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# Effect of metal oxides on some mechanical properties of clear acrylic specific for artificial eye

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## Abstract

**Aim**: the study was undertaken to assess the effect of various metal oxides on some mechanical properties of acrylic resin.

**Materials and methods**: Two hundred acrylic specimens were constructed in total. There were two tests utilized (transverse and hardness). For each test, there were nine experimental groups according to the type of metal oxides used. The specimens without use any of metal oxides were considered as control. For transverse test, the specimens were exposed to loads until fracture. For hardness test, the specimens were tested; values were obtained. All data were analyzed and compared using ANOVA and tukey tests.

**Results:** the addition of metal oxides at different concentrations enhanced the transverse strength of acrylic. Significant differences were statistically found between experimental groups and control group ($P<0.001$); among experimental groups ($P<0.001$). For hardness test, there was a slight increase in the mean values of hardness of clear acrylic as the concentration of metal oxides increases. No significant differences were statistically found among experimental groups ($P>0.05$); between experimental groups and control group ($P>0.05$) except there was significant difference between control and 5% $TiO_2$ group ($P<0.05$).

**Conclusion**:The incorporation of metal oxides improved the transverse strength and surface hardness of acrylic resin.

**Keywords: ocular prosthesis, transverse strength, hardness**

## Introduction

Congenital deformity (e.g. anophthalmia), trauma (e.g. car accidents) and eye disease (i.e. squamous cell carcinoma) are considered as the major causes of an eye removal [1,2]. Such defects will have a negative impact on the psychological and social life of the patient. The manufacture of ocular prostheses can restore the appearance, give such individuals professional and social acceptance, preserve the volume of eye socket and increase patient confidence at public [3,4,5]. The materials used for ocular prosthesis must have appropriate properties such as excellent aesthetic, durability, biocompatibility, non-irritant to eye socket, and dimensional stability [6,7]. Hence, clear and white colored acrylic substances are commonly used for making the ocular prostheses [8]. The changes in the some mechanical properties of acrylic resin (i.e. Surface hardness and transverse strength) over time are the main problems, which affect the serviceability of ocular prostheses [9-10]. The literature

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emphasized on improving the mechanical and physical properties of acrylic resin including adding the nanoparticles (i.e. ZnO and $TiO_2$). It was found that the use of metal oxides enhanced the mechanical properties of cold cured acrylic resin as they provide a strong interaction with the organic polymer due to their small size [11-13]. There were no published papers about the effects of nanoparticles on mechanical properties of heat cured artificial eye. The current research was, therefore, carried out to evaluate the effect of various metal oxides in different concentrations on hardness and transverse strength of heat-cured acrylic which used for ocular prostheses. The null hypothesis imposed that the addition of metal oxides to clear acrylic has no effect on its transverse strength and surface hardness.

## Materials and methods

### Materials and Specimen groups

The materials utilised in the current study were clear acrylic resin (Spofadental,Czech Republic), ZnO powder (Golchadent, Iran) , $TiO_2$ powder (Grumbacher,USA) and $SiO_2$ powder (USA) and Dental stone (Zhermack, Italy). A total of 200 clear acrylic specimens were prepared. The transverse strength and hardness tests were conducted. For each test, there were 9 experimental groups with different concentrations (1% , 3% and 5%) as well as control groups ( unmodified).

### Specimen preparation

In the present study, the acrylic specimens for both hardness and transverse strength tests were fabricated according to the ADA specification Number 12 [14]. The process of fabricating a stone mould started by lubricating the two parts of a metal flask with Vaseline to simplify the process of deflasking. Following that, the stone mold was made by mixing the stone powder with water (100g / 25 ml). At creamy state, it was placed into lower part of the flask. A metal pattern with dimension of 65mm length x10mm width x 2.5 mm thickness was positioned carefully with making into mind half of it must be exposed to remove it easily from stone mold (Figure 1). The separating medium was applied on the stone surface and pattern and left to dry for 30 minutes. The upper part of the flask was located on its position; the stone mix was placed over the stone surface and pattern. The mold was left to set for one hour; and the two parts of the flask were separated to remove the pattern and then lubricated with separating medium. With a ratio of 3:1, 22 g of the acrylic powder was added to 10 ml of the monomer to make the control acrylic specimens. When the mixture reached a dough state; it was then packed into the mold. The two parts of the flask were put in contact, pressed under hydraulic press for 5 min, and cured according to the instructions produced by manufacturers. The flask was taken from water bath and left to cool. Then, the acrylic specimens were carefully removed from stone mold and finished and polishing. Then the specimens were stored in water for 7 days before testing [14]. The above procedure was carried out to make the experimental acrylic groups with exception that metal oxide powders with these concentrations ( 1% , 3 % , 5%), which are equal to the weight of the acrylic powder, were added to it before mixing with the monomer.

### Mechanical tests

#### 1. Transverse strength test

The control and experimental acrylic specimens were tested using a universal testing machine (Instron /Germany) (Figure 4). All specimens were subjected to the load with a cross head speed of 5 mm/min until fracture occurred [15]. The transverse strength values ($N/mm^2$ or MPa) were recorded via the formula : transverse strength = $3FL/BD^2$,where F= maximum load , L= span length(mm) , B = width of the specimen(mm), D= Depth of the specimen (mm)[16].

**2. Surface hardness test**

For each specimen, three areas (left side, center and right side) were tested using a durometer hardness tester (Matsuzawa, Japan)( Figure 3). The load was applied on each specimen for ten seconds [17]. The maximum reading was digitally recorded, and average reading was manually calculated.

## Results

All specimens were analysed following mechanical testing using SPSS 16v software; among all groups, significant differences were computed via ANOVA and tukey tests ($P \le 0.05$).

**1. Transverse strength**

The minimum, maximum values of transverse strength, mean and standard deviation are demonstrated in Table 1. The current results showed that the transverse strength of clear acrylic resin was significantly influenced by addition of various metal oxides at different concentrations.

As shown in the Table 1, there was an increase in the mean values of transverse strength as the concentration of metal oxides increases with slight variation in standard deviation. The experimental groups presented a higher value of mean transverse strength when compared to control group. As well, the experimental groups with 5 % of metal oxides exhibited a greater value of transverse strength in comparison to other experimental groups ( 1 % and 3%) . In addition, the multiple comparison test (Tukey) exhibited that highly significant differences among experimental groups ( $P \le 0.001$); between control group and experimental groups ($P \le 0.001$) were observed as presented in Table 2. Moreover, significant differences among all studied groups were clearly shown in the one way of variance (Anova) test (Table 3).

**2. Surface hardness**

The minimum, maximum values of surface hardness, mean and standard deviation are demonstrated in Table 4. The current results showed that there was a minor increase in the surface hardness of clear acrylic resin after incorporating the metal oxides at different concentrations.

However , no significant differences were found among all experimental groups ( $P > 0.05$); between the experimental groups and the control ($P > 0.05$) with exception there was significant differences between 5% $TiO_2$ and control group ($P \le 0.05$) as illustrated in Table 5. In addition, the ANOVA test showed that no significant differences among all studied groups ($P \ge 0.05$) as demonstrated in the Table 6.

## Discussion

Heat polymerizing acrylic resins (i.e. clear resins) are commonly used for the manufacture of ocular prostheses to restore congenital and acquired abnormalities in the orbital regions. Such substances can match the form and color of the natural eye. In the literature, it was found that the remake of acrylic ocular prosthesis was due to the variation in the mechanical properties and discoloration of acrylic resin. There were no published articles about the effect of metal oxides on mechanical properties of heat acrylic ocular prosthesis (clear acrylics). As a result, the current study was done to evaluate the effect of different metal oxides at different concentrations on surface hardness and transverse strength of clear resin. The results showed that the acrylic specimens which treated with various metal oxides ($TiO_2$, $SiO_2$, and ZnO) at different concentrations (1%, 3% and 5%) presented a greater mean of transverse strength compared to control group (Table 1). As well, there was a slight increase in the values of mean hardness after incorporation of metal oxides to clear acrylic in comparison to control group (Table 4). These results agrees with other study, which was carried out by Alnamel and Mughaffer (2014)[18] who reported that the heat cured acrylic specimens with silicone dioxide ($SiO_2$) created a higher values of mean transverse strength when compared to control group. In addition, they found that there was an improvement in the surface hardness of acrylic specimens, which treated with silicone dioxide. The reason is that a strong bond was created between polymer chains by the nanoparticles. However, the study which conducted by Akkus *et al*.,(2015)[19] found the silicone dioxide filler decreased the transverse strength of heat acrylic resin. This can be explained due to use different techniques and materials. Furthermore, the current findings are similar to Alwan and Alameer (2015)[20] who indicated that the use of titanium oxide filler at different concentrations forms a strong bond with polymer matrix leading to improved surface hardness and the transverse strength of clear acrylic specimens. Moreover, the results of the current study were supported by Dahham (2014)[21] who reported that the use of zinc oxide filler (ZnO) enhanced the surface hardness of heat cured resin. However, the present results disagrees with other study which undertaken by Andreotti *et al*.,(2014)[5] who concluded the addition of both $TiO_2$ and ZnO nanfillers decreased the transverse strength of acrylic resin as they inhibited the cross-linking between the polymer chains. The null hypothesis was rejected as metal oxides had an effect on transverse strength and hardness of acrylic resin. From the current study, it is concluded that the incorporation of metal oxides to clear acrylic powder can improve transverse strength and surface hardness of clear acrylic resin. Further research to assess the other mechanical properties ( i.e. impact strength & tensile strength ) and colour stability of heat cured resin with different fillers at different concentrations will be essential.

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## References

1- Kaur A, Pavaiya A, Singh S, Singh R, Chand P. A simplified approach to fabrication of an ocular prosthesis: a case series. Indian J of Dent Res. 2010; 21: 615-617.

2- Nafij BJ, Theerathavaj S, Mohammad KA. A Complete Procedure of Ocular Prosthesis: A Case Report. J Int Med Res. 2013; 20:729 -730.

3- Jain DC, Hegde V, Aparna IN, Dhanasekar B. Ocular prosthesis an esthetic vision. J Nepal Den Asso. 2010;11(1):101-106.

4- Dheeraj K, Ajay G, Hemant G, Gaurav V. Ocular prosthesis- a case report. Baba Farid University Dental Journal. 2010; 1(1): 52-54.

5- Raizada K, Rani D. Ocular prosthesis. The Journal of Contact Lens & Anterior Eye. 2007;30(3):152–162.

6- Goiato MC, Nicolau EI, Mazaro JV. Mobility, aesthetic, implants, and satisfaction of the ocular prostheses wearers. Craniofacial Surgery Journal. 2010;21(1):160–164.

7- Fernandes AU, Goiato MC, Santos DM. Effect of weathering and thickness on the superficial micro-hardness of acrylic resin and ocular button. The Journal of Contact Lens & Anterior Eye. 2009;32(6):283–287.

8- Artopoulou I, Montgomery P, Wesley P, Lemon J. Digital imaging in the fabrication of ocular prostheses. The Journal of Prosthetic Dentistry. 2006;95:327-30

9- Newman MD, Stotland M, Ellis JI. The safety of nano-sized particles in titanium dioxide & zinc oxide-based sunscreens. Am Acad Dermatol J. 2009;61(4):685–692.

10- Beasley DG,Meyer TA,. Characterization of the UVA Potection provided by avobenzone, zinc oxide, and titanium dioxide in broad-spectrum sunscreen products. Am Acad Dermatol J. 2010;11(6):413–421.

11- .Andreotti AM, Goiato MC, Moreno A, Nobrega AS, Pesqueira AA, dos Santos DM. Influence of nanoparticles on color stability, micro-hardness, and flexural strength of acrylic resins specific for ocular prosthesis. The International Journal of Nanomedicine. 2014; 9(1): 5779-5787.

12- Tang E, Cheng G, Pang X, Ma X, Xing F. Synthesis of nano-ZnO/ polymethyl methacrylate composite microsphere through emulsion polymerization ,and its ultra-violet shielding property. The Journal of Colloid and Polymer Science. 2006;284(4):422–428.

13- Harini P, Mohamed K, Padmanabhan TV. Effect of Titanium Dioxide Nanoparticles on the Flexural Strength of Polymethyl methacrylate :An in Vitro Study. Indian Journal of Dental Research. 2014;25(4):459-463.

14- ADA. American Dental Association Specification Number 12 for Denture Base Polymer . 10th Ed. ;Chicago :Council on Dental Material and Devices.1999.

15- The Academy of Prosthodontics. Glossary of Prosthodontics. The Journal of Prosthetic Dentistry. 2005;94(1):1-92.

16- .Anusavice K.J. Philips Science of Dental Material. 11th Ed., Middle East and African Edition, 2008.

17- ANSI/ADA. American Dental Association Specification Number 57 for Denture Base Polymers & Devices . Chicago :Council on Dental Material and Devices. 2008.

18- Alnamel H, Mudhaffer M. The effect of Silicone dioxide NanoFillers reinforcement on some properties of heat polymethyl methacrylate denture base material. . Journal of Baghdad College of Dentistry.2014;26(1): 32-36

19- Akkuş B , Ozturk A, Yazman S, Akdemir A. Effects of Al2O3 and SiO2 nanoparticles on flexural strength of heat-cured acrylic resin. International Journal of Enhanced Research in Science Technology & Engineering. 2015; 4 (6):158-163.

20- Alwan S, Alameer S. The effect of the addition of silanised Nano titania fillers on some physical and mechanical properties of heat cured acrylic denture base materials. Journal of Baghdad College of Dentistry.2015;27(1):86-91.

21- Dahham TB. The effects of modified zinc oxide nanofillers addition on some properties of heat cure acrylic resin denture base material. (Master thesis). University of Baghdad, College of Dentistry, 2014.


Table 1. Mean and Standard deviation of all groups for transverse strength(MPa)

| | Groups | Mean (MPa) | Standard deviation | Manimum | Maximum |
|---|---|---|---|---|---|
| Group 1 | Control | 115.99 | 2.99 | 111.56 | 120.53 |
| Group 2 | 1% $SiO_2$ | 120.82 | 1.70 | 118.39 | 123.35 |
| Group 3 | 3% $SiO_2$ | 123.88 | 1.93 | 122.09 | 127.71 |
| Group 4 | 5% SiO2 | 128.13 | 1.35 | 126.23 | 131.13 |
| 125.47 | 118.50 | 2.22 | 121.80 | 1% $Tio_2$ | Group 5 |
| 129.54 | 120.21 | 3.07 | 125.02 | 3% $TiO_2$ | Group 6 |
| 132.23 | 125.74 | 2.13 | 128.69 | 5% TiO2 | Group 7 |
| 122.54 | 115.32 | 2.05 | 120.95 | 1% TiO2 | Group 8 |
| 125.29 | 123.35 | .54 | 124.23 | 3% TiO2 | Group 9 |
| 131.05 | 123.30 | 2.64 | 127.31 | 5% TiO2 | Group 10 |

Table 2. Tukey multiple test for transverse strength(MPa)

| Siginificance | P value | Groups | Siginificance | P value | Groups |
|---|---|---|---|---|---|
| H.S* | 0.000 | Control<br>3% $SiO_2$ | H.S* | 0.000 | Control<br>1% $SiO_2$ |
| H.S* | 0.000 | 1% $SiO_2$<br>3% $SiO_2$ | H.S* | 0.000 | Control<br>5% $SiO_2$ |
| H.S* | 0.000 | 1%$SiO_2$<br>5%$SiO_2$ | H.S* | 0.000 | 3% $SiO_2$<br>5% $SiO_2$ |
| H.S* | 0.000 | Control<br>5% $TiO_2$ | H.S* | 0.000 | Control<br>3% $TiO_2$ |
| H.S* | 0.000 | 1%$TiO_2$<br>3%$TiO_2$ | H.S* | 0.000 | Control<br>1% $TiO_2$ |
| H.S* | 0.000 | 1%$TiO_2$<br>5%$TiO_2$ | H.S* | 0.000 | 3%$TiO_2$<br>5%$TiO_2$ |
| H.S* | 0.000 | Control<br>3%ZnO | H.S* | 0.000 | Control<br>1% ZnO |
| H.S* | 0.000 | 1% ZnO<br>3%ZnO | H.S* | 0.000 | Control<br>5% ZnO |
| H.S* | 0.000 | 3%ZnO<br>5%ZnO | H.S* | 0.000 | 1%ZnO<br>5%ZnO |

Highly significant ($P<0.001$)

Table 3. Anove test for transverse strength(MPa)

**ANOVA**

| Sig. | F | Mean Square | df | Sum of Squares | | |
|---|---|---|---|---|---|---|
| .000 | 59.847 | 261.353 | 3 | 784.058 | Between Groups | $SiO_2$ |
| | | 4.367 | 36 | 157.211 | Within Groups | |
| | | | 39 | 941.269 | Total | |
| .000 | 41.466 | 289.966 | 3 | 869.897 | Between Groups | $TiO_2$ |
| | | 6.993 | 36 | 251.744 | Within Groups | |
| | | | 39 | 1121.641 | Total | |
| .000 | 45.774 | 234.477 | 3 | 703.430 | Between Groups | ZnO |
| | | 5.123 | 36 | 184.411 | Within Groups | |
| | | | 39 | 887.841 | Total | |

Highly significant ($P<0.001$)

Table 4. Mean and standard deviation of all studied groups for surface hardness(g/mm²)

| maximum | Manimum | standard deviation | Mean (g/mm²) | groups | |
|---|---|---|---|---|---|
| 90.23 | 82.78 | 2.62 | 86.51 | Control | Group 1 |
| 91.59 | 83.30 | 2.72 | 87.44 | 1% $SiO_2$ | Group 2 |
| 93.17 | 84.39 | 3.00 | 89.04 | 3% $SiO_2$ | Group 3 |
| 93.39 | 85.51 | 2.51 | 89.43 | 5% $SiO_2$ | Group 4 |
| 91.32 | 83.05 | 2.64 | 87.22 | 1% $TiO_2$ | Group 5 |
| 93.25 | 83.53 | 3.16 | 88.68 | 3% $TiO_2$ | Group 6 |
| 94.49 | 86.15 | 2.69 | 90.29 | 5% $TiO_2$ | Group 7 |
| 91.32 | 82.71 | 2.88 | 86.92 | 1% ZnO | Group 8 |
| 90.91 | 85.13 | 1.80 | 88.15 | 3% ZnO | Group 9 |
| 92.21 | 85.53 | 2.47 | 88.51 | 5% ZnO | Group 10 |

Table 5. Tukey multiple test for surface hardness(g/mm²)

| Siginificance | P value | Groups | Siginificance | P value | Groups |
|---|---|---|---|---|---|
| (NS)* P>0.05 | 0.097 | Control 3% $SiO_2$ | (NS)* P>0.05 | 0.872 | Control 1% $SiO_2$ |
| (NS)* P>0.05 | 0.373 | 1% $SiO_2$ 3% $SiO_2$ | (NS)* P>0.05 | 0.184 | Control 5% $SiO_2$ |
| (NS)* P>0.05 | 0.564 | 1%$SiO_2$ 5%$SiO_2$ | (NS)* P>0.05 | 0.988 | 3% $SiO_2$ 5% $SiO_2$ |
| (S )* P<0.05 | 0.022 | Control 5% $TiO_2$ | (NS)* P>0.05 | 0.320 | Control 3% $TiO_2$ |
| (NS)* P>0.05 | 0.649 | 1%$TiO_2$ 3%$TiO_2$ | (NS)* P>0.05 | 0.941 | Control 1% $TiO_2$ |
| (NS)* P>0.05 | 0.083 | 1%$TiO_2$ 5%$TiO_2$ | (NS)* P>0.05 | 0.574 | 3%$TiO_2$ 5%$TiO_2$ |
| (NS)* P>0.05 | 0.299 | Control 3%ZnO | (NS)* P>0.05 | 0.984 | Control 1% ZnO |
| (NS)* P>0.05 | 0.493 | 1% ZnO 3%ZnO | (NS)* P>0.05 | 0.492 | Control 5% ZnO |
| (NS)* P>0.05 | 0.990 | 3%ZnO 5%ZnO | (NS)* P>0.05 | 0.705 | 1%ZnO 5%ZnO |

N.S : non significant(*P*>0.05)

Table 6. Anove test for surface hardness(g/mm²)

**ANOVA**

| Sig. | F | Mean Square | df | Sum of Squares | | |
|---|---|---|---|---|---|---|
| .074 | 2.510 | 18.633 | 3 | 55.898 | Between Groups | $SiO_2$ |
| | | 7.424 | 36 | 267.269 | Within Groups | |
| | | | 39 | 323.166 | Total | |
| .023 | 3.602 | 28.040 | 3 | 84.120 | Between Groups | $TiO_2$ |
| | | 7.784 | 36 | 280.238 | Within Groups | |
| | | | 39 | 364.358 | Total | |
| .246 | 1.447 | 8.990 | 3 | 26.969 | Between Groups | ZnO |
| | | 6.215 | 35 | 217.508 | Within Groups | |
| | | | 38 | 244.477 | Total | |

Non significant: P>0.05

**Figures**

Figure 1. Metal pattern within the stone mould

Figure 2.Specimen under trasverse strength test

Figure 3.Specimen under hardness test