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The Effect of Zirconium Oxide Nanoparticle on the Surface Roughness of Maxillofacial Silicone Material

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Abstract

Aims: The study intended to inspect the consequence of the addition of zirconium oxide (ZrO_2) nanoparticle at two concentrations (1% and 1.5% by weight) on the surface roughness of the maxillofacial silicone material (room temperature vulcanized). **Materials and methods**: Thirty samples were prepared according to the manufacture instructions and divided into three groups (n=10). A digital surface roughness profilometer tested the surface roughness samples for the control group (A) free from nanoparticle, group (B) 1% ZrO_2, group (C) 1.5 % ZrO_2 .**Results**: The mean values of the surface roughness measured groups a highly significant difference among groups. Group A (.2137 µm) exhibited a highly significant difference compared to group B (.2698 µm) and group C (.2801 µm). Besides, a highly significant difference between group B and group C .**Conclusions**: Incorporation of 1% and 1.5% by weight of ZrO_2 nanoparticle into maxillofacial silicone material increases surface roughness.

الخلاصة

الأهداف: تهدف الدراسة إلى فحص نتيجة إضافة تركيزين (١ ٪ ، ١.٥ ٪ بالوزن) من جزيئات أكسيد الزركونيوم النانوية (ZrO_2) على خشونة سطح مادة سيليكون للوجه والفكين مبركن بدرجة حرارة الغرفة. **المواد وطرائق العمل** : تم تحضير ٣٠ عينة باتباع تعليمات التصنيع وقسمت إلى ثلاث مجموعات (ن = ١٠). اختبر مقياس خشونة السطح الرقمي عينات خشونة السطح لمجموعة التحكم (أ) الخالية من الجسيمات النانوية ، المجموعة (ب(١٪ ZrO_2 والمجموعة (ج) ١.٥٪.ZrO_2 **النتائج** : اظهرت النتائج بوجود فرق معنوي كبير بين القيم المتوسطة للمجموعات. أظهرت المجموعة الضابطة (٢١٣٧, ميكرومتر) فرقا معنويا مع كل من مجموعة ب (٢٦٩٨ ,ميكرومتر) ومجموعة ج (٢٨٠١, ميكرومتر) وفرق معنوي كبير بين المجموعة ب والمجموعة ج. **الاستنتاجات** : دمج ١٪ و ١.٥٪ بالوزن من جسيمات ZrO_2 النانوية في مادة السيليكون للوجه والفكين كان له السبب في زيادة خشونة السطح.

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INTRODUCTION

Maxillofacial silicone elastomers are used to restore defects in the facial area, which can cause patient social fear [1]. The maxillofacial silicone elastomers used to repair deformities resulted from surgical management of benign/malignant tumour, congenital deformities, or trauma, given an appealingly good-looking and functional reestablishment of the defect [2]. When silicone elastomer was first effectively used as a maxillofacial material in 1960, it has come to be the first choice for soft tissue repair [3]. Silicone elastomers have been commonly used facial prostheses material because of their ease of manipulation, flexibility, chemical, mechanical properties, and pigment acceptance [4]. The main drawback of silicone material is deterioration in the physical and mechanical properties and variations in the materials' display (shade and surface roughness) [5-7]. Such changes happened due to exposure to UV energy, moisture, air contamination, and care chemicals [5,8-10]. Many organic and inorganic nanoparticles of various types and sizes have been incorporated into maxillofacial silicone elastomers to prevent such degradation. These filler particles strengthen maxillofacial silicone elastomers and permit the material to enhance its resistance during standard function and weather changes [11]. Although numerous studies have demonstrated the benefits of incorporating filler particles [11-13], a review of these filler particle effects on the surface roughness is lacking. The roughness is an amount of the materials' surface texture's slight irregularities. Surface roughness average (Ra) is the nonconformity of the surface vales and crests in microinches or micrometres; for a rough surface, the deviations are excessive, while for a smooth one, the deviation was slight. A silicone material's surface roughness can be measured using scanning electron microscopy, surface profilometer, and optical techniques [14-16].

The purpose of the current study was to evaluate the influence of nano Zirconium oxide addition on surface roughness property for VST-50F RTV silicone elastomer.

MATERIALS AND METHODS

For the present study, VST 50F RTV silicone elastomer (Factor II, Inc., Lakeside, AZ, USA) and Zirconium oxide nanoparticle (US research nanomaterials inc., Houston, USA.) were used. Thirty (30) samples were divided into three groups. The control group (A) was free from nanoparticle and experimental groups of 1% ZrO_2 group (B) and 1.5% ZrO_2 group (C). All samples prepared according to (ASTM D2240-15) with dimensions (length 25 mm x width 25 mm) and 6 mm thickness [14,17].

The tested samples dimensions were firstly designed using AutoCAD 2015 (Autodesk Inc., San Rafael, CA, USA). Following designing, the computer-controlled laser cutting machine (Boye Laser Application Technology Co., Ltd, China) was used to scratch places in the hardened acrylic mold (Figure 1) [18]. 10:1 by weight is Part A (base) mixing ratio to part B (cross-linker) according to the manufacturer's instructions. Digital electrical balance (0.000 digits, China) was used to weigh the base and cross-linker for the group (A), which will manually mix for 5 minutes and be traced by motorized mixing by way of vacuum for 5 min. Using the Multi-Vac 4 vacuum mixer (Degussa, Frankfurt, Germany) [5].

Figure (1): Acrylic plastic mold for the surface roughness test.

Conversely, for the experimental groups (B, C), the nanoparticle was located in an unpolluted container and weighted using a digital electrical balance. After that, they were mixed by hand for one min with pre weighted base. Followed by ten minutes of mechanical mixing, the first three minutes., the vacuum mixer was turned off to avoid nanoparticle suction. For the remaining seven minutes, the vacuum turned on to prevent voids in the final silicone [19]. Earlier to the cross-linker addition, the combination was left aside for around 2 min to prevent heat generated from the rotation to working time reduction [20]. Then the base and cross-linker mixed following the manufacture's instruction. The part A and part B combination mixed with vacuumed mechanical mixer for 5 minutes. To ensure a precise result, the process of silicone elastomers mixing should be at a measured temperature of (23±2°C) and relative humidity (RH) of (50±10%) [21].

Gradually dispensed the silicone blend inside the acrylic molds' formed places; Now, the acrylic mold cover steadily and slowly applied from one end to another. Adequate finger pressure was used by one hand till the molds' fragments were squeezed by a screw, nuts, and G clamps (China) in four places (Figure.2). Conferring to silicone instruction, silicone vulcanized for 2-3 hours. After that, the sample should be wisely uninvolved from the spaces deprived of any pressure [22], then scalpel and blade 10# (Dr. Quillel Surgicals, Pakistan) were used for eliminating flares nearby the sample [23].

Figure (2): Parts of mold squeezed by screw, nuts, and G-clamps

The samples stored in a personalized lightproof container in an air-conditioned area while waiting for testing at 10–30 °C, and RH did not go above 80% [24]. The surface roughness sample was prepared and tested following ASTM D2240-15 (American Society for Testing and Materials). A portable digital roughness profilometer (TR200, Time High Technology Ltd., China) (Figure 3) measured the more delicate irregularities of surface texture inherent in the materials. [25]

Figure (3): A portable surface roughness profilometer.

The sample was located on a plane, stiff, and steady surface. Three measurements were conducted for each sample by tracing the profilometer analyzing diamond needle on the sample surface in three points. The average of these readings considered the mean values of surface roughness. [26]

The tested data were statistically examined using a one-way ANOVA test and post hoc (Tukey HSD). A probability *P*-value > 0.05 was considered statistically non-significant, while $P \leq 0.05$ was considered statistically significant, and $P \leq 0.01$ was considered statistically highly significant.

RESULTS

Descriptive statistics for the control group (A), 1 % ZrO_2 group (B), and 1.5% ZrO_2 group (C) were revealed in (Figure. 4). One-way statistical analysis ANOVA showed a highly significant difference between groups *P*-value ≤ 0.01 (Table.1).

Table (1): Statistical test of surface roughness (μm) test among groups using one-way ANOVA.

SOV	SS	Df	MS	F-value	P-value
	.026	2	.013	2230.283	.000 **
	.000	27	.000		
	.026	29			

SOV: the source of variance; SS: Sum of Squares; df: the degree of freedom; MS: mean square
** highly significant at $P \leq 0.01$

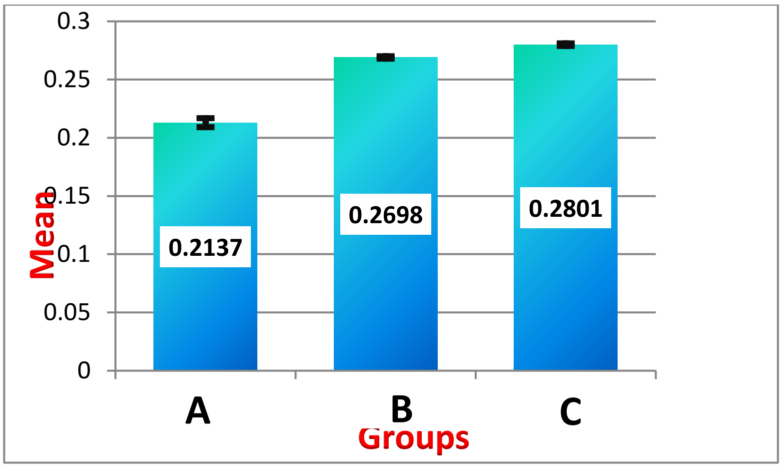

Figure (4): Bar chart represents the mean value and standard deviation of surface roughness(μm) of all study groups.

To compare groups (A, B, and C) mean values, the Tukey Honestly Significant Difference (Tukey HSD) was carried out and displayed a highly significant difference (HS) ($P \leq 0.01$) among mean values of group (A) and group (B) as well as between group (A) and group (C), and HS between group (B) and group (C), as shown in (Table. 2).

Table (2): Tukey (HSD) test multiple comparisons of surface roughness (μm) test mean values between tested groups

(I) groups	(J) groups	Mean Difference (I-J)	Sig
	Group B	-.056100	.000 **
	Group C	-.066400	.000 **
	Group C	-.010300	. 000 **

**highly significant at $P \leq 0.01$

DISCUSSION

Surface roughness is frequently a good analyst of a mechanical element's performance, as abnormalities in the surface may form starting sites for fissures or corrosion [(14)]. The silicone prosthesis replacement is necessary when there are surface irregularities even if the bulk of the material is intact [(27)], since silicone's surface roughness affects microbial adhesion and appropriate tissue adaptation silicone prostheses [(28)].

This study investigated the change in the surface roughness property of commercially available silicone elastomer, VST 50F RTV silicone elastomer, following the incorporation of ZrO_2 nanoparticle at two concentrations.

The results of the surface roughness mean values indicate a highly-significant increase after the addition of Zirconium oxide Nanoparticle at 1% (.2698 μm) and 1.5% (.2801 μm) groups when compared with group A (.2137 μm), as shown in (Table.2) and (Figure.4) According to the literature review and previous studies, to date, no study was attempted to evaluate the effect of nano-sized additives on surface roughness of maxillofacial silicone materials (both types RTV and HTV). And that was the exceptionality of this study so that some interpretation of the results of surface roughness of maxillofacial silicone elastomers for the present study compared with other polymer material as denture base acrylic resin.

Gad *et al.* [(29)] stated no substantial enhance in surface roughness of acrylic material after the incorporation of 0.5% ZrO_2 nanoparticles, since if the nanoparticles added at low concentration result in fair distribution inside the polymer matrix in addition to the capability of these nanofillers to seal the areas between the polymer chains, subsequently less nanoparticles on the samples superficial layer. But, when nanofillers weight increased (1.0%, 2.5%, and 5.0% by weight), it results in a rougher surface. Such surface roughness increase might be caused by the nanoparticle agglomeration affinity and the reduction inhomogeneity within the matrix [(30)].

The present study results agreed with Akash & Guttal (2015) [(31)] that once the adding concentration of nanoparticles increased, its dispersion within the polymer matrix will decrease.

CONCLUSIONS

Within the limitations of the current study, it recognized that the incorporation of zirconium oxide nanoparticles at a concentration of (1% and 1.5% by weight) outcomes surface roughness increasing.

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None

ETHICAL STATEMENT

By submitting this manuscript to the Al-Rafidain Dental Journal, all authors confirmed that the manuscript meets the ethical standards including proper statistical investigations and thorough ethical reviews by the data owning organizations.

Conflicts of Interest

The authors declare no conflict of interest.

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