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A Comparative Evaluation of Measuring Impact Strength of Heat Cure Acrylic Denture Base Resin With and Without Addition of Zirconia Nano-Particles -An In Vitro Study

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Abstract:
Polymethyl methacrylate (PMMA) acrylic resin, is a most popular denture base material, but has poor mechanical properties. Some researches proved that acrylic resin can be strengthened with a structural component (filler) added in the acrylic matrix, to form a composite structure.
Objective: To evaluate and compare the impact strength of zirconia (ZrO_2) reinforced high impact acrylic resin with that of high impact acrylic resin (acryl on H, ASIAN ACRYLATES, Mumbai, India).
Materials and methods: There were 40 specimens in the test. Each group has 20 specimens fabricated from high impact acrylic resin (control) [fig 1]; 20 specimens fabricated from 1% zirconia (ZrO_2) reinforced high impact acrylic resin [fig 2]. Specimens were subjected to the test of impact strength in the Izod pendulum impact testing machine [fig 4].
Results: Even with a mild percentage of nano particles that are 1%, there is a significant increase in the impact strength observed in the reinforced specimens when compared to the control group.

Key words: Heat Cure Acrylic Resin ,Nano Zirconia, Impact Strength

Introduction

Polymethyl methacrylate (PMMA) is one of the main materials used in dentistry for the construction of denture base. There are many other polymeric materials which have been used for fabrication of denture base.[1,2]Acrylic resins came into use in dentistry between 1930 and 1940 and is used as denture base materials So far. PMMA still remains the preferred material for removable prostheses, and orthodontics appliances, Obturator,[3-5] because of its low cost, ease of application polishability along with its reliance on simple processing equipment [6-8]. The major drawback of the use of PMMA as a denture base material is its low impact strength that leads to the fracture of the prosthesis.
Increasing impact strength is required to prevent the fracture of the denture resulting from its accidental fall and helps to withstand higher flexural stresses developed during mastication. [9-12]

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Many attempts have been made to improve Mechanical properties of acrylic resins including its chemical modification by the addition of rubber graft copolymer and also by the addition of various reinforced materials like metals, metal fillers, carbon fibers, aramid fibers, glass fibers, and ultra high modulus polyethylene[13-14].The literature reveals that, addition of varying amount of metal fillers such as powdered silver ,copper and Aluminium into PMMA at various concentrations increases strength and reduces the polymerization shrinkage and warpage make the material radiopaque and inhibit the growth of bacteria over the denture surface. The major disadvantage of adding metal fillers is its compromised aesthetics [15,16].many recent approaches has been improve the properties of heat cure acrylic resins are the addition of zirconium oxide as a filler study has shown that zirconia is a compatible and additional advantage of zirconia over other metal filler is it has superior esthetics. [17,18,]
Ayad et al. investigated the effect of reinforced high impact resin with 5% and 15% zirconium oxide and concluded that reinforcement of high impact resin with zirconium powder increases its transfer strength significantly, further studies were recommended with different concentrations of zirconia fillers reinforcements to different acrylic resin systems to understand more on the effect of zirconia enforcement on mechanical properties of acrylic resin. This study was planned to evaluate the effect of a very mild percentage, i.e., 1% zirconium oxide reinforcement on the impact strength of high impact acrylic resin.[21]

Materials and Methodology

This in vitro study consist of HIGH IMPACT Heat cure acrylic denture base resin material PMMA (ACRALYN-H plane pink material) was used as a control group in this study and Zirconium oxide Nanoparticle (size30-50nm, purity99.9%, were purchased from Nano labs PVT ltd.) are used in a concentration of 1%by weight in experimental group. Metal analogs of the desired dimensions (60mm x 7mm x 4mm)[8] are fabricated according to ISO standardization 20795-1(2008) (FIG 3)and invested by exposing 2mm of the metal analog from the invested surface of the lower compartment of the invested flask by 2 pour technique with dental stone. After the material has set, both halves of the flask are separated, and metal samples are retrieved. Sodium alginate separating media (cold mold seal) is applied over the stone and both the halves of the flask, including the mold space.

- For fabricating the control group, resin powder is mixed with the monomer in 3:1 by volume in a porcelain jar.
- For fabricating the test Samples, an acrylic liquid containing zirconium nanoparticles, 1% wt were prepared, to achieve the above concentration 0.04g of nanoparticles were added to each milliliter of acrylic monomer respectively. After the addition of nano fillers to the monomer, the fillers will be dispersed in the monomer by ultra-sonication using a probe sonicator apparatus. The suspension of the monomer with nanoparticles will be mixed with acrylic powder. The powder/liquid ratio for mixing acrylic resin will be 3:1 by volume. The mixing is done in a porcelain jar with a clean dry wax spatula and packed into mold space in the dough stage using a pneumatic bench press at 1500-2000psi. The specimen will be bench cured for 30-45 min and polymerized by using a long curing cycle at 74-degree cent, for 8hrs and boiled for 1hour. After curing, the flask will be bench cooled to room temperature, and the specimen will be trimmed to appropriate dimensions, and polishing will be done with the help of 320,420grit silicon carbide papers.

Grouping of samples:

- A total of 40 specimens is fabricated for this study each group containing 20 specimens of dimensions 60 x 7 x 4mm.(fig -3)
- Group 1(control group, n=20): PMMA samples (fig 1)
- Group 2 (test group, n=20): 1% zirconium reinforced PMMA samples(fig 2)
- Samples are tested in the Impact testing machine for Impact strength.(fig4)

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Figure 1(group 1 , control group, PMMA samples

Figure 2 (group 2= zirconium oxide reinforced PMMA samples)

Figure 3 (metal analogue)

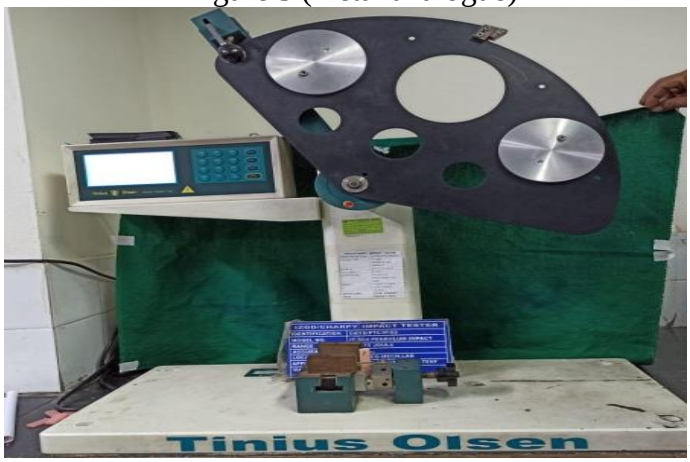

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Figure 4 (IZOD impact testing machine containing sample)

Impact Strength:

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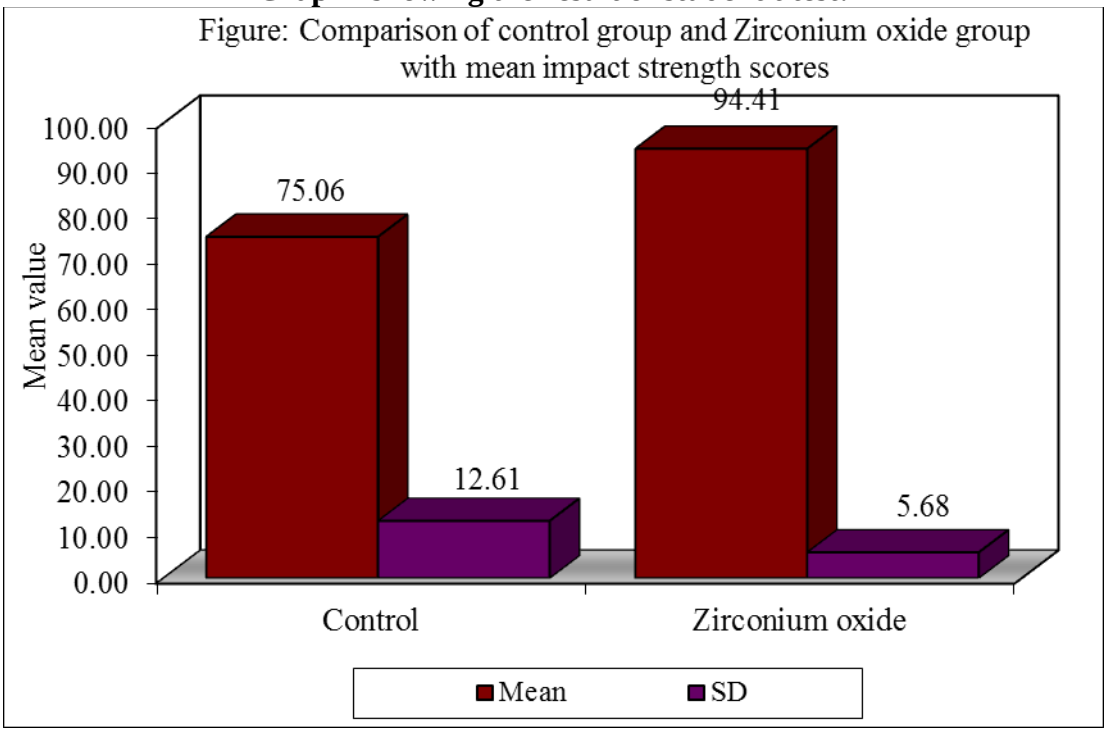
After that all specimens are stored in distilled water at 37˚C for 24 hours , The samples were tested with Pendulum impact tester (CSR Hyderabad, India) using the IZOD method. The un-notched specimens were clamped at one end vertically and facing the pendulum to break the specimens. The test was performed with a 0.85 J pendulum impact testing machine (bench type). The energy absorbed by the specimen up to fracture was detected .the machine gives a digital reading and values obtained were tabulated for statistical analysis. The mean impact strength of each group was calculated, and data were analyzed by means of student t-test.
Result: Table 1 shows the mean values and standard deviation of test groups A and B (control group and 1% Zro2). Graph 1 shows the result of student t-test
The result revealed an increase in values of impact strength in group B as compared to the control group. The student T-test indicates that there is a significant difference between the two groups.

Table 1: shows the mean values and standard deviation of testing groups:

Groups	N	Min	Max	Mean	SD	SE	P value
CONTROL GROUP A	20	55.99	99.76	75.06	12.61	2.82	0.0001*
TEST GROUP B	20	87.81	104.88	94.41	5.68	1.27	

*p<0.05 indicates significant at 5% level of significance

Graph1 showing the result of student t test:



Discussion:
Fracture of an acrylic denture base is a common clinical problem that every onecome across. Therefore a numerous trials were done to improve the mechanical properties of PMMA, in particular, the impact strength, through incorporating of ZrO2 Nanoparticles. There are three ways to improve the mechanical properties of PMMA: chemically modifying it, replacing PMMA with an alternative material and reinforcing it with other materials [14,19]
The incorporation of zirconia in various dental materials has been studied, and it was found to be biocompatible and it has significant beneficial effects on mechanical properties of PMMA. [17,21]
Zuccari et al..12 in his study, he concluded that (1) addition of particles usually increases the water sorbed by the resins systems; (2) however, two-volume % admixtures in a PMMA resin matrix shows a significant

improvement in the mechanical properties; (3) among the oxide particles, zirconia exhibited the most significant improvement in modulus of elasticity, transverse strength, toughness and hardness; and (4) mechanical properties (transverse strength, 0.2% offset yield strength and modulus of elasticity) were linearly correlated to hardness numbers.

In the present study, the impact strength of acrylic denture base material is evaluated after the addition of Nano Zirconia (ZrO2) was used because it is excellent biocompatible material also esthetic because of white color and is less likely to alter esthetic.[23]

The nano-sized zirconia has been successfully used to fabricate nanocomposite with high hardness, high refractive index and improved scratch resistance.[18,22]

Moreover, due to the presence of more than one active side, this will lead to physical interaction (molecular interaction) by Vander Waal forces, which enhanced the bond strength. Both Vander Waal force and covalent bonding will increase the shear strength and adhesion force. The proper percentage range of zirconium oxide Nano-fillers (Percentages of 1.0%by weight) was selected because percentages above 7% were leads to massive changes occurred in the color of acrylic [20]

Impact strength

Impact strength is defined as the energy required to break a material by an impact force .The results of the impact strength test showed that the addition of nano-ZrO2 powder increased the value of the impact strength, when compared to the control group, 1wt% group has the highest impact strength, The increase in impact strength due to the interfacial shear strength between nano-filler and matrix is high due to the formation of cross-links or supra molecular bonding which cover or shield the nano fillers and prevent the propagation of the crack. Also, the crack propagation can be changed by good bonding between the nano filler and the resin matrix [23, 24]. Also, the increase in the percentage of nano-ZrO2 powder effects the interface region lead to a lowering of energy dissipation per unit volume and consequently lowers the impact strength [23]. A similar finding was reported by Nabil [25] when he added zirconia nanoparticles and concluded that the Impact strength increases at 3% and 5% percentage of addition Nano-ZrO2, Then a slight decrease at the percentage 7% addition of nano- ZrO2 fillers.

Clinically, zirconia reinforced PMMA may be useful in conditions where masticatory forces are relatively very high, like distal extension bases opposing natural teeth, single complete denture, over dentures, long term provisional restorations, and implant-supported complete arch prosthesis.

This study is limited with the use of zirconia only, rather other forms like YSZ and nano composites of titanium, Aluminium with zirconium oxide can also be used for reinforcement. Further studies are required to check the effect of zirconium reinforcement on the denture base resins. Invitro studies are suggested to investigate the clinical performance of this material in the oral cavity. These studies help in the development of PMMA/Zr composite reinforcements.

Conclusions

Within the limitation of this study, we can conclude that:

The addition of zirconium oxide nanofillers to high impact acrylic resin increases the impact strength when compared to the control group. According to the results in the present study, the best result was found even when using a concentration of 1%wt.

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