexing of a material and is a

mode of fracture. Thus, a denture base material should have sufficient flexural strength to resist torsional forces in function, leading to a longer clinical service life for the prostheses.

Attempts to overcome the limitations of PMMA have taken researchers through many avenues. These include chemical modification to prepare high impact resin, mechanical reinforcement glass fibers, sapphire whiskers, aramid fibres, carbon fibres, metal wires, nylon, polyethylene fibres and zirconia.[9] Metal inserts in the form of wires, mesh and plates have also been tried. The main drawbacks faced with these techniques was that the added materials themselves weakened the resin matrix. **Zappini et al**[10] suggested that a more reasonable test for evaluating the strength of denture base resins would be a fatigue test; however, the time and number of specimens required for fatigue testing and the fracture toughness test might be more practical.

Johnston EP et al[11] studied flexural fatigue of 10 commonly used denture base resins, and among the Polymethyl methacrylate pour resins, PMMA thermosetting resins, vinyl resins, and PMMA grafted resins, they found that grafted resin lucitone 199 tended to withstand repeated flexure when compared to other resins. In a study by **Dagar SR et al**[12] found that the flexural and impact strengths of heat polymerized acrylic resin reinforced with fibers was significantly higher than those of conventional heat polymerized acrylic resin. Glass fiber reinforcement significantly improved both impact and flexural strengths of denture base resin when compared with nylon fibers. In another study by **Bowman AJ and Manley TR**[13] it was observed that reinforcement of upper dentures with carbon fibres significantly reduces the upper denture breakages. Similarly **Yadav NS and Elkawash H**[14] compared the flexural strength of acrylic resin reinforced with 5% aluminum oxide and found that the specimens of heat-curing acrylic resin reinforced with 5% Al_2O_3 filler provided no superior flexural strength than those with normal acrylic resin and when processed by microwave technique.

In the current study, the addition of diamond powder fillers did not improve the flexural strength of the polymer tested which may be attributed to irregular distribution of diamond powder fillers into the acrylic resin which causes stress concentration due to filler agglomeration. The second reason may untreated fillers act as inclusion bodies in the resin mixture, which decreases the bonding filler particles and the acrylic resin, thus weakening it.

Further research is needed to quantify the filler distribution in the polymer matrix and to evaluate the effect of aging on this new reinforced denture base material. The other tests for predicting the clinical function of this experimental composite should also be conducted like fatigue test, impact test and color stability. The suitability of this experimental composite for use as a denture base material should be assessed before clinical application.

CONCLUSION

Based on the observations and results of this study following conclusions were made:

1. Incorporation of small and large particle sized diamond powder fillers in conventional heat polymerized acrylic resin decreased the flexural strength.
2. With the increasing concentration, flexural strength progressively decreased in the small particle size group and generally decreased in large particle size group.
3. Large particle size group showed more flexural strength than the small particle size group.
4. Comparison between small and large particle size groups showed highly significant differences in flexural strength of subgroups in concentrations of 5%, 10%, 15% and 20%.
5. Large particle sized diamond powder fillers in concentration of 5% and 15% showed flexural strength comparable to the conventional heat polymerized acrylic resin.

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Tables

Groups	**F_C Group I**	**F_S Group II**				**F_L Group III**			
Subgroups	-	F_{S5}	F_{S10}	F_{S15}	F_{S20}	F_{L5}	F_{L10}	F_{L15}	F_{L20}
No. of samples	8	8	8	8	8	8	8	8	8
PMMA (g)	100	95	90	85	80	95	90	85	80
Diamond powder fillers (g)	0	5	10	15	20	5	10	15	20

FC-control group

FS- small particle sized diamond reinforced conventional heat polymerized acrylic resin

FL -large particle sized diamond reinforced conventional heat polymerized acrylic resin

Table 1. Group distribution of samples.

Groups	Subgroups	N	Mean	Standard Deviation
I (F_C)	-	8	87.18	2.80445
II (F_S)	F_{S5}	8	55.94	8.95016
	F_{S10}	8	46.72	8.50279
	F_{S15}	8	46.71	5.41336
	F_{S20}	8	35.30	4.41797
Group III (F_L)	F_{L5}	8	80.90	10.75026
	F_{L10}	8	75.52	7.98608
	F_{L15}	8	83.47	7.02339
	F_{L20}	8	46.20	4.37722

Table 2. Mean flexural strength (MPa) values for the groups tested.

	Sum of Squares	df	Mean Square	F	p value	Remarks
Between groups	24814.301	8	3101.788	61.096	0.000	VHS
Within groups	3198.470	63	50.769			
Total	28012.771	71				

df- degree of freedom

Table 3. Analysis of variance among groups for flexural strength.

	Mean Difference	t value	p value
F_{S5} :F_{L5}	24.95375	5.046	0.000
F_{S10}:F_{L10}	28.80375	6.984	0.000
F_{S15}:F_{L15}	36.76125	11.726	0.000
F_{S20}:F_{L20}	10.89625	4.955	0.000
F_{S5} :F_C	31.24000	9.421	0.000
F_{S10}:F_C	40.46875	12.784	0.000
F_{S15}:F_C	40.47875	18.779	0.000
F_{S20}:F_C	51.88375	28.044	0.000
F_{L5}:F_C	6.28625	1.600	0.132
F_{L10}:F_C	11.66500	3.898	0.002

F_{L15}:F_C	3.71750	18.779	0.186
F_{L20}:F_C	51.88375	28.044	0.000

Table 4. Statistical comparisons (by Students unpaired t-test).

Figures

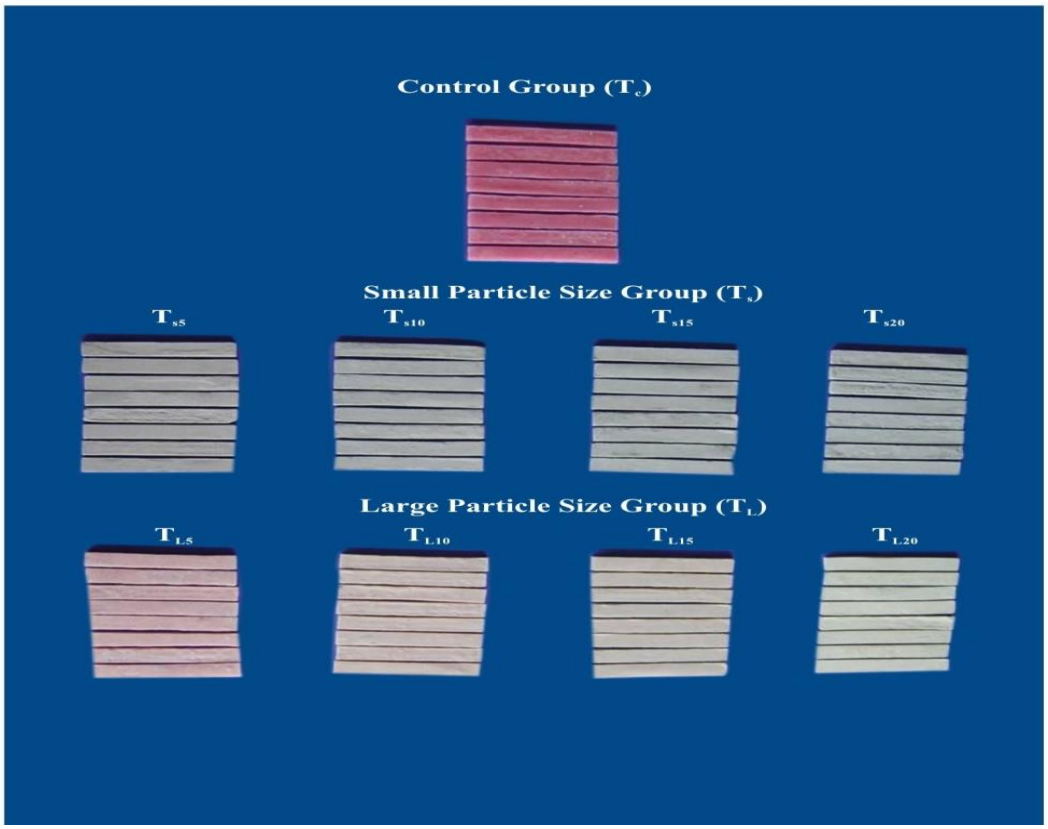

Figure 1: Specimens Fabricated

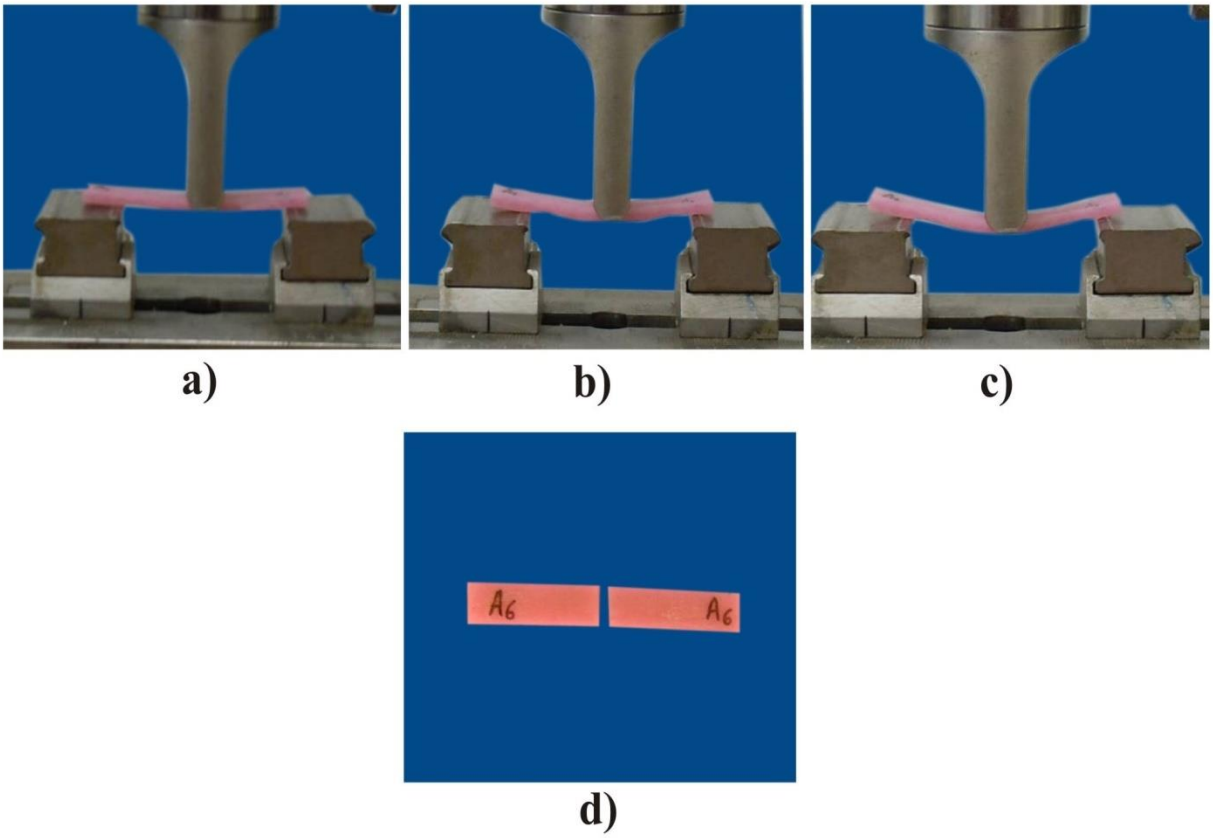

Figure 2:a-c) Flexural strength testing- gradual flexing of the sample d) Fractured resin sample