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# Translucency of Nanoparticles Reinforced Denture Base Materials

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**Abstract**
**Aims**: To evaluate the effect of adding salinized zirconium oxide ($ZrO_2$) and silicon oxide ($SiO_2$) nanoparticles in two concentrations on the translucency of heat-cured denture base material. **Materials and methods**: Fifty discs (15×2.5mm) were prepared in accordioning to the manufacturer's instructions and divided into five groups, control without nanoparticles reinforcement, 1%$ZrO_2$, 3%$ZrO_2$, 1%$SiO_2$ and 3%$SiO_2$ NPs reinforcement. Translucency was measured using a colorimeter. **Results**: The result showed a highly significant ($P \leq 0.01$) decrease in the translucency. The $ZrO_2$ Np reinforced more reduced in translucency than the $SiO_2$ Np reinforced group. The 3% by weight is more reduced than 1% by weight. **Conclusions:** Both nanoparticles reduced the translucency.

## شفافية المواد الأساسية لأطقم الأسنان المقواة بالجسيمات النانوية

**الملخص**
**الأهداف:** دراسة تأثير اضافة جسيمات النانوية (اوكسيد الزركونيوم واوكسيد السليكون وبتركيزين مختلفين على شفافية قاعدة الطخم الاكليرليكي. **المواد وطرائق العمل:** تم تحضير 50 عينة (15*2.5ملم) باتباع تعليمات المصنع وقسمت الى خمس مجموعات (المجموعة الضابطة ومجموعة 1% و 3% لكل من جزئيات اوكسيد الزركونيوم والسيليكون النانوية).
**النتائج:** اظهرت النتائج وجود فرق معنوي كبير بين المجموعات وقد وجد ان اضافة جسيمات اوكسيد الزركونيوم النانوية قلل الشفافية اكثر من اوكسيد السليكون وان تركيز 3% قد تسبب بنقصان كبير اكثر من 1%. **الاستنتاجات:** كلتا الجسيمات النانوية قللت شفافية قاعدة الطخم الالكريلكي .

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## INTRODUCTION

Denture bases are the parts of dentures that rest on soft tissues. To construct denture bases today, acrylic resin is widely employed [(1)].

Advantages of poly methyl methacrylate denture bases include ease of molding, good aesthetics, mechanical features such as high modulus of elasticity, impact strength, flexural strength, and hardness, appropriate binding strength with artificial teeth, and repairability [(2)].

Although poly methyl methacrylate is the material most commonly used for dentures, it has drawbacks including thermal shrinkage, reduced mechanical and fatigue strength, brittleness upon impact, lower color stability of self-cured resins, residual monomer allergy, porosity, and poor heat conductivity [(3)].

For the fabrication of dental prostheses with good final appearance, the optical properties must be considered before use [(4)].

The zirconium oxide and silicon oxide nanoparticles have numerous beneficial qualities that boost strength and toughness, corrosion and abrasion resistance, and great biological characteristics, making them an effective material for use in dental materials [(5-8)].

The translucency refers to the opacity of a colored layer that permits the appearance of a background to show through [(9)].

According to the result of the previous pilot study, the research chose two percentages (1% and 3%) by weight of zirconium oxide and silicon oxide nanoparticles, which improved the transverse strength of heat-cured denture base material [(10)].

## MATERIALS AND METHODS

For the current study, Triplex® (Ivoclar Vivadent, Liechtenstein), Zirconium oxide nanoparticles (US Research nanoparticles, Inc. USA), and Silicone Oxide Nanoparticles (Sky Spring Nanomaterials, Inc. USA) were used.

**Salinization of Nano-Particle:**

To salinize nano-$ZrO_2$ particles, a silane coupling agent which is TMSPM (3-(trimethoxysilyl) propyl methacrylate) was dissolved in acetone (0.3 g of TMSPM in 100 ml) added to the solution, and stirred with hot plate magnetic stirrer for one hour at temperature 80ºC. Then the solution was transferred to a rotary evaporator to remove the solvent under vacuum at 60ºC and 150 rounds per min for half an hour, when the solvent dried, the powder was heated to 120º C for 2 hours and then left to cool naturally to get surface treated ZrO2 nanoparticles [(11)].

For salinized $SiO_2$ NPs, the MPS (γ-meth acryloxy propyl trimethoxy silane) was pre-hydrolysed in 80 percent ETH for 1 hour at room temperature. The hydrolysed MPS was added to the NP suspension and mixed at 200 rpm for 2 hours at room temperature (RT), then refluxed for 4 hours at 70°C. After the reaction was completed, the liquid was allowed to cool. The component was dried in an oven (Memmert, Schwabach, Germany) at 505°C by evaporating the solvent [12].

**Sample Preparation**

Fifty discs (15×2.5mm) [10], were constructed and separated into 5 main groups (n=10); 1%$ZrO_2$, 3%$ZrO_2$, 1%$SiO_2$, 3%$SiO_2$ NPs reinforcement. The control group has no nanoparticle reinforcement.

Dental stone (Synarock/Germany) was utilized according to manufactured instruction, poured into the flask's lower section, and given appropriate vibration [5]. Then plastic disk was positioned [10].

Using probe sonication equipment at 120 W and 60 KHz for around three minutes. Salinized $ZrO_2$ and $SiO_2$ NPs were mixed with monomer after the powder of PMMA was mixed [13].

After finishing and removing them with tungsten carbide burs (Meisinger, Centennial, CO, USA), then used silicon carbide polishing paper (China).

The final polish was given with slurry pumice and soft bristle brushes for one minute at 1500 rpm (Steribim Super, Bego, Wilhelm-Herbst-Strabe, Germany). For 72 hours, samples were kept in distilled water [14-17].

**The translucency measurement**

Portable colorimeter (3NH High NR110, precision color testing portable colorimeter. China). The Commission Internationale de l'Eclairage (CIELAB) was used to measure (lightness-L*, red/green-a*, and yellow/blue-b*) of all specimens on a background of white and black. It had a 4 mm measuring window in diameter [15].

The colorimeter device was placed at a right angle to the specimen's surface. Measurements were taken at three separate locations in the center of the specimen to capture a mean value for the Initial calibration as in Figure (1A). Then the same specimen was fixed against the port, backed by black backing [18].

The colorimeters software automatically calculated the translucency value according to the following equation:

$\Delta E= [(L^*white-L^*black)^2 + (a^* white-a^* black)^2 + (b^*white-b^*black)^{2]\,1/2}$

The device screen displayed L, a, b, ΔL, Δa, Δb, and ΔE all the necessary data as in Figure (1B) [19], a higher value indicated a higher level of translucency and vice versa.

Statistical analysis was done by SPSS software version 26 (2019), and applied ANOVA test and post hoc (Duncan’s multiple comparison test) to data results.


**Figure (1):** A. colorimeter device during initial reading; B. colorimeter devices automatically presented the translucency value (ΔE).

## RESULTS

### 1. Effect of Nanoparticles

The mean and standard deviation of the translucency (ΔE) of specimens belong to different types of nanoparticles reinforced. The results were grouped according to nanoparticles reinforced type ($ZrO_2$ and $SiO_2$ NPs reinforced) not respect to concentrations of NPs, as shown in Table (1) and Figure (2).

**Table (1):** Means and Standard deviations of translucency test (ΔE) for study groups that reinforced with NPs.

| Groups | No. | Mean ±SD (ΔE) |
|---|---|---|
| **Control** | 10 | 7.9720 ±0.54026 |
| **ZrO2 NP reinforcement** | 20 | 3.5060 ±1.08376 |
| **SiO2 NP reinforcement** | 20 | 5.0055 ±1.42355 |
| **Total** | 50 | 4.9990 ±2.00212 |

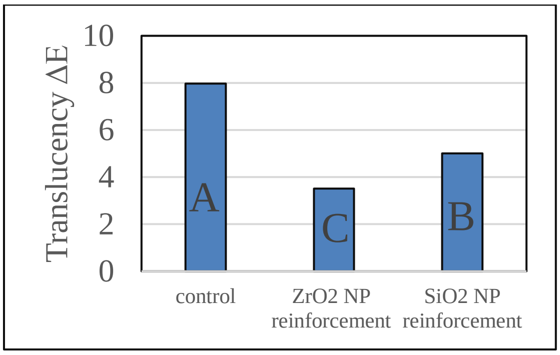


**Figure (2):** Bar chart representation of mean values for translucency of study groups reinforced with NPs.

Two-way ANOVA showed a highly significant ($P \leq 0.01$) effect of the type of nanoparticles reinforced on the translucency (ΔE) as shown in Table (2).

Duncan's multiple comparison tests showed the control had higher translucency than $ZrO_2$ and SiO2NP reinforced groups. The $ZrO_2$NP reinforced showed a more significant reduction in the translucency when compared with $SiO_2$ NP reinforced group as shown in Figure (2).

**Table (2):** two-way ANOVA Table for Comparing translucency test (ΔE) for study groups.

| SOV | Type III SS | Df | MS | F | P – value |
|---|---|---|---|---|---|
| **NPs** | 22.485 | 1 | 22.485 | 85.867 | .000** |
| **Conc** | 50.693 | 1 | 50.693 | 193.587 | .000** |
| **NPs*conc** | .970 | 1 | .970 | 3.706 | .000** |
| **Total** | 1445.916 | 49 | | | |

SOV: source of variance; SS: Sum of Squares; df: degree of freedom; MS: mean square; NPs: nanoparticles; conc: concentration of nanoparticles.
**: high significance at ($P \leq 0.01$)

### 2. Effect of Concentration of Nanoparticles

The mean and standard deviation of the translucency (ΔE) for different concentrations of NPs were reinforced. The results were grouped according to concentrations of NPs reinforced (1% and 3% by weight concentration of NPs reinforced) regardless of the type of NPs used, as in Table (3) and Figure (3).

**Table (3):** Means and standard deviations of translucency test (ΔE) for study groups reinforced with NPs.

| Groups | No. | Mean ±SD(ΔE) |
|---|---|---|
| **control** | 10 | 7.9720 ±0.54026 |
| **1 % reinforcement** | 20 | 5.3815 ±1.08355 |

| | | |
|---|---|---|
| **3 % reinforcement** | 20 | 3.1300 ±.73644 |
| **Total** | 50 | 4.9990±2.00212 |

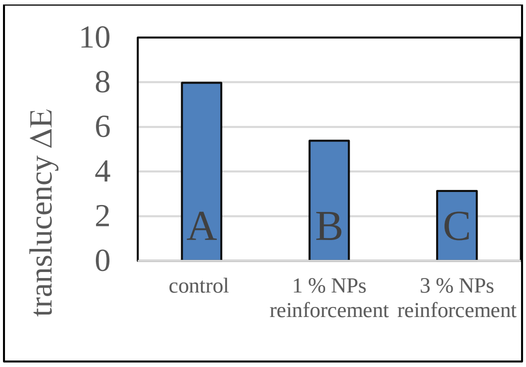


**Figure (3):** Bar chart representation of mean values for translucency of study groups reinforced with NPs.

Two-way ANOVA revered highly significant difference ($P \leq 0.01$) effect of concentration of NPs reinforced on the translucency as shown in Table (2).

Duncan's multiple comparison test showed the control group had higher translucency than 1% and 3% concentration of NPs reinforcement groups. The 3% concentration showed a more significant reduction in the translucency than the 1% concentration of the NPs reinforced group, as shown in Figure (3).

### 3. Interaction between Variables

The analysis of variance showed a highly significant difference ($P \leq 0.01$) of interaction between two NPs and two concentrations used, as shown in Table (2).

The mean and standard deviations of the translucency (ΔE) of interaction between type and concentration of NPs. The results data were grouped according to two types and two concentrations as shown in Table (4) and Figure (4).

**Table (4):** Mean and Standard deviation for the translucency (ΔE) of interaction between two types and two concentrations of NPs.

| **Groups** | **No.** | **Concentration** | |
|---|---|---|---|
| | | **1 %** | **3%** |
| | | **Mean ± SD (ΔE)** | **Mean ±SD(ΔE)** |
| **Zirconium oxide NP** | 20 | 4.4760±0.53014 | 2.5360±0.32810 |
| **Silicon oxide NP** | 20 | 6.2870±0.61279 | 3.7240±0.50319 |
| **Control** | 10 | 7.9720 ±0.54026 | |
| **Total** | 50 | 4.9990±2.00212 | |

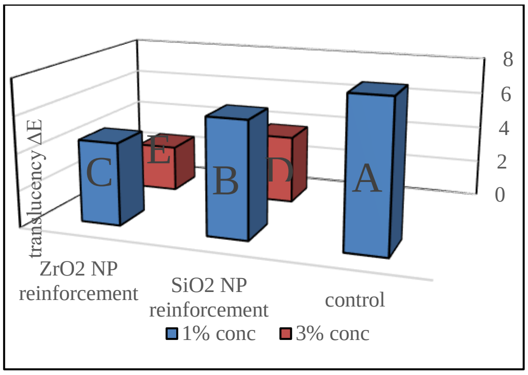


**Figure (4):** Bar chart representation of mean values for translucency of interaction between two types and two concentrations of NPs.

Duncan's multiple comparison test was employed to analyze the translucency. The results showed significant differences in interaction between types and concentrations. The control group was highly significant in the translucency then followed by 1% wt of $SiO_2$ NP, 1% wt of $ZrO_2$ NP, 3 % wt of $SiO_2$ NP reinforced group, and less translucency in 3%wt of $ZrO_2$ NP reinforced group, as shown in Figure (4).

## DISCUSSION

### 1. Effect of Nanoparticles Factor:

The results were obtained because of the difference in the optical properties of the nano-$ZrO_2$ and $SiO_2$ that were distributed in the resin matrix. Lower translucency was caused by high nano $ZrO_2$'s opacity and crystallinity, which prevented absorbed light from passing through the matrix [19, 20].

The other cause is affected by the refraction and reflection of light at the filler/matrix interface. This interface was influenced by the difference in refractive indices between the fillers and matrix. PMMA's refractive index (1.4813) is lower than that of nano-$ZrO_2$ (2.1750) and nano-$SiO_2$ (1.475) which may contribute to differences. Therefore, the more the two matrix components' refractive indices diverged, the opaque the resin matrix became [21,22].

The translucency of $SiO_2$NP's more advantageous over $ZrO_2$NP, because $ZrO_2$NPs' higher weight than $SiO_2$NPs'. The $SiO_2$NPs were added in a higher volume for the same concentration than $ZrO_2$NPs. In addition, the $ZrO_2$NPs showed more crystallinity than $SiO_2$NPs, which may cause an increase in their degree of opacity [4,23].

The results agree with the result of Gad et al. [24] Who discovered that the denture bases reinforced with $ZrO_2$NP or Ag NP had lower translucency than the control. The results are also, in agreement with the results of Gad et al. [10] who found that the addition of more than 0.5% by weight of $ZrO_2$ or $SiO_2$NPs to PMMA denture base material could significantly reduce the translucency characteristic.

The study results disagree with the results of Kolb *et al.* [25] and Shiraishi *et al.* [26] who found the translucency of composites would be raised from 26% up to 71% by increasing the refractive index of the matrix by merging with $ZrO_2$ nanoparticles. The difference from present study because used different materials other than heat-cured acrylic resin.

**2. Effect of Concentration Factor:**

The results showed a reduction in the translucency following the strengthening of the heat-cured denture base with nanoparticles of different percentages. 3% NPs strengthening showed more reduction than 1%.

The addition of nano-$ZrO_2$ decreased the translucency in direct relation to its concentrations. The absorbed light was not permitted to pass through the matrix because of the formation of $ZrO_2$NPs cluster, which reduced the translucency [27,28].

The results agree with the result of Aszrin *et al.* [18] Who showed that merging filler of zirconium oxide, aluminum oxide, and silicon oxide Will reduce the translucency. Increasing the concentration of $ZrO_2$Nps will decrease the translucency. Moreover, in agreement with Shirkavand and Moslehifard [29] the aggregation of nanoparticles within the matrix was influenced by the reflectance of the UV beam, which decreased translucency. Also, the results in agree with the results of Gad *et al.* (2018) who discovered that increasing in $ZrO_2$Np concentration will reduce the translucency parameter. The results also agree with the result of Alzayyat *et al.* [30] who found the translucency decreased as the percentage of nano-$SiO_2$ increased; Ihab *et al.* (31) who discovered the amount of light absorption increased with the increasing modified $ZrO_2$ NP concentration.

## CONCLUSION

The translucency was reduced by both nanoparticles reinforced to heat-cured denture base material.

**Conflicts of Interest**

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

## REFERENCES


1. Rashid H, Sheikh Z, Vohra F. Allergic effects of the residual monomer used in the denture base acrylic resins. *Eur J Dent.*2015**;** 9(4): 614-619.
2. Zafar M. S. Prosthodontic Applications of Polymethyl.
3. Methacrylate (PMMA): An Update. Polymers.2020; 12(10): 2299.
4. Alla R, Sajjan S, Alluri V, Ginjupalli K, Padhya NU. Influence of fiber reinforcement on the properties of denture base resins. *J Biomat Nano-Biotechnol*.2013*;* 4(1):91–97.
5. Saridag S, Tak O, Alniacik G. Basic properties and types of zirconia: an overview. *World J Stomatol*.2013; 2(3):40–47.
6. Anusavice, K.J., Shen, C and Rawls, H.R. Philips Science of Dental Materials. 12th Edn. *Elsevier, China***.**2013; Pp: 64, 93, 192, 476, 483.
7. Gad, M. M., Rahoma, A., Al-Thobity, A. M., & ArRejaie, A. S. Influence of incorporation of $ZrO_2$ nanoparticles on the repair strength of polymethyl methacrylate denture bases*. Int J Nanomed*.2016;11: 5633–5643.
8. Gad MM, Al-Thobity AM, Rahoma A, Abualsaud R, Al-Harbi FA, Akhtar S. Reinforcement of PMMA Denture Base Material with a Mixture of $ZrO_2$ Nanoparticles and Glass Fibers. *Int J Dent*.2019; 2019: 2489393.
9. Sakaguchi, R., Ferracane, J. and Powers, J. Craig's Restorative Dental Materials,14th Edn*. Elsevier, St Louis, USA.*2019**;** Pp: 116-7.
10. Powers, J.M. and Sakaguchi, R.L. Craig's Restorative Dental Materials. *12th Edition, Mosby, Missouri*,.2006; 386-393.
11. Gad, M. M., Al-Thobity, A. M., Shahin, S. Y., Alsaqer, B. T., & Ali, A. A. Inhibitory effect of zirconium oxide nanoparticles on Candida albicans adhesion to repaired polymethyl methacrylate denture bases and interim removable prostheses: a new approach for denture stomatitis prevention. *Int J Nanomedicine.*2017; (28)12: 5409–5419.
12. Gad, M. M., Rejaie, A. S., Abdel-Halim, M. S., Rahoma, A. The reinforcement effect of nano-zirconia on the transverse strength of repaired acrylic denture base. *Int. J. Dent*. 2016; 7094056.
13. Jiangkongkho, P., Arksornnukit, M., Takahashi, H. The synthesis, modification, and application of nanosilica in polymethyl methacrylate denture base. *Dent Mater J.* 2018; 37(4):582-591.
14. Hashem, Mohamed & Al Rez, Mohammed Fayez & Fouad, Hassan & Elsarnagawy,

Tarek & ElSharawy, Mohamed & Umar, Ahmad & Assery, Mansour and Ansari, S G. Influence of titanium oxide nanoparticles on the physical and thermomechanical behavior of poly methyl methacrylate (PMMA): a denture base resin. *Sci Adv Mater*.2017; 9(6): 938–944.

15. Polychronakis N, Polyzois G, Lagouvardos P, Andreopoulos A, Ngo HC. Long-term microwaving of denture base materials: effects on dimensional, color and translucency stability. *J Appl Oral Sci* .2018; 26: e20170536.
16. Alp, G., Johnston, W. M., & Yilmaz, B. Optical properties and surface roughness of prepolymerized poly (methyl methacrylate) denture base materials. *J Prosthet Dent*.201; *121*(2):347-352.
17. Giti R, Kazemi R, Mohammadi F. Effect of a Surface Sealant Agent on the Color Stability and Surface Roughness of Polymethyl Methacrylate and Nylon Denture Base Materials. *Int J Prosthodont*.2021;34(1):70-78.
18. Al-Noori A. Kh. The effect of Beverages on Color Stability of Highly Impact Acrylic Resin. *Al–Rafidain Dent J*.2007; 15(1):329-339.
19. Aszrin FN, Takarini V, Hasratiningsih Z, Purwasasmita BS. Translucency evaluation of polymethyl methacrylate (PMMA) reinforced with $ZrO_2$-$Al_2O_3$-$SiO_2$ filler system in fabricating indirect restoration**.** *UIP Health Med.*2016; 1:1–7.
20. Gad MM, Abualsaud R, Rahoma A, Al-Thobity AM, Al-Abidi KS, Akhtar S. Effect of zirconium oxide nanoparticles addition on the optical and tensile properties of polymethyl methacrylate denture base material. *Int J Nanomedicine*.2018;13: 283–292.
21. Balos S, Pilic B, Markovic D, Pavlicevic J, Luzanin O. Poly(methyl-methacrylate) nanocomposites with low silica addition. *J Prosthet Dent*.2014;111(04):327–334.
22. Nakajima M, Arimoto A, Prasansuttiporn T, Thanatvarakorn O, Foxton RM, Tagami J. Light transmission characteristics of dentine and resin composites with different thickness. *J Dent* .2012;40(2):77–82.
23. Bodurov I, Vlaeva I, Viraneva A, Yovcheva T, Sainov S. Modified design of a laser refractometer. *Nano sci Nanotechnol*.2016; 16:31–33.
24. Yang F, Nelson GL. PMMA/silica nanocomposite studies: synthesis and properties**.** *J Appl Polym Sci*.2004; 91: 38443850.
25. Gad, M. M., Abualsaud, R., Rahoma, A., Al-Thobity, A. M., Akhtar, S., & Fouda, S. M. (2022). Double-layered acrylic resin denture base with nanoparticle additions: An in vitro study. *J Prosthet Dent*.2022;127(1), 174–183.
26. Kolb, C., Gumpert, K., Wolter, H., & Sextl, G. Highly translucency dental resin composites through refractive index adaption using zirconium dioxide nanoparticles and organic functionalization. *Dent Mater*.2020; 36(10): 1332–1342.
27. Shiraishi T, Watanabe I. Thickness dependence of light transmittance, translucency and opalescence of aceria-

stabilized zirconia/alumina nanocomposite for dentalapplications. *Dent Mater* 2016; 32:660–700.

28. Anusavice KJ. Dental ceramics. In: *Phillip's Science of Dental Materials*. 11th ed. Missouri: *Elsevier Inc*. 2003;721–724.
29. Asopa V, Suresh S, Khandelwal M, Sharma V, Asopa SS, Kaira LS. A comparative evaluation of properties of zirconia reinforced high impact acrylic resin with that of high impact acrylic resin. *Saudi J Dent Res.2015;*2(6):*146*–151.
30. Shirkavand S, Moslehifard E. (2014). Effect of TiO2 nanoparticles on tensile strength of dental acrylic resins. *J Dent Res Dent Clin Dent Prospects* .2014;8(4):197–203.
31. Alzayyat, S. T., Almutiri, G. A., Aljandan, J. K., Algarzai, R. M., Khan, S. Q., Akhtar, S., Matin, A., & Gad, M. M. Antifungal Efficacy and Physical Properties of Poly (methyl methacrylate) Denture Base Material Reinforced with $SiO_2$ Nanoparticles. *JProsthodont*. 2021; 30 (6):500-508.
32. Ihab, N. S., Hassanen, K. A., & Ali, N. A. Assessment of zirconium oxide nano-fillers incorporation and salination on impact, tensile strength and color alteration of heat polymerized acrylic resin. *J Bagh Coll Dentistry*.2012; 24(4): 36-42.