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Comparative Evaluation of Impact Strength of Two Denture Base Resins Under Two Processing Techniques by Incorporating Titanium Dioxide Nanoparticles In 1.5 W/W% And 3.5 W/W% – An in Vitro Study

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KEYWORDS

PMMA, titanium dioxide nanoparticles, impact strength, acrylizer

ABSTRACT:

INTRODUCTION- Conventional heat cure acrylic resin has a chain of PMMA where as in high impact denture base resins, the PMMA in the polymer are substituted with a copolymer with styrene or methyl methacrylate and are incorporated into the beads. TiO2 is one of the most preferred nanoparticles to be incorporated in the acrylic resin to enhance the modulus, strength and ductility of the resin.

4 OBJECTIVE- -The purpose of the study was to check the effective processing technique and optimum percentage of TiO2 to improve the impact strength of the acrylic resin when incorporated in different weights by percentage and three different processing techniques.

METHOD- 360 samples were prepared from heat cure resin and were divided into 12 groups. The samples for each group were tested for impact strength. Impact strength Test was conducted by the ISO 179 IZOD Type Impact Testing Machine.

RESULTS - The result of the study stated that -When compared with same processing technique that is in acrylizer but incorporated with 1.5w/w% and 3.5w/w% respectively, the impact strength was found higher in first group with 1.5w/w% incorporation.

CONCLUSION-There is a highly significant increase in the impact strength of heat polymerized PMMA denture base samples reinforced with 1.5 w/w% and 3.5 w/w % titanium dioxide nanoparticles processed in acrylizer, when compared with Heat polymerized PMMA denture base material processed in pressure pot.

1. INTRODUCTION

Walter Wright introduced the wonder material, Poly Methyl Methacrylate (PMMA) in 1937 which proved to be very useful in dentistry because of its various advantages like low cost, lack of toxicity, stability in oral environment, and ease of microbial adherence to the intaglio surface.[1,2] It had a few disadvantages like inferior mechanical properties and low thermal conductivity, so to overcome these, the conventional PMMA materials have been incorporated with metallic fillers for e.g. aluminium oxide, zinc oxide, zirconium oxide and titanium dioxide.[5]

After years of use, dentures will deteriorate and the bases may fracture due to constant exposure to external stresses caused by poor occlusion or fit of dentures. [4, 5] Dentures may fail inside the mouth during function which is fatigue phenomenon and denture failure may also occur extra-orally when the dentures are dropped on hard surfaces which occurs due to impact force. There are many types of fibers that can be used as reinforcement for denture base resins such as; polyethylene fibers, aramid fibers and carbon fibers but the carbon has an adversely effect on denture aesthetic because of its black color, while the Kevlar fibers are also used to reinforce and strengthen the PMMA; but they are

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causing problems in aesthetics and difficulty in polishing.

Recently, studies have investigated the effect of incorporating inorganic nano-particles into PMMA to improve its properties. The shape and size as well as the concentration and interaction of these nano-particles with a polymer matrix determines the properties of a polymer Nano-composite mixture. Many reports proved the dependence of acrylic resin properties on nanoparticle concentrations. Nano-materials are known for their superior characteristics compared to the conventional ones.[8]

One of the widely used additives to biomaterials is TiO_2 nanoparticles to induce antimicrobial properties along with prominent catalytic effect, other characteristics such as white colour, cheap, biocompatible, low toxicity, high stability and efficiency as well as availability, resistant to corrosion and high refractive index. [7] Therefore, it is one of the most preferred nanoparticles to be incorporated in the acrylic resin to enhance the modulus, strength and ductility of the resin.[4] Studies have shown that addition of TiO_2 nanoparticles to denture base resins have resulted in a positive effect compared to pure PMMA in various concentrations like 1 w/w %, 2 w/w % and 3 w/w % [7]. Further addition of TiO_2 nanoparticles with more than 5 w/w % leads to decrease in thermal stability.[8]

Therefore the aim of the present study was to evaluate the impact strength of two different denture base resins i.e. conventional heat cure acrylic resin and high impact acrylic resin under acrylizer and pressure pot as the processing techniques by incorporation of 1.5 w/w % and 3.5 w/w % titanium dioxide particles.

2. AIM AND OBJECTIVES OF THE STUDY

The purpose of the study was to check the effective processing technique and optimum percentage of TiO_2 to improve the impact strength of the acrylic resin.

3. MATERIALS AND METHOD:

S. No.	Material	Manufacturer	Lot No.
1.	Conventional heat cure denture base resin.(Trevalon)(FIG- 1)	Dentsply India Pvt Ltd, Gurgaon,Himachal Pradesh.	CP0012
2.	High impact heat cure denture base resin.(Trevalon High Impact) (FIG-2)	Dentsply India Pvt Ltd, Gurgaon,Himachal Pradesh.	HI1123
3.	Titanium dioxide nanoparticles. (FIG-3)	Parmali Wallace pvt. Ltd., Bhopal, India	2111985
4.	Dental plaster -Type III (FIG-4)	DPI limited, Mumbai, India	17091965
5.	Alginate separating media (FIG-5)	DPI limited, Mumbai, India	29081960
6.	Sand paper (320 grit)	Century, India	6021994
7.	Distilled water (FIG-6)	CPAP Products	5429

Standardization of samples: The stainless steel die was used to make the test samples to analyze the impact strength of the heat polymerized resins. All samples were manufactured in the dimension 3.0 mm X 10.0 mm X 65.0 mm (thickness X width X length) according to the ISO 1567:1999 standard.[10]

Grouping of samples :360 samples were fabricated and were divided into 12 groups, each group consisted of 30 samples : Heat cure acrylic resin was then mixed and

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packed into the moulds in dough stage as per manufacturer's instructions. Then the flask was closed and a pressure of 4 lbs was applied and bench cured for 30 minutes in a hydraulic press apparatus. [9] Then the flask was tightly secured in a clamp and transferred into a thermostatically controlled acrylizer and cured as per manufacturer's recommendation using short curing cycle which involved polymerization of the resin at 74 degree C for 90 minutes and then the temperature of the acrylizer was increased to 100 degree C and maintained for 30 minutes.[12]

All the excess material from the sample was removed with tungsten carbide bur. Finishing and smoothening of all borders of the samples was done with WL-B2, WL-B6, WL-B11 burs. Final finishing was done by sand paper of 320 grit and polishing of samples were done by wet pumice then buffed with a clean soft dry brush wheel.The finished samples reinforced with titanium dioxide nanoparticles (1.5%, 3.5% w/w) processed in acrylizer and pressure pot were then stored in distilled water for seven days in incubator prior to testing and samples were air dried before testing to determine impact strength by IZOD method in Pendulum impact tester.The samples for each group were tested for impact strength. Impact strength Test was conducted following the procedure given by the ISO 179 **IZOD Type Impact Testing Machine** (Tinius Olsen IZOD/Charpy Impact Tester Model IT504, USA) (Parmali Wallace Pvt. Ltd. Bhopal India).[25]

Statistical Analysis: Data was entered in Microsoft excel 2016 for Windows. Mean, standard deviation (SD), minimum and maximum values of impact strength in different denture base resin groups were calculated. One-way ANOVA was applied for comparison of impact strength between different groups. When One-way ANOVA showed significant difference, chi square was applied for pairwise comparison. P value <0.05 was considered statistically significant. Data analyses were performed using version 21.0 of the Statistical Package for Social Sciences (IBM Corporation, Armonk, New York, USA).

4. OBSERVATION- Table.1. Pairwise comparison of conventional resin incorporated with 1.5w/w% and 3.5 w/w% processed in acrylizer

Groups	RC2	RC3
Count	30	30
Sum	339.05	300.78
Average	11.30	10.02
P value	0.02	0.02

Table.2. Pairwise comparison of conventional resin incorporated with 1.5w/w% and 3.5 w/w% processed in pressure pot

Groups	RP2	RP3
Count	30	30
Sum	224.78	237.11
Average	7.49	7.90
P value	0.02	0.02

Table.3. Pairwise comparison of high impact resin incorporated with 1.5w/w% and 3.5 w/w% processed in acrylizer

Groups	TC2	TC3
Count	30	30
Sum	335.53	312.65
Average	11.18	10.42
P value	0.03	0.03

Table. 4 Pairwise comparison of high impact resin incorporated with 1.5w/w% and 3.5 w/w% processed in pressure pot

Groups	TP2	TP3
Count	30	30
Sum	236.05	244.76
Average	7.86	8.15
P value	0.05	0.05

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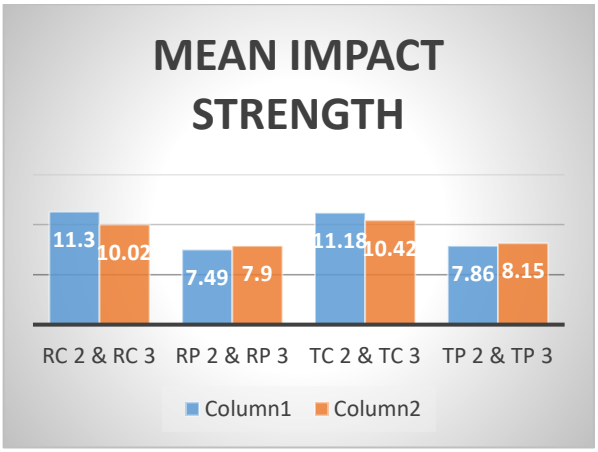
COMPARISON OF IMPACT STRENGTH BETWEEN TWO GROUPS

The mean impact strength was highest for Group RC2 when compared to Group TC2(11.24 kJ/m^2). When the Group RC3 & TC3 were compared the mean value was found to be 10.34 kJ/m^2.This difference was highly statistically significant since the p value was p≤0.05 (p=0.004).

Similar trend was observed when the impact strength was compared between Group TC2 and Group TC3. This difference was also statistically significant (p=0.03).

INTERCOMPARSION OF TWO GROUPS

GRAPH 1



GRAPH 1 shows inter comparison of groups. There is a visible difference when RC2 was compared with RC3. The impact strength for the group RC2 was found to be 11.30 kJ/m^2 and for other group RC3 was found to be 10.02 kJ/m^2. It also shows not so significant difference when RP 2 was compared with RP 3 with mean impact strength of 7.49 kJ/m^2 and 7.90 kJ/m^2 respectively. When TC2 & TC 3 were compared, the mean impact strength was 11.18 kJ/m^2 & 10.42 kJ/m^2 which was significant (p value=0.002)

5. RESULTS- The result of the study stated that

1. Conventional heat polymerized PMMA denture base material without reinforcement processed in pressure pot (Group RP1) showed the least impact strength of 7.15 ± 2.81 kJ/m^2.
2. Similar values were found in Group RP2 wherein the resin was incorporated with 1.5 w/w% of titanium dioxide nanoparticles and processed under pressure pot technique.
3. When compared with same processing technique that is in acrylizer but incorporated with 1.5w/w% and 3.5w/w% respectively, the impact strength was found higher in first group with 1.5w/w% incorporation.
4. Similar difference in impact strength was found when incorporated in less percent and different techniques except for Group TP2 & TP3 where the impact strength of second group was more than the first one.
5. When processed in pressure pot the high impact PMMA incorporated with 3.5w/w% shows more impact strength in the resin than 1.5w/w%.
6. Conventional resin reinforced with 1.5w/w% of TiO2 showed a mean impact strength of 11.30 kJ/m^2 and high impact resin when added with 1.5w/w% of TiO2 gave an impact strength of 11.18 kJ/m^2 which is quite similar when compared and hence it can be stated that when conventional resin can be incorporated with TiO2 it can give an impact strength as good as high impact resin.

6. DISCUSSION

The denture base resin is subjected to various stresses during function, which include compressive, tensile, shear, and impact stresses.[11] A study by ***Johnston et al***[48] observed that 68% of acrylic resin dentures fractured within the first three years after fabrication.

Smith[6] analyzed the practical situation with respect to fracture of dentures and showed that there are two types of failure.

1. Outside the mouth which is caused by impact forces, i.e., a high stress rate and

2. Inside the mouth, usually in function; probably due to a fatigue phenomenon, i.e., a low and repetitive stress.

Zirconium oxide, commonly referred to as zirconia (ZrO_2), possesses strong ionic inter atomic bonding, giving rise to its desirable material characteristics. Addition of zirconia nano-fillers to acrylic resin was found to improve mechanical

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properties. In addition to that ZrO_2 is known to have excellent biocompatibility and white colour which was less likely to alter esthetics.

In this study titanium dioxide nanoparticles were used in a concentration of 1.5w/w % and 3.5w/w % to evaluate the increase in impact strength if any after incorporation of titanium dioxide nanoparticles. After completion of polymerization cycle, the flask was allowed to cool in water bath to room temperature and the acrylic resin samples were retrieved after deflasking. After curing the samples were removed, trimmed and finished using tungsten carbide burs WL-B2, WL-B6, WL-B11 and fine abrasives of grit size 120/140 microns and dry sand paper without altering the sample surfaces and dimensions.[3]

The results of the present study indicate that there was significant increase in impact strength in Heat polymerized PMMA denture base material reinforced with titanium dioxide nanoparticles (1.5 w/w% and 3.5 w/w%) processed under two techniques. The result of this study stated that conventional heat polymerized PMMA denture base material without reinforcement processed in pressure pot Group RP1 showed the least impact strength of 7.15 ± 2.81 kJ/m^2. Similar values were found in Group RP2 wherein the resin was incorporated with 1.5 w/w% of titanium dioxide nanoparticles and processed under pressure pot technique.Conventional resin reinforced with 1.5w/w% of TiO2 showed a mean impact strength of 11.30 kJ/m^2 and high impact resin when added with 1.5w/w% of TiO2 gave an impact strength of 11.18 kJ/m^2 which is quite similar when compared and hence it can be stated that when conventional resin can be incorporated with TiO2 it can give an impact strength as good as high impact resin.

The results obtained are similar to the study done by ***Paul L et al,*** that 1 w/w % of TiO_2 modified high impact acrylic had less impact strength compared to conventional veined acrylic and also least among all. The increase in filler content (both veined fibers and the nanoparticles) causes these particles to agglomerate.

SCOPE FOR FURTHER STUDIES

1. Fatigue testing of these materials under dynamic loading using the denture base configurations in simulated oral conditions, using saliva or its substitutes is an area for further research.

2. Further research is needed to evaluate the effect of aging on the new reinforced denture base material before clinical application.

3. Other physical and mechanical properties like thermal diffusivity, hardness, abrasion resistance, colour stability and disinfectant property can be studied.

LIMITATIONS OF THE STUDY

In this study samples were prepared in accordance with ADA specification number 12. The study was designed and carried out with utmost accuracy. The present study has certain limitations which are enlisted below.

1. In the oral cavity, reinforced denture base is exposed to forces of varying magnitudes acting in different directions. The same situation could not be simulated in this in vitro study.

2. Scanning electron microscopy (SEM) examination of the samples to evaluate the adhesion of TiO_2 nanofillers on the surface of PMMA was not performed.

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