Brazilian Dental Science

unesp
UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Instituto de Ciência e Tecnologia
Campus de São José dos Campos

ORIGINAL ARTICLE

DOI: https://doi.org/10.4322/bds.2025.e4639

# Evaluation the effect of different titanium stains on specific properties of acrylic ocular prosthesis

Avaliação do efeito de diferentes corantes de titânio sobre propriedades específicas de próteses oculares acrílicas

**Firas Abd KATI[1], Nihad Hasan Mohammed ALFURAIJI[1], Ali Radhi NAEMAH[2], Dasmawati MOHAMAD[3]**

1 - Middle Technical University, College of Health & Medical Techniques, Department of Prosthetic Dental Techniques. Baghdad, Iraq.
2 - Amarah University College, Department of Prosthetic Dental Techniques. Mayasan, Iraq.
3 - Universiti Sains Malaysia, School of Dental Sciences, Biomaterials & Craniofacial Aesthetics Research Cluster. Gelugor, Malaysia.

**How to cite:** Kati FA, AlFuraiji NHM, Naemah AR, Mohamad D. Evaluation the effect of different titanium stains on specific properties of acrylic ocular prosthesis. Braz Dent Sci. 2025;28(3):e4639. https://doi.org/10.4322/bds.2025.e4639

## ABSTRACT

**Objective:** To evaluate the specific characteristics of clear acrylic resins modified with different oil dyes available in the local market. **Material and Methods:** The study specimens were made from clear heat-polymerized acrylic materials, and they were 4 sets (control, Titanium-White (TW) and Zinc-Titanium-White (ZTW) and zinc white (ZW) dyed substances. Each group consisted of 10 specimens that were randomly distributed. All study groups and specimens were submitted to surface roughness test, hardness test, Charpy's impact strength test, and color meter. Data were analyzed by SPSS version 24 and the comparisons among the groups were made by ANOVA and Tukey HSD tests. **Results:** There was a significant reduction in the acrylic resin impact strength following the addition of white dyes. Regarding surface hardness, there was an increase in mean values for the dyed acrylic groups in comparison to the non-dyed group. In addition, the results revealed a decrease in the surface roughness for the dyed acrylic groups compared to the non-dyed group. The least amount of color change was found in the zinc titanium group. The highest amount of color change was in the titanium and zinc white group when compared to the non-dyed group. **Conclusion:** The white dyes improved the acrylic resin hardness. Nevertheless, they adversely affect the acrylic impact strength. Furthermore, white dyes decrease somewhat the surface roughness of the acrylic resin. Zinc-Titanium-White dye seemed to have an acceptable effect to be used as a coloring agent for ocular prosthesis.

## KEYWORDS

Color change; Hardness; Impact strength; Oil dyes; Roughness.

## RESUMO

**Objetivo:** Avaliar as características específicas de resinas acrílicas transparentes modificadas com diferentes corantes a base de óleo disponíveis no mercado local. **Material e Métodos:** Os corpos de prova do estudo foram confeccionados com materiais acrílicos transparentes polimerizados por calor, divididos em 4 grupos (Controle, Titânio Branco (TW), Zinco-Titânio Branco (ZTW) e Zinco Branco (ZW)). Cada grupo foi composto por 10 espécimes distribuídos aleatoriamente. Todos os grupos e espécimes foram submetidos a testes de rugosidade superficial, dureza, ensaio de resistência ao impacto de Charpy e análise de cor. Os dados foram analisados no SPSS versão 24, e as comparações entre os grupos foram realizadas por meio dos testes ANOVA e Tukey. **Resultados:** Houve uma redução significativa na resistência ao impacto da resina acrílica após a adição dos corantes brancos. Em relação à dureza da superfície, observou-se um aumento nos valores médios para os grupos com corantes em comparação ao grupo sem corante. Além disso, os resultados revelaram uma diminuição da rugosidade superficial nos grupos com corantes em relação ao grupo controle. A menor alteração de cor foi observada no grupo de Zinco-Titânio Branco. A maior alteração de cor ocorreu nos grupos com Titânio Branco e Zinco Branco, quando comparados aos grupos sem corante. **Conclusão:** Os corantes brancos melhoraram a dureza da resina acrílica.

No entanto, afetaram negativamente a resistência ao impacto. Ademais, os corantes brancos reduziram, em certa medida, a rugosidade superficial da resina acrílica. O corante de Zinco-Titânio Branco demonstrou ter um efeito aceitável para ser utilizado como agente corante em próteses oculares.

## PALAVRAS-CHAVE

Alteração de cor; Dureza; Resistência ao impacto; Corantes oleosos; Rugosidade.

## INTRODUCTION

Acrylic resins are the preferred materials for many dental and maxillofacial restorations due to their suitable mechanical and physical characteristics. The ideal hue must be added while creating the ocular prosthesis out of these materials to resemble the color of a natural eye. This, however, could significantly impact acrylic resins' mechanical qualities. Facial abnormalities in humans can be caused by genetics, acquired trauma, or even surgery to remove cancer [1]. In the region of the defect, facial restorations are made to be worn by the patient in order to maintain the remaining tissues [2]. These prostheses can also help patients engage with others by restoring their confidence and protecting the tissues in the region of the deformity [3,4]. Ocular and orbital prostheses are the two types of prostheses used to repair eye abnormalities, depending on whether the restoration involves the entire socket region or simply the eyeball [5].

The preferred material for creating some facial prostheses, particularly ocular restorations, is acrylic resin, often referred to chemically as polymethylmethacrylate [5]. Depending on the patient's needs and circumstances, the ocular restoration may be ready-made or custom-made [6-8]. White acrylic resin is used to restore the scleral portion of the eye to its natural color [9]. However, in certain local marketplaces, it is not readily available. Consequently, during preparation, coloring chemicals are combined with clear acrylic resin to create the white material with the desired hue [10,11]. There are several acrylic dyes available globally that offer a vast array of hues and tones [12]. Numerous investigations have assessed the physical and mechanical characteristics of colored resins [13-16]. Titanium dioxide has been shown to adversely influence the transverse strength of acrylic resin ocular prostheses [13,14]. Additionally, research has demonstrated that using white oil paints, which contain titanium dioxide, greatly increased the hardness of acrylic resin [15,16]. Nonetheless, Kati 2018 found that the acrylic ocular prosthesis' impact strength was decreased by Grumbacher titanium white [17]. Thus, the goal of this investigation was to see how different types of oil paints (Titanium-White (TW) and Zinc-Titanium-White (ZTW) and zinc white (ZW) affected the impact strength, hardness, surface roughness and color change of acrylic resins ocular prosthesis.

## MATERIAL AND METHODS

### Materials and grouping

Heat-polymerized acrylic resin (Spofadental, Czech Republic) was used to create the specimens for the impact strength test using plastic strips that were 80 mm long, 10 mm wide, and 4 mm thick. Plastic patterns of 65 mm in length, 10 mm in width, and 3 mm in thickness were utilized to create acrylic specimens for surface roughness, hardness and color stability testing. Table I illustrates the materials used in the current study.

### Sample preparation

The first step in the specimen preparation procedure was to apply the separating medium to the upper and lower of a metal flask so that the stone mold could be easily removed after deflasking. The mixed dental stone was then poured into the flask's lower section in a creamy state. The strips were placed gently in the center of the surface, keeping in mind that 1 mm of their thickness must be visible to allow for easy removal from the mold when the acrylic dough is ready to be packed.

**Table I -** Materials utilized in the study.

| Groups | No. | Pigment used | Origin |
|---|---|---|---|
| Control | 10 | None (clear acrylic) | Czech Republic |
| ZW | 10 | Zinc White | China |
| ZTW | 10 | Zinc-Titanium White | China |
| TW | 10 | Titanium White | USA |

After the stone surface had fully set, it was coated with the separating medium. The upper portion was positioned on top of the lower portion. The patterns and stone surface were then filled with another mixture of the dental stone. For sixty minutes, the flask was allowed to set. The plastic strips were then removed from the mold.

The non-dyed group (control) was made by mixing 10 milliliters of the monomer liquid and 22 grams of the acrylic powder. The acrylic dough was packed inside the mold, the upper and lower portions were put under the hydraulic press and then the flask was cured in accordance with manufacturer's instructions. After curing, the flask was removed from the water bath. Once cooling, acrylic samples were taken out of the mold and polished and completed using the conventional method [18]. With regards to the experimental groups, 22g of acrylic powder, 1 ml of ZTW dye, and 9 ml of liquid monomer were combined to create the ZTW acrylic samples. In a similar manner, 22g of acrylic powder, 9ml of liquid monomer, and 1ml of TW dye were combined to create TW acrylic samples. The ZW acrylic samples were fabricated from 22g of acrylic powder, 1 ml of ZW dye and 9 ml of liquid monomer.

The acrylic samples were prepared, polished, and treated in line with standard practices by general practitioners before being submitted to the analytical process [18].

### Mechanical testings

*Impact strength test*

The strength of acrylic samples was assessed using the Charpy's impact strength tester (Tinius Olsen, Houston, USA). After positioning each sample on the bending fixture, the force was applied until the samples broke.The unnotched specimen's impact strength was expressed in KJ/M2, and impact strength values were calculated using the formula below [19]:

$$\text{Impact strength}\left(KJ/M^2\right) = E/B.\ D \times 103 \quad (1)$$

Where: the impact absorbed energy is denoted by the symbol E; the sample's breadth, expressed in millimeters, is denoted by the letter "B"; the sample's thickness, expressed in millimeters, is denoted by the letter "D".

*Surface hardness test*

Shore A hardness tester (China) was used for the surface hardness test. The process required applying a fifty-gram force on the surface of each sample for ten seconds. Three readings were performed on each sample (right, center and left), and an average was calculated for each.

*Surface roughness test*

In the current investigation, the surface roughness ($\mu$m) was measured using a digital roughness tester (China). The average reading was taken after the diamond stylus was moved three times across a sample surface (center, right, and left).

### Color analysis

The colour meter app, which was downloaded from the Google Play, was utilized to provide more accurate colour measurements using a white reference to compensate for changing lighting conditions that were directly conducted using the mobile phone (Nokia) camera (Figure 1). The distance between the sample and phone camera was constant (10 cm). The Delta E (ΔE) was then recorded.


**Figure 1 -** Specimen under color meter test.

**Table II -** Impact strength descriptive data for each category.

| Groups | No. | Mean (KJ/M²) | Standard deviation (SD) | Minimum | Maximum |
|---|---|---|---|---|---|
| Control | 10 | 10.5600 | .28363 | 10.10 | 10.90 |
| Zinc | 10 | 5.3400 | .31340 | 5.00 | 5.80 |
| Titanium | 10 | 6.4500 | .32745 | 6.10 | 6.90 |
| Zinc-Titanium | 10 | 7.5400 | .30258 | 7.10 | 7.90 |

**Table III -** Impact strength ANOVA test

| | Sum of Squares | Degree of freedom (df) | Mean Square | F -value | Sig. |
|---|---|---|---|---|---|
| Between Groups | 151.303 | 3 | 50.434 | 534.481 | $p$<0.01 |
| Within Groups | 3.397 | 36 | .094 | | |
| Total | 154.700 | 39 | | | |

**Table IV -** Tukey HSD comparison test for impact strength test

| Groups | Mean difference (KJ/M²) | p value | Sig. |
|---|---|---|---|
| Control<br>Zinc | 5.22000 | $p$<0.01 | *H.S. |
| Control<br>Titanium | 4.11000 | $p$<0.01 | *H.S. |
| Control<br>Zinc-Titanium | 3.02000 | $p$<0.01 | *H.S. |
| Zinc<br>Titanium | -1.11000 | $p$<0.01 | *H.S. |
| Zinc<br>Zinc-Titanium | -2.20000 | $p$<0.01 | *H.S. |

*H.S.: Highly significant.

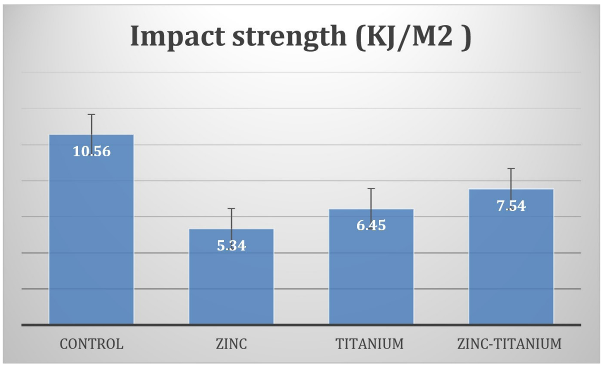


**Figure 2 -** Impact strength data chart.

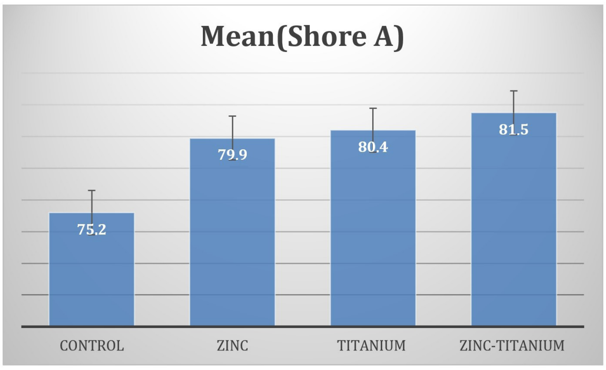


**Figure 3 -** Surface hardness (Shore A) data chart.

## RESULTS

The SPSS (Statistical Package for the Social Sciences) version 24 software (North castle, New York, USA) was used for the statistical analysis.

### Impact strength

Table II and Figure 2 showed that the impact strength significantly decreased after the addition of the white dyes as compared to the non-dyed group. Furthermore, significant differences ($p$<0.01) among all studied groups as illustrated in one-way ANOVA test (Table III).

Furthermore, the Tukey HSD comparison test revealed a highly significant difference ($p$<0.01) between the 2 groups as shown in Table IV.

### Surface hardness

The descriptive statistics showed that the hardness values for the dyed acrylic groups were higher than those for the non-dyed group, as shown in Table V and Figure 3. Furthermore, statistically significant differences *($p$≥0.05)* among groups were found as revealed in the ANOVA test (Table VI). Moreover, the Tukey comparison test showed a significant difference between the 2 groups with the exception no substantial changes between the zinc and titanium groups as illustrated in Table VII.

**Table V -** Surface hardness (Shore A) descriptive statistics for each group.

| Groups | No | Mean (Shore A) | Standard deviation (SD) | Minimum | Maximum |
|---|---|---|---|---|---|
| Control | 10 | 75.2000 | 1.39841 | 73.00 | 77.00 |
| Zinc | 10 | 79.9000 | 1.19722 | 77.00 | 81.00 |
| Titanium | 10 | 80.4000 | .69921 | 79.00 | 81.00 |
| Zinc-Titanium | 10 | 81.5000 | .52705 | 80.50 | 82.00 |

**Table VI -** ANOVA test for surface hardness (Shore A) among all groups.

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 232.100 | 3 | 77.367 | 74.471 | $p$<0.01 |
| Within Groups | 37.400 | 36 | 1.039 | | |
| Total | 269.500 | 39 | | | |

**Table VII -** Tukey HSD comparison test for surface hardness test.

| Groups | Mean difference | p value | Sig. |
|---|---|---|---|
| Control<br>Zinc | -4.70000 | $p$<0.01 | *H.S. |
| Control<br>Titanium | -5.20000 | $p$<0.01 | *H.S. |
| Control<br>Zinc-Titanium | -6.30000 | $p$<0.01 | *H.S. |
| Zinc<br>Titanium | -.50000 | $p$> 0.05 | **N.S. |
| Zinc<br>Zinc-Titanium | -1.10000 | $p$<0.01 | *H.S. |

*H.S.: highly- significant; **N.S.: non-significant.

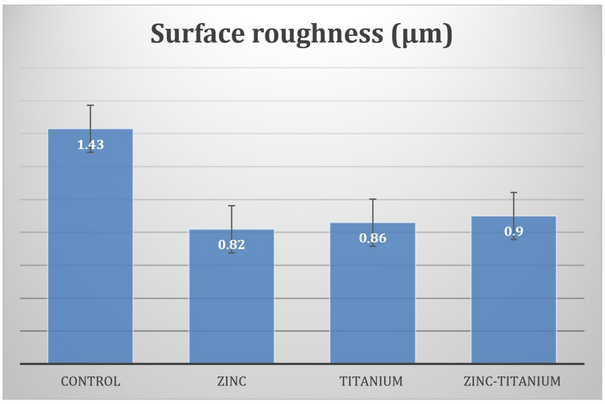


**Figure 4 -** Surface roughness data chart.

## Surface roughness

The results showed that the dyed acrylic groups had lower mean values for surface roughness than the non-dyed group (Table VIII and Figure 4). However, the ANOVA comparison test demonstrated significant differences between the groups ($p$<0.01) (Table IX). Besides, the Tukey comparison test presented a significant difference between the 2 groups with exception no significant changes between the zinc and titanium groups; zinc and zinc-titanium as illustrated in Table X.

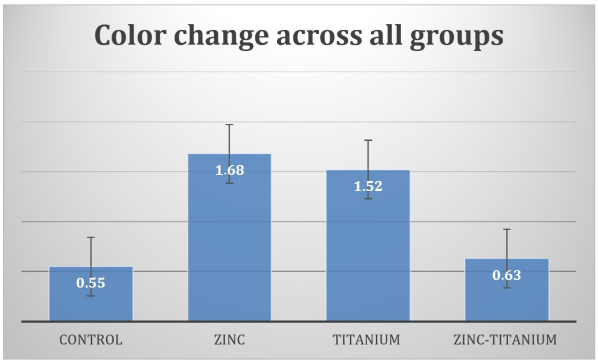


**Figure 5 -** Color change data chart.

## Color change

The zinc-titanium group showed the least degree of color change, according to the data. When compared to the non-dyed group, the titanium and zinc white group showed the greatest level of color change (Table XI and Figure 5). The results revealed significant differences between the groups ($p$<0.01) as illustrated in the One-Way ANOVA test (Table XII). As well, Table XIII showed a significant difference between 2 groups with the exception no significant changes between the control and zinc-titanium; zinc and titanium groups as demonstrated in the Tukey comparison test.

**Table VIII -** Surface roughness descriptive statistics for each group.

| Groups | No | Mean(µm) | Standard deviation (SD) | Minimum | Maximum |
|---|---|---|---|---|---|
| Control | 10 | 1.4300 | .26687 | .80 | 1.80 |
| Zinc | 10 | .8200 | .07888 | .70 | .90 |
| Titanium | 10 | .8600 | .05164 | .80 | .90 |
| Zinc-Titanium | 10 | .9000 | .09428 | .80 | 1.10 |

**Table IX -** ANOVA test for surface roughness test.

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 2.469 | 3 | .823 | 36.985 | $p$<0.01 |
| Within Groups | .801 | 36 | .022 | | |
| Total | 3.270 | 39 | | | |

**Table X -** Tukey HSD comparison test for surface roughness test.

| Groups | Mean difference | p value | Sig. |
|---|---|---|---|
| Control<br>Zinc | .61000 | $p$<0.01 | *H.S. |
| Control<br>Titanium | .57000 | $p$<0.01 | *H.S. |
| Control<br>Zinc-Titanium | .53000 | $p$<0.01 | *H.S. |
| Zinc<br>Titanium | -.04000 | $p$> 0.05 | **N.S. |
| Zinc<br>Zinc-Titanium | -.08000 | $p$> 0.05 | **N.S. |

*H.S.: highly significant; **N.S.: non-significant.

**Table XI -** Descriptive statistics for color change across all groups.

| Groups | No | Mean | Standard deviation (SD) | Minimum | Maximum |
|---|---|---|---|---|---|
| Control | 10 | .5500 | .05270 | .50 | .60 |
| Zinc | 10 | 1.6800 | .19322 | 1.40 | 1.80 |
| Titanium | 10 | 1.5200 | .16865 | 1.20 | 1.60 |
| Zinc-Titanium | 10 | .6300 | .09487 | .40 | .70 |

**Table XII -** One-Way ANOVA test among all groups for the color change test.

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 10.361 | 3 | 3.454 | 178.126 | $p$<0.01 |
| Within Groups | .698 | 36 | .019 | | |
| Total | 11.059 | 39 | | | |

**Table XIII -** Tukey HSD comparison test for color change test.

| Groups | Mean difference | p value | Sig. |
|---|---|---|---|
| Control<br>Zinc | -1.13000 | $p<0.01$ | *H.S. |
| Control<br>Titanium | -.97000 | $p<0.01$ | *H.S. |
| Control<br>Zinc-Titanium | -.08000 | $p> 0.05$ | **N.S. |
| Zinc<br>Titanium | .16000 | $p> 0.05$ | **N.S. |
| Zinc<br>Zinc-Titanium | 1.05000 | $p$0.01 | *H.S. |

*H.S.: highly significant; **N.S.: non-significant.

## DISCUSSION

Acrylic materials are commonly employed in a wide range of applications in the disciplines of dentistry and maxillofacial rehabilitation because of their appropriate chemical, mechanical, and physiological characteristics. An ocular prosthesis is made to replace the tissues of the eyes that have been lost. For the prosthesis to be aesthetically pleasing, it is crucial to replicate the color of the recovered tissues. One of the most difficult aspects of the production process is the ocular prosthesis's scleral component. White acrylic resins, which are not easily found in the local markets, are utilized to construct the scleral part of the ocular prosthesis. It is necessary to utilize specific colors, such as white dyes, to mimic the hue of the human eye. This research aimed to assess the mechanical properties of heat-cured acrylic resin colored with three different coloring agents (TW, ZW, and ZTW).

According to the current findings, utilizing white oil paints significantly reduced the mean impact strength values of acrylics. The poorer link between the oil white dye filler and the matrix may be the cause of the drop in impact strength values. The crack propagation was accelerated as a result. The present study runs counter to the findings of Alwan and Alameer [20], who found that the acrylic resin impact strength has risen with the addition of titanium dioxide. This was because the smaller size of these fillers creates a stronger link between polymer chains.

The findings of the (Shore A) hardness test revealed a notable difference in surface hardness across the groups, with surface hardness rising as the concentration of white dyes increased. The findings show that the concentration of white dyes increases surface hardness. The present results were consistent with a study carried out by Kati and Al-Kaabi [15], who revealed that the incorporation of $TiO_2$ oil paints improved the acrylic resins surface hardness because of strong bond between the filler and polymer matrix. However, the research by Sayed and Mahmoud [21], contradicts the current results where they found the acrylic resin hardness diminishes as the amount of plasticizer—an oil-soluble compound—increases.

With regards to the surface roughness, the mean surface roughness decreased somewhat. The comparatively high filler loading quantity and the different particle sizes of the nano fillers and the acrylic material may be the cause of this, which might lead to the formation of some filler aggregates on the surface. The current findings corresponded with those of Alwahab et al. [22], who discovered that the adding of ZnO oil paints reduced the acrylic resins surface roughness. However, the current findings contradict those of Alwan and Alameer [20], they found that the presence of $TiO_2$ particles on the surface of the acrylic samples increased their surface roughness.

In terms of color change, white dye material would have a major impact on the color characteristics of the ocular prosthesis. Zinc-Titanium-White dye on the other hand seemed to have an acceptable effect to be used as a coloring agent for ocular prosthesis. The present results are consistent with a study by Andreotti et al. [14] they discovered that after exposing their samples to an accelerated aging environment, titanium-based dyes were more color durable than zinc-based dyes.

Although color stability is a separate issue, it could reflect the effectiveness of the dyes involved in the study. The application of acrylic dyes is so crucial to achieve a successful extra-oral restoration since esthetics is considered a priority. Given the significant differences between the white dyes and non-dyes groups, the null hypothesis was refused based on the existing data.

## CONCLUSIONS

According to the study's findings, oil dyes would considerably raise the hardness of acrylic resins. Though, the use of white dyes adversely affects the impact strength of the acrylic resin's ocular prostheses. Furthermore, the white dyes decrease slightly the surface roughness of the acrylic resin. Zinc-Titanium-White dye seemed to have an acceptable effect to be used as a coloring agent for ocular prosthesis. It is recommended to study the effect of accelerated aging on both Titanium-dyed and zinc -dyed acrylic resin for future prosthetic dental studies. Further studies on other acrylic dyes are also important and recommended.

### Acknowledgements

Special thanks to all members in the Prosthetic Lab at Prosthetic Dental Techniques Dept., College of Health & Medical Techniques for their assistance.

### Author's Contributions

FAK: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing – Original Draft Preparation. NHMA: Conceptualization, Methodology, Software, Validation, Investigation, Resources, Data Curation, Writing – Original Draft Preparation, Writing – Reviewing & Editing. ARN: Formal Analysis, Investigation, Resources, Data Curation. DM: Visualization, Supervision, Writing – Original Draft Preparation, Writing – Reviewing & Editing.

### Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

### Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### Regulatory Statement

This *in vitro* study was carried out in compliance with all the rules and regulations set forth by the local research subjects oversight committee: neither humans nor animals were involved in this investigation.

## REFERENCES

1. Putanikar NY, Patil AG, Shetty PK, Nagaral S, Mithaiwala HI. Prosthetic rehabilitation of a patient with ocular defect using semi-customized prosthesis: a case report. J Int Oral Health. 2015;7(4):81-4. PMid:25954078.
2. Dheeraj K, Ajay G, Hemant G, Gaurav V. Ocular prosthesis: a case report. Baba Farid Univ Dent J. 2010;1(1):52-4.
3. Jain DC, Hegde V, Aparna IN, Dhanasekar B. Ocular prosthesis an esthetic vision. J Nepal Dent Assoc. 2010;11(1):101-6.
4. Goiato MC, Bannwart LC, Haddad MF, Santos DM, Pesqueira AA, Miyahara GI. Fabrication techniques for ocular prostheses: an overview. Orbit. 2014;33(3):229-33. http://doi.org/10.3109/01676830.2014.881395. PMid:24568127.
5. Raizada K, Rani D. Ocular prosthesis. Cont Lens Anterior Eye. 2007;30(3):152-62. http://doi.org/10.1016/j.clae.2007.01.002. PMid:17320467.
6. Nafij BJ, Theerathavaj S, Mohammad KA. A complete procedure of ocular prosthesis: a case report. Int Med J. 2013;20:729-30.
7. Gunaseelaraj R, Karthikeyan S, Kumar MN, Balamurugan T, Jagadeeshwaran AR. Custom-made ocular prosthesis. J Pharm Bioallied Sci. 2012;4(6, Suppl 2):177-9. http://doi.org/10.4103/0975-7406.100264. PMid:23066246.
8. Sethi T, Kheur M, Haylock C, Harianawala H. Fabrication of a custom ocular prosthesis. Middle East Afr J Ophthalmol. 2014;21(3):271-4. http://doi.org/10.4103/0974-9233.134694. PMid:25100916.
9. Jayaswal GP, Dange SP, Khalikar AN. Restoration of an atrophic eye socket with custom made eye prosthesis, utilizing digital photography. Indian J Dent Res. 2011;22(3):482-5. http://doi.org/10.4103/0970-9290.87076. PMid:22048594.
10. Goiato MC, Santos DM, Souza JF, Moreno A, Pesqueira AA. Chromatic stability of acrylic resins of artificial eyes submitted to accelerated aging and polishing. J Appl Oral Sci. 2010;18(6):641-5. http://doi.org/10.1590/S1678-77572010000600018. PMid:21308298.
11. Fernandes AU, Goiato MC, Batista MA, Santos DM. Color alteration of the paint used for iris painting in ocular prostheses. Braz Oral Res. 2009;23(4):386-92. http://doi.org/10.1590/S1806-83242009000400007. PMid:20027445.
12. Mundim FM, Antunes PL, Sousa AB, Garcia LF, Pires-de-Souza FC. Influence of artificial accelerated ageing on the colour stability of paints used for ocular prosthesis iris painting. Gerodontology. 2012;29(2):e312-7. http://doi.org/10.1111/j.1741-2358.2011.00473.x. PMid:21453414.

13. Kati F, Al-Kaabi A, Part II. Effect of oil paint addition on the flexural strength of acrylic ocular prosthesis. Proc 3rd Congr Med Health Spe. 2016;4(4):100-4.

14. Andreotti AM, Goiato MC, Moreno A, Nobrega AS, Pesqueira AA, Santos DM. Influence of nanoparticles on color stability, microhardness, and flexural strength of acrylic resins specific for ocular prosthesis. Int J Nanomedicine. 2014;9(1):5779-87. PMid:25525359.

15. Kati F, Al-Kaabi A. Part I: effect of oil paint addition on micro hardness of acrylic ocular prosthesis. Iraqi Dent J. 2016;38(2):87-9. http://doi.org/10.26477/idj.v38i2.83.

16. Al-Shammari F. Effect of metal oxides on some mechanical properties of clear acrylic specific for artificial eye. Mustansiria Dental J. 2016;13(1):77-84.

17. Kati F. Effect of oil paint addition on impact strength of the scleral part of the acrylic ocular prosthesis. Open Dent J. 2018;12(1):946-51. http://doi.org/10.2174/1874210601812010946.

18. American National Standers Institute. American Dental Association specification n° 12 for denture base polymer. Washington, D.C.: ANSI; 2002.

19. International Organization for Standardization. ISO 179-1: plastics: determination of charpy impact properties part 1: non-instrumented impact test. 1st ed. Geneva: ISO; 2000.

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. J Baghdad Coll Dentistry. 2015;27(1):86-91. http://doi.org/10.12816/0015269.

21. Sayed B, Mahmoud E. Effect of adding TiO2 nanoparticles on the mechanical properties of heat cured acrylic resin before and after thermocycling. Egypt Dent J. 2023;69:675-81. http://doi.org/10.21608/edj.2023.176776.2358.

22. Alwahab S, Moosa J, Muafaq S. Studying the influence of nano ZnO and nano ZrO2 additives on properties of PMMA denture base. Indian J Public Health Res Dev. 2020;11(2):2053-7. http://doi.org/10.37506/v11/i2/2020/ijphrd/195133.

**Nihad Hasan Mohammed AlFuraiji**
**(Corresponding address)**
Middle Technical University, College of Health and Medical Techniques, Department of Prosthetic Dental Techniques, Baghdad, Iraq.
Email: nihad.hassan@mtu.edu.iq

**Editor: Leonardo Marchini**

Date submitted: 2025 Jan 04
Accept submission: 2025 Jul 23