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# EFFECT OF TITANIUM DIOXIDE AND ZINC OXIDE NANO PARTICLES ON IMPACT STRENGTH, REINFORCED WITH TWO DIFFERENT DENTURE BASE RESINS WITH AND WITHOUT VEINED ACRYLIC.

Dentistry


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## ABSTRACT

**Introduction:** Poor mechanical properties are among the main limitations of denture base resin. There has been a continuous attempt to improve the mechanical properties of denture base resins. Nanotechnology has evolved healthcare industry to a large scale and its applications are a boon to modern medicine and dental science. Nanoparticles are nowadays, extensively used in prosthodontics as they are incorporated in Polymethyl Methacrylate denture bases to alter the properties such as impact strength. **Aim:** To evaluate and compare the effect of Titanium Dioxide (TiO ) and Zincoxide (ZnO ) nanoparticles on impactstrength of two commercially available heat cure acrylic resins. **Materials and Methods:** The in-vitro study was conducted in Department of Prosthodontics, Meghna istitute of Dental Sciences, that involved 120 samples. Materials compared were Dental Products of India (DPI) heat cure acrylic and Trevalon heat cure acrylic. Each group was further categorized into six groups to measure the impact strength i.e, without incorporation of nanoparticles and with incorporation ofnanoparticles Zno and TiO2 and with and without veined acrylic. Samples obtained were tested for impact strength using Izod method. Statistical analysis was done using a Kruskal wallis test and Mann Whitney U Test . **Results:** In the two types of materials studied, the mean impact strength of Trevalon significantly higher (p-value=0.045) than DPI. After the addition of nanoparticles, i.e; Zno and TiO2 the mean impact strength was higher in Trevalon without veined (11.33 kJ/m2 with the addition of 1% TiO2 nanoparticles, 10.194kJ/m2 addition of1.4% ZnO nanoparticles, 9.163 kJ/m2 in control group) compare to Trevalon with veined acrylic( 8.173 kJ/m2 with the addition of 1% TiO2 nanoparticles, 7.245kJ/m2 addition of 1.4% ZnO nanoparticles, 6.143 kJ/m2 in control group).Mean impact strength of DPI without veined(5.174 kJ/m2 with the addition of 1% TiO2 nanoparticles, 4.107kJ/m2 addition of 1.4% ZnO nanoparticles, 3.837 kJ/m2 in control group) and Mean impact strength of DPI with veined acrylic( 3.79 kJ/m2 with the addition of 1% TiO2 nanoparticles, 3.071kJ/m2 addition of 1.4% ZnO nanoparticles, 3.163 kJ/m2 in control group).



## KEYWORDS


## INTRODUCTION

Polymethyl Methacrylate (PMMA) is one of the most frequently used material in dentistry that is commonly used for prosthetic dental applications, that includes the fabrication of artificial teeth, denture bases, dentures, obturators, orthodontic retainers, temporary/ provisional crowns, and for the repair of dental prostheses[1]. Many desirable properties such as stability in the oral environment, ease of manipulation, polish ability, and fabrication with the use of inexpensive equipment has led to its extensive use in fabrication of prosthesis, and orthodontic appliances. Since its introduction there has been continuous trials to improve the mechanical properties of acrylic resins [2].

Various properties of heat cure acrylic resin like tensile strength, compressive strength, and surface hardness are important but impact strength has a significant role to play clinically. Impact strength is the ability of the material to withstand a sudden applied load and is stated in terms of energy lost per unit of thickness[1]. Many studies have been carried out to improve the properties of denture base materials by adding suitable fillers into PMMA denture base that included, PMMA reinforcement with glass fibers, sapphire whiskers, aramid fibers, carbon fibers, metal wires, nylon, polyurethane fibers and zirconia that showed improved fracture resistance3-5.Nanotechnology has evolved healthcare industry to a large scale and its application are a boon to modern medicine and dental science. Futuristically, it is expected that it will pervade and further revolutionise the art and science of dentistry and will expand all the aspects of oral diseases, diagnosis, prevention and treatment. Nanomaterials are now successfully being used in caries inhibitors, antimicrobial resins, hard tissue remineralising agents, targeted drug delivery, scaffolds, biomembranes, restorative cements, adhesion promoters and boosters, bioactive glass, tissue wires and nano composites[6].

The scientific advancements have led to the era of nanotechnology and nano-phased materials, and thus; a great attention is directed towards the use of nano-sized fillers to reinforce the denture base resins leading to the production of a polymer nanocomposite with improved mechanical and physical properties as compared to those filled with microscale particles[7].

Inorganic carriers like Titanium dioxide ($TiO_2$) nanoparticles have been used as additives to biomaterials due to its certain characteristics such as white colour, low toxicity, antimicrobial properties, high stability and efficiency as well as availability and low cost[11].

In literature, various advantages as well as disadvantages of $TiO_2$ and ZnO nanoparticles on mechanical properties, especially flexural strength of PMMA have been recorded. The addition of nano-filler $TiO_2$ improved the thermal, mechanical and viscoelastic properties of the PMMA. A study done by Vikram S and Chander NG, wherein, the incorporation of ZnO in denture base resin, led to a significant increase in the flexural strength[9]. As many studies done before evaluated the flexural strength therefore, the present study aimed to evaluate the and compare the effect of titanium dioxide and Zic oxide nanoparticles on impact strength of two commercially available heat cure acrylic resins (DPI and Trevalon).

## MATERIALS AND METHODS:-

In this invitro study, Total of 120 samples were prepared using denture base resin.To fabricate the acrylic samples a stainless steel rectangular shape mould was measuring 80mm x 4mm x 10mm and wax pattern was prepared to create a mould space.(FIGURE 1)

**Figure 1: Waxpattern fabrication**

Two pour technique, was used for the flasking of wax blocks. After 15-20 minutes when the gypsum was completely set, it was placed in the dewaxing unit at 100°C for 5-7 minutes. Flask was carefully opened and clean boiling water was poured over it to completely eliminate the wax. A brush and soap solution was used to clean any traces of wax. It was allowed to cool for 10 minutes and then two layers of cold mold seal (DPI- The Bombay Burmah Trading Corporation Ltd. Cold Mold seal) was applied all over the set gypsum. Gypsum moulds were thus, obtained.(FIGURE 2)

- Total 120 samples divided in to two groups containing 60 samples each, group 1 with DPI acrylic resin and group 2 with Trevalon acrylic resin.
- Group 1 (DPI) again divided in to sub group 1a with conventional heat cure acrylic resin containing 30 samples each, subdivided in to control (10 samples); 1% of titanium dioxide nano particles incorporated acrylic (10 samples); 1.4% of zinc oxide nanoparticles incorporated acrylic (10 samples).
- Group 1b with heat activated veined acrylic resin containing 30 samples each, subdivided in to control (10 samples); 1% of titanium dioxide nano particles incorporated veined acrylic (10 samples); 1.4% of zinc oxide nanoparticles incorporated veined acrylic (10 samples).
- Group 2 (Trevalon) also again divide in to sub group 2a with conventional heat cure acrylic resin containing 30 samples each, subdivided in to control (10 samples); 1% of titanium dioxide nano particles incorporated acrylic (10 samples); 1.4% of zinc dioxide nanoparticles incorporated acrylic (10 samples).
- Group 2b with heat activated veined acrylic resin (Trevalon) containing 30 samples each, subdivided in to control (10 samples); 1% titanium dioxide of nano particles incorporated veined acrylic (10 samples); 1.4% of zinc oxide nanoparticles incorporated veined acrylic (10 samples).
- Finally impact strength tested with IZOD impact testing machine.

**Curing of the samples:**
The flask was immersed in an acryliser at room temperature. The temperature was raised to 73°C, held for 1 ½ hours, then to 100°C and this temperature was maintained for half an hour. After the curing cycle, the flask was removed from the acryliser water-bath and bench cooled for 30 minutes, immersed in cool tap water for 15 minutes preceding the deflasking[11].

**Finishing and polishing of samples:**
The acrylic specimens were then retrieved, finished and polished. The dimension and quality of specimens were verified for any porosity, visible impurities and dimensional deformity. Finally there were twelve groups of 10 samples in each group. (FIGURE 3)

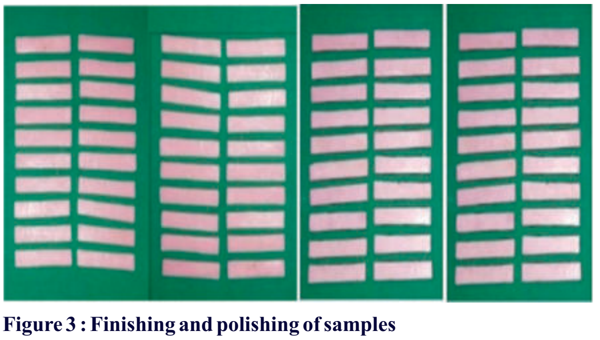

**Figure 3 : Finishing and polishing of samples**

**Evaluation of Samples for Impact Strength:**
Evaluation of test samples was done using Izod Impact Testing Machine (**CIPET:Centre For Skilling And Technical Support (CSTS)** ). The un-notched sample was clamped vertically and hammer with 2 Joules was used to break the samples . Breaking energy was then recorded in joules and then Impact strength was calculated in kJ/m2.

**Statistical Analysis**
The data obtained were tabulated and subjected to statistical analysis using SPSS 23.0 software for windows version 23.0 (Armonk, NY: IBM Corporation. Released 2015). The significance value was p-value <0.05 (α=0.05). Parametric tests namely Kruskal wallis test and Mann Whitney U Test were used to statistically analyse the data.

**RESULTS:**
The mean impact strength of group 2 (6.49 kJ/m2) heat cure acrylic resin was significantly more than group (6.12 kJ/m2) (p-value- 0.045) [Table 1]. The mean impact strength. was also compared between subgroups D1, D2, D3 and D4 and T1, T2, T3 and T4 using the one-way ANOVA test. There was a significant difference in the mean impact strength of all the subgroups

**Table 1:** *Highly statistically significant difference was found in the overall mean impact strength values between DPI and Trevalon heat cure acrylic resins (p>0.05).

| GROUP | N | Mean | Std. Deviation | Mann Whitney U | Z | P value |
|---|---|---|---|---|---|---|
| 1.DPI | 60 | 3.8570 | 0.76770 | 1.000 | -9.443 | 0.000* |
| 2.TREVALON | 60 | 8.7086 | 1.79231 | | | |

The mean impact strength. was also compared between A, B, C, D, E, F, G, H, I, J, K, L using the Mann Whitney U Test. There was a significant difference in the mean impact strength of all the subgroup. [Table 2]

**[Table:3]:** Intragroup Comparison of mean impact strengths -Kruskal wallis test

**Intragroup (within group) Comparison – Kruskal Wallis Test**

| | | N | Mean | Std. Deviation | Kruskal Wallis Test Chi Square | P value |
|---|---|---|---|---|---|---|
| DPI | DPI+HCA+control | 10 | 3.8370 | 0.42377 | 19.492 | 0.000* |
| | DPI+HCA+1%Tio2 NP | 10 | 5.1740 | 0.30281 | | |
| | DPI+HCA+1.4%Zno2 NP | 10 | 4.1070 | 0.49200 | | |
| | DPI+HCVA+control | 10 | 3.1630 | 0.18105 | | |
| | DPI+HCVA+1%Tio2 NP | 10 | 3.7900 | 0.29848 | 17.177 | 0.000* |
| | DPI+HCVA+1.4%Zno2 NP | 10 | 3.0710 | 0.06903 | | |
| Trevalon | Trevalon+HCA+control | 10 | 9.1630 | 0.30948 | | |
| | Trevalon+HCA+1%Tio2 NP | 10 | 11.3330 | 0.38624 | 23.871 | 0.000* |
| | Trevalon+HCA+1.4%Zno2 NP | 10 | 10.1940 | 0.34629 | | |
| | Trevalon+HCVA+control | 10 | 6.1430 | 0.30801 | | |
| | Trevalon+HCVA+1%Tio2 NP | 10 | 8.1738 | 0.30703 | 24.150 | 0.000* |
| | Trevalon+HCVA+1.4%Zno2 NP | 10 | 7.2450 | 0.39931 | | |

*Statistically significant (p<0.05)

**Intragroup (within group) Comparison – Mann Whitney U Test**

| | | | | Mann Whitney U | Z | P value |
|---|---|---|---|---|---|---|
| DPI | HCA | Control | 1%Tio2 NP | 0.000 | -3.781 | 0.000* |
| | | 1%Tio2 NP | 1.4%Zno2 NP | 9.000 | -3.106 | 0.001* |
| | | Control | 1.4%Zno2 NP | 18.000 | -2.424 | 0.015* |
| | HCVA | Control | 1%Tio2 NP | 6.000 | -3.330 | 0.001* |
| | | 1%Tio2 NP | 1.4%Zno2 NP | 2.000 | -3.633 | 0.000* |
| Trevalon | HCA | Control | 1.4%Zno2 NP | 35.000 | -1.139 | 0.255 |
| | | Control | 1%Tio2 NP | 0.000 | -3.794 | 0.000* |
| | | 1%Tio2 NP | 1.4%Zno2 NP | 5.000 | -3.415 | 0.000* |
| | HCVA | Control | 1.4%Zno2 NP | 3.000 | -3.566 | 0.000* |
| | | Control | 1%Tio2 NP | 0.000 | -3.787 | 0.000* |
| | | 1%Tio2 NP | 1.4%Zno2 NP | 6.000 | -3.334 | 0.000* |
| | | Control | 1.4%Zno2 NP | 1.000 | -3.717 | 0.000* |

*Statistically significant (p<0.05)

[Table 3:]: Intragroup Comparison of P value - Mann Whitney U test (p<0.05)

## DISCUSSION

The above study was planned to evaluate and compare the effects of titanium dioxide and Zinc oxide nanoparticles on the impact strength of PMMA with and with out veined . The ideal denture base material should possess adequate physical and mechanical properties which are key attributes for the basic requirements of denture base materials like biocompatibility, good aesthetics, high bond strength with available denture teeth, radiopacity and ease of repair[12]. The impact and flexural strength of PMMA is not satisfactory as continuous efforts are being done to improve the same.

Fracture in an acrylic denture base is a common clinical problem. Therefore, numerous trials were done to improve the mechanical properties of PMMA, but they can be summarised in three ways: replacing PMMA with an alternative material; chemically modifying it; and reinforcing the PMMA with other materials like fibers or metals, and recently nanoparticles[13].

Acrylic specimens in size 60 mm in length, 7 mm in width and 4 mm in thickness were prepared from two different heat cure acrylic denture base resin (DPI and Trevalon). The test samples were incorporated with 1% nano $TiO_2$ and 1.4% nano Zno and without nanoparticles .

The test samples thus obtained were tested for Impact Strength using Izod method. The results were obtained and data was statistically analysed.

Narendra R et al., in an in-vitro study evaluated the impact strength of conventionally heat cured and high impact heat cured polymethyl methacrylate denture base resins. They concluded that Trevalon had higher impact strength than DPI. The mean impact strength of Trevalon was found to be higher than DPI[14]. Praveen B et al., in a Scanning Electron Microscopy (SEM) study compared the impact strength and fracture morphology of different heat cure denture acrylic resins and it was concluded that the mean impact strength of Trevalon was higher than DPI. The SEM was also done to study the matrix structure. It was concluded that the impact strength of the acrylic resins was affected by the reinforcement of fibers[15].

The reason for high impact strength in Trevalon is co-polymerization of Methyl Methacrylate (MMA) and butadiene monomer molecules. The resultant polymer is further surface coated with MMA, thus enabling further cross linkage on polymerization. Due to this complex structure there is increased cross linking amongst the polymer chains resulting in rapid polymerization and increase in mechanical properties specially impact strength[16].

Some studies have also shown the adverse effect of addition of $TiO_2$ nanoparticles[10,17,18]. One of such examples is a study conducted by Ahmed MA et al., where it was concluded that the addition of $TiO_2$ nanoparticles adversely affected the impact strength of conventional acrylic resin [17]. The reason of decrease in the impact strength on addition of $TiO_2$ nanoparticles in PMMA could be the lack of chemical bond between $TiO_2$ nano particles and PMMA. Also, the $TiO_2$ nanoparticles agglomerate into larger particles, thus acting as stress concentrating center in the matrix. This agglomeration of $TiO_2$ nanoparticles probably gives rise to some microporosities and microcracks as structural defects resulting in loss of mechanical properties. Thus, concluding that the content of nanoparticle additives is of critical importance[17]. Similarly, Han Y et al., had a similar conclusion and related the results to agglomeration of particles within the matrix, which makes them stress concentration areas[18].Vikram S and Chander NG in 2020 concluded that the flexural strength of PMMA denture base increased with the addition of zinc oxide nano particle concentration [0.4 %, 0.6%, 0.8%, 1.2% and 1.4%] to the polymethyl methacrylate denture base. [9]

Silanisation of the nanoparticles is an effective pretreatment for improved bonding thus resulting in improved mechanical properties. The Silane coupling agent act as a mediator for formation of metallic bond between the metal nanoparticles and the polymer chains, which otherwise are not reactive and act only as impurities. This is detrimental on the mechanical properties of the resin especially the impact strength[8].

### Limitation

The present study has its limitation in use of single concentration of the nanoparticles. Also, there could have been a lack of visualisation of dispersion of nanoparticles in the resin matrix especially at the fracture site.

## CONCLUSIONS

Within the limitations of this in vitro study, it can be concluded that the mean impact strength of Trevalon was found to be the higher than the mean impact strength of DPI. Also, it was observed that the incorporation of $TiO_2$ and Zno nanoparticles incorporation increased the impact strength of both the commercially available heat cure denture base resin (though, statistically significant difference was found). Finally to conclude, as the number of studies evaluating the effect of nanoparticles on the mechanical properties of heat cure acrylic resin are limited; the futuristic approach can aim on the pretreatment of the nanoparticles, SEM can be utilised for better understanding of dispersion of nanoparticles in resin matrix.

## REFERENCES

[1] Zafar MS. Prosthodontic Applications of Polymethyl Methacrylate (PMMA): An update. Polymers. 2020;12:2299. Doi: 10.3390/polym12102299.
[2] Gautam R, Singh RD, Sharma VP, Siddhartha R, Chand P, Kumar R. Biocompatibility of polymethylmethacrylate resins used in dentistry. J Biomed Mater Res B Appl Biomater. 2012;100(5):1444-50.
[3] Gad MM, Al-Thobity AM, Rahoma A, Abualsaud R. Reinforcement of PMMA denture base material with a mixture of ZrO2 nanoparticles and glass fibres. Int J Dent. 2019:01-12. Available from: https://doi.org/10.1155/2019/2489393.
[4] Mowade TK, Dange SP, Thakre MB, Kamble VD. Effect of fiber reinforcement on impact strength of heat polymerized polymethyl methacrylate denture base resin: In vitro study and SEM analysis. J Adv Prosthodont. 2012;4(1):30-36.
[5] Somani MV, Khandelwal M, Punia V, Sharma V. The effect of incorporating various reinforcement materials on flexural strength and impact strength of polymethy lmethacrylate: A meta-analysis. J Indian Prosthodont Soc. 2019;19(2):101.
[6] Sharan J, Singh S, Lale SV, Mishra M, Koul V, Kharbanda OP. Applications of nanomaterials in dental science: A review. J Nanosci Nanotechnol. 2017;17(4):2235-55.
[7] Wang W, Liao S, Zhu Y, Liu M. Recent applications of nanomaterials in prosthodontics. J Nanomat. 2015:01-11.
[8] Kango S, Kalia S, Celli A. Surface modification of inorganic nanoparticles for development of organic-inorganic nanocomposites- A review. Progress in Polymer Science. 2013;38:1232-61.
[9] Vikram, Chander. Effect of zinc oxide nanoparticles on the flexural strength of polymethylmethacrylate denture base resin. Official Publication of Istanbul University Faculty of Dentistry 2020; 54(1): 31-35.
[10] Sodagar A, Bahador A, Khalil S, Shahroudi AS, Kassaee MZ. The effect of TiO2 and SiO2 nanoparticles on flexural strength of poly (methyl methacrylate) acrylic resins. J Prosthodont Res. 2013;57(1):15-19.
[11] Phillips RW. Skinner's Science of Dental Materials. W.B. Saunders Company. 12th ed. 1973; p. 682.
[12] Prajwala N, Kumar CR, Sujesh M, Rao DC, Pavani L. Denture base reinforcing materials-A review. IP Annals of Prosthodontics and Restorative Dentistry. 2020;6(2):52-59.
[13] Alla RK, Sajjan S, Alluri VR, Ginjupalli K, Upadhya N. Influence of fiber reinforcement on the properties of denture base resins. Journal of Biomaterials and Nanobiotechnology. 2013;14(1):91-97.
[14] Narendra R, Reddy NS, Reddy SD, Purna CS, Shekar MC, Balasubramanyam S. A comparative evaluation of impact strength of conventionally heat cured and high impact heat cured polymethyl methacrylate denture base resins: An in vitro study. The Journal of Contemporary Dental Practice. 2013;14(6):1115.
[15] Praveen B, Babaji HV, Prasanna BG, Rajalbandi SK, Shreeharsha TV, Prashant GM. Comparison of impact strength and fracture morphology of different heat cure denture acrylic resins: An in vitro study. Journal of International Oral Health. 2014;6(5):12.
[16] Albeladi HK, Al-Romaizan AN, Hussein MA. Role of cross-linking process on the performance of PMMA. Int J Biosens Bioelectron. 2017;3(3):279-84.
[17] Ahmed MA, El-Shennawy M, Althomali YM, Omar AA. Effect of titanium dioxide nano particles incorporation on mechanical and physical properties on two different types of acrylic resin denture base. World Journal of Nano Science and Engineering. 2016;6(3):111-19.
[18] Han Y, Kiat-amnuay S, Powers JM, Zhao Y. Effect of nano-oxide concentration on the mechanical properties of a maxillofacial silicone elastomer. J Prosthet Dent. 2008;100(6):465-73.