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To evaluate and compare the efficacy of titanium-dioxide nanoparticles and carbon fibers influencing the flexural and impact strength on fractured repaired dentures.

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Abstract

Introduction: Poly methyl methacrylate (PMMA) is most commonly used material to fabricate complete and partial dentures. Since, acrylic resins have unsatisfactory mechanical properties the dentures are prone to fractures. In such situations, denture repair is considered as an alternative. Dentures reinforced with titanium dioxide nanoparticles and carbon fibres improve the mechanical properties of the acrylic resins.

Methodology: A total of 30 heat cure acrylic samples were prepared and fractured using compressive strength instrument. Further, these samples were divided into 3 groups and group 1 samples were repaired with self-cure resin, group 2 samples reinforced with titanium dioxide nanoparticles and group 3 with carbon fibers and were subjected to flexural and impact test.

Results: The test results demonstrate that the mean flexural strength for Group 1 was 320.650 ± 45.861, Group 2 was 497.467 ± 73.163 and for Group 3 was 1019.750 ± 198.987 and the mean Impact strength for Group 1 was 36.36 ± 11.81, Group 2 was 62.88 ± 8.01 and for Group 3 was 159.90 ± 12.46.

Conclusion: It was concluded that the fractured acrylic samples demonstrate that Group 3 samples reinforced with carbon fibres demonstrated significantly highest mean flexural and impact strength followed by Group 2

reinforced with 1wt% titanium dioxide nanoparticles and least with Group 1(control group).

Keywords: PMMA, Denture, Nano Dentistry.

Introduction

A favourable denture base material is required for the fabrication of long-lasting complete dentures which are biologically acceptable. Among the various denture base materials available Poly methyl methacrylate (PMMA) is most commonly used material to fabricate complete and partial dentures. This material is been in use for more than 60 years in the field of dentistry. Poly methyl methacrylate (PMMA) was introduced in 1937 by Dr. Walter Wright.

This denture base material gained its popularity due to its high aesthetic quality, economic cost, bio compatibility, needs inexpensive equipment's, its easy Manufacturing process and ease in repair, finishing and polishing.[1] These properties make this, the material of choice for fabrication of denture bases. Despite its desirable properties, the acrylic resin denture base material does not fulfill all the requirements of acceptable mechanical properties. Acrylic resins also have several disadvantages such as unsatisfactory flexural strength, impact strength, low thermal conductivity, fatigue resistance, transverse strength, produces residual monomers, porosity and sensitive to allergic reactions and easily fracture. Flexural fatigue due to repeated masticatory load and various high-impact forces are the main causes of denture fractures thereby reducing the longevity of the dentures. Vallittu et al performed a survey of damage to removable dentures in Finland and reported that the most common problems included fracture of the acrylic base (64%)[2]. Denture fracture is still becoming an unsolved problem until now. And as the fabrication of a new denture is time-consuming and would generate additional cost for patients, denture repair is considered an alternative procedure. So, after repairing these acrylic dentures fractured joints with self-curing resins, have lower mechanical properties compared to the conventional dentures.

Various reinforcing methods are available to overcome this disadvantage and improve the mechanical properties of the fractured denture base thereby increasing the flexural and the impact strength.

The development of Nano dentistry has introduced new approaches for reinforcement of dental material. The concept of nanotechnology was first introduced in 1959 by Feynman. These nano materials have high surface area to volume ratio, which enhances interfacial interaction and specific new biological, physical, and chemical properties. Various types of nanomaterials available such as zirconium oxide, carbon nanotube, aluminium dioxide, silver, zinc oxide, titanium dioxide and silicon dioxide were used to increase the mechanical properties of Acrylic Denture Base Resin[3]. Titanium dioxide are the most commonly used nanoparticle for prosthodontic approaches. The use of titanium dioxide nanoparticles is increasing due to the advantages over other nanoparticles, which are ease of availability, low toxicity, inert chemical properties, cost - effectiveness, anti-bacterial properties, corrosion resistance, and high level of hardness[4].

Also, incorporation of different kinds of fibres in the fractured, repaired dentures have known to improve the mechanical properties of the denture bases. Various types of fibres including carbon fibres, glass fibres aramid fibres and ultra-high modulus polyethylene fibres, Kevlar fibres have been employed to reinforce PMMA resin[5]. However, the ability of fibres to reinforce the denture base was found to be dependent on the individual properties of the fibres and resin matrix;

impregnation of fibres with resin; orientation of the fibres in the prosthesis. Larson et al. have reported the use of carbon fibres to improve the strength of denture bases. Carbon fibres have been used to enhance both the fatigue and impact strength.[6]

But there are no studies comparing the flexural and the impact strength of the carbon fibers and the titanium dioxide nanoparticles.

Therefore, the aim of this in-vitro study is to evaluate and compare the efficacy of 1wt% titanium-dioxide nanoparticles and carbon fibers influencing the flexural and impact strength on fractured repaired dentures.

Materials and Methodology

The sample size was estimated using the G Power software v. 3.1.9.4 [(Franz Faul, Universität Kiel, Germany)

Considering the effect size to be measured (f) at 60%, power of the study at 80% and the margin of the error at 10%, the total sample size needed is 3O. Each study group will comprise of 10 samples. It is will be further sub-divided into 5 samples, based on the testing of study parameters [Flexural & Impact strength] in each study group. [5 samples x 2 parameters x 3 groups = 3O samples]

Sample preparation

➢ A total of 30 wax patterns were prepared using Modelling wax each measuring to a dimension of about 65 x 10 x 3 mm (American Dental Association Specification No. 12) [Figure 1].

Figure 1: 30 wax patterns.

Then, these wax patters were packed with dental stones and the dewaxing procedure was carried out. Later slots measuring of about 65 x 10 x 3 mm were obtained in the flasks which created space for the packing of heat cure acrylic resin denture base material [Figure 2].

Figure 2: before and after dewaxing.

Heat cure acrylic resin (DPI heat cure) was mixed according the manufacture instruction (2g powder with 1 ml of liquid). At dough stage, material was placed in mould space created (65 X 2.5 X 10 mm) and the flasks were closed and kept under bench press (for 30 min). Clamped flasks were kept in thermostatically controlled polymerization unit and polymerized in water for 30 minutes at 60ºC and 1 hour at 100ºC. After the curing cycle was completed, the flasks were allowed to bench cool for a period of 24 hours and then the samples were retrieved and finished and polished using carbide bur and 600 grit silicon carbide paper under water irrigation. All of the 40-heat cure acrylic samples were fractured in compressive strength instrument.[7] Two pieces of fractured samples were collected together, and breaking edges were ground with carbide bur to create 3 mm space for self-cure acrylic resin. Ana sane N conducted a study, to evaluate the effect of joint surface contours and the reinforcers on the transverse strength of repaired acrylic resins. According to this study 4 joint surface contour (butt, bevel, rabbet and round) were created among which round surface design exhibited highest transverse strength; hence, it was advocated for repair of

denture base resins.[8] Based on these results round surface joints were prepared on the broken edges then the samples were divided into 3 groups and each group consisting of 10 samples. [FIGURE 3]

Figure 3: Fractured acrylic samples placed back into mould space.

Group 1

10 fractured acrylic resin samples with round surface joints were wetted with monomer for better adhesion and improving the wettability, and were placed back into the mold space which was created after the acrylisation process. Self-cure acrylic resin (DPI cold cure) was mixed according to the manufacturer's instructions (2g powder with 1 g of liquid) and was packed in the 3mm space which was created between the 2 broken pieces of acrylic samples. [FIGURE 4]

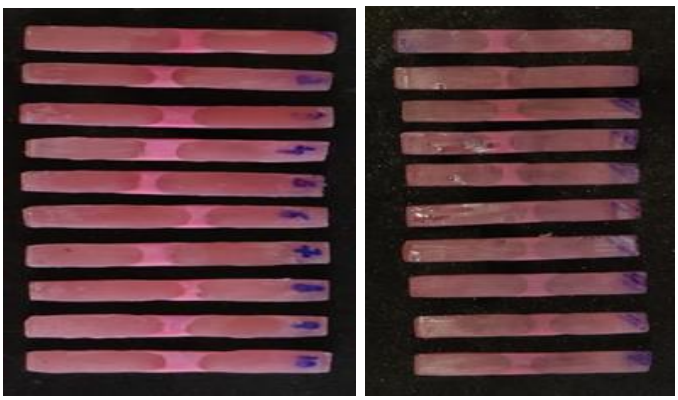
Group 2

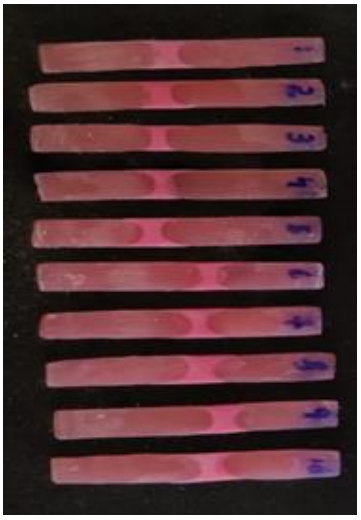
10 ractured acrylic resin samples with round surface joints were wetted with monomer for better adhesion and improving the wettability and were placed back into the mould space which was created after the acrylisation process.1wt% Titanium dioxide nanoparticles were measured using Digital weighing machine (MH-series Pocket scale, 200g*0.01g) and was mixed thoroughly to the acrylic powder by using spatula before mixing with the acrylic monomer. The suspensions of the polymer and TiO2 NPs were immediately mixed manually with monomer to minimise the possible aggregation of the particles.[9] The mixing continued for approximately 3 minutes until the mixture reached a dough-like stage, which was suitable for handling and then was packed into the joint space created [Figure 4]

Group 3

10 fractured acrylic resin samples with round surface joints were placed back into the mould space which was created after the acrylisation process and slots measuring of about 2.5 X 40 mm were created in the broken edges of the acrylic samples with the help of carbide bur for the placement of fibers. These acrylic resin samples were wetted with monomer for better adhesion and improving the wettability. Fibers were stored in the glass with monomer for 5 minutes for good soaking. Then the carbon fibers were placed into the slots created at the broken edges and Self-cure acrylic resin (DPI cold cure) was mixed according to the manufacturer's instructions (2g powder with 1 g of liquid) and was packed in the 3mm space which was created between the 2 broken pieces of acrylic samples reinforced with carbon fibres. Then the specimens were removed from the moulds and the surfaces were finished using carbide bur and 800-, 400- and 200-grit sandpapers.[Figure 4]

Figure 4- a) group 1- samples repaired with self-cure resin. b) group 2- samples repaired with 1wt% titanium dioxide nano parties. C) group 3- samples repaired with carbon fibres





For the purpose of testing each group was divided into two, first part in each group was tested for its flexural strength (Three-point flexural test, adopted by international standards for polymer materials-universal testing machine) and the second part of each group was tested for impact strength (pendulum Charpy-type impact test machine). The values obtained were noted.

Results

Statistical Package for Social Sciences [SPSS] for Windows Version 22, was used to perform statistical analyses. One-way ANOVA test followed by Tukey's post hoc analysis was used to compare the flexural & impact strength between 3 groups. The level of significance [P-Value] was set at P<0.05. There was a difference in the mean Flexural Strength and Impact Strength between 03 groups.

Table no. 1 represents the comparison of mean flexural strength values between different groups. The test results demonstrate that the mean flexural strength for Group 1 was 320.650 ± 45.861, Group 2 was 497.467 ± 73.163 and for Group 3 was 1019.750 ± 198.987.

The results demonstrate that Group 3 demonstrated significantly highest mean flexural strength followed by Group 2 and least with Group 1. [Refer Graph no. 1]

Table 1: Comparison of mean Flexural Strength (in Kg/ sqcm) between different groups using One-way ANOVA Test.

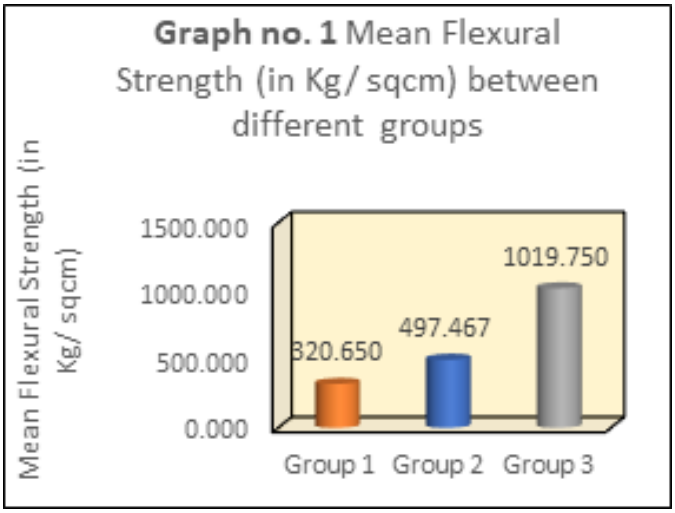
Groups	N	Mean	SD	Min	Max	P-Value
Group 1	5	320.650	45.861	262.6	382.9	<0.001*
Group 2	5	497.467	73.163	444.8	618.6	
Group 3	5	1019.750	198.987	853.2	1286.6	

Table no. 2 represents the comparison of mean Impact strength values between different groups. The test results demonstrate that the mean Impact strength for Group 1 was 36.36 ± 11.81, Group 2 was 62.88 ± 8.01 and for Group 3 was 159.90 ± 12.46. The results demonstrate that Group 3 demonstrated significantly highest mean impact strength followed by Group 2 and least with Group1. [Refer Graph no. 3].

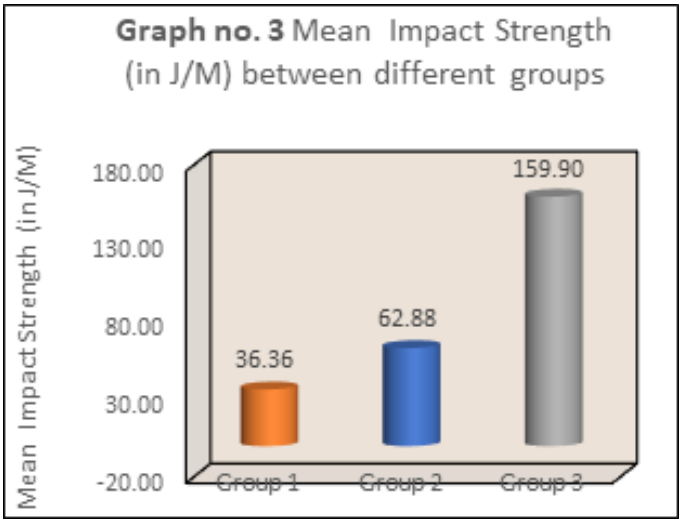
Table 3: Comparison of mean Impact Strength (in J/M) between different groups using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	P-Value
Group 1	5	36.36	11.81	23.3	50.0	<0.001
Group 2	5	62.88	8.01	53.3	73.3	
Group 3	5	159.90	12.46	144.0	176.6	

Graph 1:



Graph 2:



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. This clinical drawback necessitated the need for denture strengthening. In an earlier and separate study, Hargreaves reported that 68% of dentures had broken within 3 years of their provision. Previous studies have showed that as much as 68% of denture fracture occurred almost after 3 years of use, 28% occurred after 1 year, and 39% of the denture needs to be repaired after 3 years of use. In dentistry, many efforts have been made by reinforcing polymers with different materials to improve flexural strength and impact strength like the addition of glass, polyurethane, aramid fibre, metal wires, in the forms of particle, flake, fibre or fabric. Flexural strength is a force directly related to the fracture resistance of a denture and impact strength is the energy required to fracture a material under an impact force. The results of this study showed that adding TiO2 NPs in heat cure acrylic (PMMA) resins improved their flexural strength and impact strength compared to the control groups. The fibres oriented parallel to the long axis of the sample gives a substantial support to the sample, giving a stiffer sample. The orientation of fibres in fact increased the flexural strength and impact strength of the material, which in turn prevent the midline fracture of the denture clinically.[10] The main disadvantage reported for carbon was the unaesthetic appearance due to the black colour of the fibres. Hence, more clinical studies are required to obtain satisfactory results from the patient by incorporating the fibres in the unnoticeable region like palatal area in the maxillary denture and lingual regions of lower denture.

Conclusion

Within the limitations of the study, it can be concluded that the fractured acrylic samples when repaired with different materials.

1) Group 3 samples reinforced with carbon fibres demonstrated significantly highest mean flexural strength followed by Group 2 reinforced with 1wt% titanium dioxide nanoparticles and least with Group 1(control group).

2) Group 3 samples reinforced with carbon fibres demonstrated significantly highest mean impact strength followed by Group 2 reinforced with 1wt% titanium dioxide nanoparticles and least with Group 1(control group).

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