Original Article

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Dentistry Section

The Effect on the Flexural Strength, Flexural Modulus and Compressive Strength of Fibre Reinforced Acrylic with That of Plain Unfilled Acrylic Resin – An in Vitro Study

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ABSTRACT

Aim: The aim of this in vitro study was to compare the flexural strength, the flexural modulus and compressive strength of the acrylic polymer reinforced with glass, carbon, polyethylene and Kevlar fibres with that of plain unfilled resin.

Materials and Methods: A total of 50 specimens were prepared and divided into 10 specimens each under 5 groups namely group 1- control group without any fibres, group 2 – carbon fibres, group 3- glass fibres, group 4 – polyethylene, group 5- Kevlar. Universal testing machine (Tinius olsen, USA) was used for the testing of these specimens. Out of each group, 5 specimens were randomly selected and testing was done for flexural strength using a three point deflection test and three point bending test for compressive strength and the modulus was plotted using a graphical method. Statistical analysis was done using statistical software.

Results: The respective mean values for samples in regard to their flexural strength for PMMA plain, PMMA+ glass fibre, PMMA+ carbon, PMMA+ polyethylene and PMMA+ Kevlar were 90.64, 100.79, 102.58, 94.13 and 96.43 respectively. Scheffes post hoc test clearly indicated that only mean flexural strength values of PMMA + Carbon, has the highest mean value. One-way ANOVA revealed a non-significant difference among the groups in regard to their compressive strength.

Conclusion: The study concludes that carbon fibre reinforced samples has the greatest flexural strength and greatest flexural modulus, however the compressive strength remains unchanged.

Keywords: Glass, Kevlar fibres, Polyethylene, Poly methyl methacrylate

INTRODUCTION

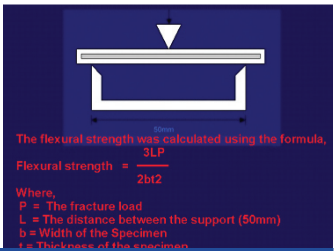
The introduction of poly methyl methacrylate (PMMA) in 1937 by Dr. Walter Wright, heralded a new age in the field of prosthodontics [1]. The PMMA was so well received by the dental profession, that currently most of the dentures are constructed by this. The ease of use, biocompatibility, excellent aesthetics and ease of repair makes this, the material of choice for denture bases. The PMMA have a wide variety of application not only as a denture base material but also as a denture repair material, material for artificial teeth, record base, facing for crowns and bridges, special trays, material for making obturator, etc. The desirable qualities of PMMA is offset by certain drawbacks, significant among them are its reduced strength and stiffness. Various researchers have proposed modalities for strengthening the resin like- embedding of solid metal forms in the resin, incorporation of a rubber phase in the bead polymer, reinforcing of acrylic resin with various fibres [2-4].

The embedding of solid metal forms resulted in poor aesthetics [2,5] whereas the incorporating of rubber phase [6-8] in the bead polymer worked out to be expensive. These limited the use of fibres to reinforce the acrylic. Various studies reveal a significant increase in physical and mechanical properties of reinforced acrylic resin. The commonly used fibres to strengthen acrylic resin are carbon [9-12] glass [2,5,13] polyethylene [14-20] and Kevlar [7,21] However, there is paucity of information in literature on the comparison of all the above fibres with regard to their mechanical properties. The aim of this in vitro study was to compare the flexural strength, the flexural modulus and compressive strength of acrylic polymer reinforced with glass, carbon, polyethylene and Kevlar fibres with that of plain unfilled resin.

MATERIALS AND METHODS

A total of 50 specimens were prepared and divided into 10 specimens each under 5 groups, which were divided according to the reinforcement material used. The specimens for testing the flexural strength, the flexural modulus and compressive strength were fabricated using stainless steel dies. The dimensions of each test specimen were length 60mm x width 10mm x thickness 4mm. The dies were invested in number 7 varsity flask (Jabbar & co, Aligarh, India) using type III Gypsum (Goldstone, Asian chemicals, India). Once the dental stone was set, the two halves of the flask were separated and the dies were lifted out of the mould. Sodium alginate separating medium (DPI, India) was applied on the mould [Table/Fig-1]. The packing of PMMA (DPI- Dental product of India) was done during dough stage. Initially a thin layer of acrylic material was evenly spread over the mould space. The fibre specimens were prepared by cutting the fibre slightly short of the length of acrylic specimens and weighed. The pre weighed amount of fibres (5% by weight of acrylic) depending on the group (group 2 – carbon fibres, group 3- glass fibres, group 4 – polyethylene, group 5- Kevlar, All fibres manufactured by VSSC-Vikram Sarabhai, Space Research Centre, India) were spread over this thin layer of acrylic. Care was taken to prevent over extension of the fibres outside the mould space. Another layer of acrylic was placed over the fibres. Trial packing was done and manufactures instructions were followed during the process of curing and finishing. Group 1 was kept as a control group without any fibres incorporated. All the specimens were stored in water at room temperature before testing. Universal testing machine (Tinius olsen, USA) was used for the testing of specimens.

Out of each group 5 specimens were randomly selected and testing was done for flexural strength using a three point deflection test with a cross head speed of 3mm/min. The parallel arms of the jig were kept 50 mm apart. The specimen is positioned on the jig and load was applied on the centre as shown in the [Table/Fig-2].



[Table/Fig-1]: Mould for preparation of specimen
[Table/Fig-2]: Flexural strength tested using a three point deflection test with a cross head speed of 3mm / min. The parallel arms of the jig were kept 50 mm apart. The specimen is positioned on the jig and load was applied on the centre.

The flexural strength was calculated using the formula

Flexural strength = 3LP/2bt2

Graph is plotted for measuring the flexural modulus. The X axis of the graph represents the deflection of the specimen and the Y axis represents the load.

Flexural modulus was calculated using the formula

Flexural modulus = ¼(p/α)L3/bt3

Where = p/α is the slope of the graph

b = width of the specimen

t = Thickness

L = Span length

5 specimens from each group were subjected to three point bending test to determine the breaking load. Compressive strength was calculated using the formula

Compressive strength = P/bt

Where P = breaking load

b = width of the specimen

t = thickness of the specimen.

STATISTICAL ANALYSIS

Statistical analysis was done using SPSS version 16. The results were tabulated and one-way ANOVA was employed to determine the significance of difference among the mean values of the different group. Scheffes post-hoc test was applied to find the difference between the mean values in flexural strength, flexural modulus and compressive strength among the different groups.

RESULT

The mean test result for the flexural strength, flexural modulus and compressive strength of the five groups of samples.

Flexural strength (MPa)

The respective mean value for samples PMMA plain, PMMA+ glass fibre, PMMA+ carbon, PMMA+ polyethylene and PMMA+ Kevlar were 90.64, 100.79, 102.58, 94.13 and 96.43 respectively. One-way ANOVA revealed a significant difference (p<0.009) among mean values of flexural strength of samples between the groups [Table/Fig-3]. Further Scheffe's post hoc test clearly indicated that the flexural strength value of PMMA+carbon, had differed significantly from PMMA plain.

Flexural modulus (GPa)

The respective mean values of samples PMMA plain, PMMA+ glass fibre, PMMA+ carbon, PMMA+ polyethylene and PMMA+ Kevlar were 2.55, 2.69, 3.06, 2.42 and 2.78 respectively. One-way ANOVA revealed a significant difference (p<0.028) in the mean values among the groups [Table/Fig-4]. Scheffes post hoc test clearly indicated that only mean flexural strength values of PMMA + Carbon has the highest mean value. Rest of the mean differences of the group were found to be non significant.

Compressive strength (MPa)

The mean difference of the samples PMMA plain, PMMA+ glass fibre, PMMA+ carbon, PMMA+ polyethylene and PMMA+ Kevlar were 100.61, 99.59, 100.95, 97.88 and 100.30 respectively. One-way ANOVA revealed a non significant difference among these values [Table/Fig-5].

SAMPLES	N	Mean±Standard Deviation	Standard Error	F (df = 4)	Significance (Anova test)
PMMA Plain	5	90.64±4.73	2.12	4.64	0.009
PMMA + Glass Fiber	5	100.79±4.83	2.16		
PMMA + Carbon	5	102.58±5.07	2.27		
PMMA + Polyethelene	5	94.13±3.16	1.58		
PMMA + Kevlar	5	96.43±6.31	2.82		

[Table/Fig-3]: Flexural strength of study samples

SAMPLES	N	Mean±Standard Deviation	Standard Error	F (df = 4)	Significance (Anova test)
PMMA Plain	5	2.55±0.12	0.05	3.40	0.028
PMMA + Glass Fiber	5	2.69±0.21	0.09		
PMMA + Carbon	5	3.06±0.40	0.18		
PMMA + Polyethelene	5	2.42±0.34	0.15		
PMMA + Kevlar	5	2.78±0.30	0.13		

[Table/Fig-4]: Flexural modulus of study samples

SAMPLES	N	Mean	Standard Deviation	Standard Error	F (df = 4)	Significance (Anova test)
PMMA Plain	5	100.61	5.00	2.24	0.228	0.920*
PMMA + Glass Fiber	5	99.59	5.53	2.47		
PMMA + Carbon	5	100.95	6.91	3.09		
PMMA + Polyethelene	5	97.88	5.42	2.42		
PMMA + Kevlar	5	100.30	5.47	2.45		

[Table/Fig-5]: Compressive strength of study samples

DISCUSSION

The major cause of clinical failure of upper and lower acrylic dentures were reported to be fatigue failure, midline failure and impact failure because of the low flexural strength and impact strength of the material [18]. This clinical drawback necessitated the need for denture strengthening. In the past, metal wire was often embedded in the denture base, but no worthwhile gain in strength was achieved due to the difference in the physical properties of the two materials [3]. But, there are various studies which revealed an increased strength of acrylic by the incorporation of solid metal forms, but at the expense of aesthetics [2-4]. So, an aesthetic option put forward was the incorporation of a rubber phase in the bead polymer, but this was expensive [6-8] and more economical fibres like nylon and whiskers fibres were tried. But the difficulty in positioning it during packing and processing led to the exposure of the fibres. This exposes the outer surface of the denture base on polishing, which acts as a tissue irritant [21]. This led to the introduction of other fibres like carbon [2,5,9-13] glass [2,5,13,22] polyethylene [14-20] and Kevlar [7,21].

The fibres oriented parallel to or at a small angle from the long axis of the sample gives a substantial support to the sample, giving a stiffer sample [19]. The orientation of fibres in fact increased the flexural strength of the material, which in turn prevent the midline fracture of the denture clinically.

Studies by Ladizeisky et al., [19] reported that, the fibres over the wall of the specimen provided very little strength or weakened the specimen. Thus the orientation of fibres plays an important role in the strength of the specimen. Among the materials, carbon showed the maximum strengthening effect. Scriber CK [10] reported a 50% increase in transverse strength of acrylic resin when surface treated carbon fibres were incorporated. Viguie G et al., [11] also reported 60% increase in strength.

The main disadvantage reported for carbon was the unaesthetic appearance due to the black colour of the fibres. Scriber CK [10] reported a pre- pregs (impregnated fibre bundles) i.e. the single stage veneering technique to mask the unaesthetic colour of the carbon fibres. He also suggested the incorporation of fibres in the unnoticeable region like palate, lingual regions of lower denture etc. The fibres are considered to be inert by various authors, but Subramanian et al., [23] reported that the silane coating of the fibres could be toxic. Various studies [2] presented the optimum amount by volume of glass fibres ranged from 25% to 5%. The main disadvantage of the glass fibres is reported to be the irritation of the tissues when exposed to the outer surface. The Kevlar or aramid fibres have a pleated structure, hence they were weaker in flexural strength than carbon and glass fibers [13,21]. The yellow colour of the fibre is a disadvantage, which limits its use in the aesthetic areas [21]. The exposed fibre at the surface of the resin presents a rough surface, which cannot be polished and may result in patient discomfort. The use of fewer fibres or the development of thin woven mesh of these fibres may offer a possible solution to this problem.

The use of polyethylene fibres were shown to increase flexural strength of the resin by many authors [14-18]. A 0.5% to 3% by weight of fibres was reported to increase the strength of the resin. After 3% by weight, it was difficult to manipulate the material due to the formation of dry fragile dough and no increase in strength was reported [6].

All the fibre reinforced specimens demonstrated an increase in flexural modulus except those incorporated with poly ethylene fibres. No statistical significance was noted among the groups for compressive strength. The addition of untreated fibres to the resin matrix can result in void formation between the resin and the fibre interface due to improper wetting of the fibre by the resin. This may be the reason for the above findings. The fibers used in the present study are not surface treated and also the sample size could be considered as a limitation of the study.

CONCLUSION

The ease of use, biocompatibility, excellent aesthetics and ease of repair makes this, the material of choice for denture bases. The study concludes that carbon fibre reinforced samples had the greatest flexural strength and greatest flexural modulus. The compressive strength of the fibre reinforced samples was not statistically different from the plain acrylic. Further studies are required to evaluate the physical properties of fibres at varying percentage concentrations and further clinical evaluations are required to substantiate these results as well as the biocompatibility of the fibres. The effects of various surface treatments of the fibres also have to be evaluated for improving the properties.

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