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Research Article

The Effects of Magnesium Oxide Nanoparticles Addition on Some Mechanical Properties of Room Temperature Vulcanized Maxillofacial Silicone

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Abstract

Aims: This study aimed to assess the effect of incorporating different concentrations of MgO nanoparticles on some mechanical properties of room-temperature vulcanized(RTV) maxillofacial silicone material.

Materials and Methods: A total of 120 silicone specimens were constructed,40 specimens for each mechanical property, which were tear, tensile, and hardness groups, and each group was divided into four subgroups according to MgO Nps concentration (0%, 1%, 2%, and 3%) groups with 10 specimens for each one. Silicone and MgO Nps were mixed and cured according to their standardization procedures. Tear and tensile strength were estimated by utilizing a universal testing machine; Shore A hardness was estimated with a durometer. Fourier transform infrared spectroscopy (FTIR) was used to check the chemical integrity and molecular interactions between silicone and MgO NPs.

Results: One-way ANOVA showed that the addition of MgO NPs significantly changed the mechanical properties of silicone elastomers ($p \leq 0.05$). Both tear and tensile strength reached their highest values at 2% MgO Nps, followed by 1% MgO Nps, and then declined at 3% MgO Nps concentration. Post-hoc pairwise comparison revealed no significant difference between the 1% and 3% groups for the tear strength test and no significant difference between the control and 3% groups for tensile strength. Shore A hardness increased as the concentration of MgO NPs increased from 1% to 3%, with a significant difference among all groups. FTIR showed the same peak intensities in the control and experimental groups, indicating that no changes or molecular interactions had occurred.

Conclusion: The incorporation of MgO nanoparticles affected the tested mechanical properties of RTV maxillofacial silicone. The concentration of 2% was considered the ideal percentage of MgO NPs for both tear and tensile strength; higher concentrations further increased surface hardness but reduced the overall material strength parameter.

Keywords: Maxillofacial silicone, Magnesium oxide nanoparticles, Tear strength, Tensile strength, Shore A hardness.

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INTRODUCTION

Maxillofacial defects stemming from oncologic surgery, trauma, and congenital anomalies may engender aesthetic issues, lead to functional deficits, psychological problems, anxiety, reduced self-esteem, and social isolation (1,2). Using maxillofacial prostheses for facial restoration, affected patients can enhance function, regain appearance, support mental health, and overcome speech problems, thereby permitting them to resume social relationships. (3,4)

Maxillofacial prosthetics is the subdivision of prosthodontics that is interested in the restoration of the stomatognathic and craniofacial parts of the human body with a prosthesis that may or may not be separated on a regular or elective basis. (5) Acrylic resins, acrylic copolymers, vinyl polymers, polyurethane elastomers, and silicone elastomers are the most popular materials utilized for the construction of maxillofacial prostheses. (6)

Among these materials, maxillofacial silicone elastomers have crucial importance in prosthodontics. In many cases, the extensive nature of defective areas of the maxillofacial part often complicates reconstructive and plastic surgical procedures, occasionally to the extent of precluding their feasibility; accordingly, the utilization of a maxillofacial silicone prosthesis that ensures satisfactory esthetics and functional outcomes can be considered the optimal therapeutic approach. (7)

These materials are selected for their perfect biocompatibility, simplicity, and the capability to reproduce the natural appearance of soft tissues. (8,9)

Despite the previously stated advantages, maxillofacial silicones exhibit significant problems, including insufficient tear strength, low resistance to mechanical forces, and susceptibility to environmental deterioration, resulting in reduced prosthesis lifespan. (10). Silicone elastomers used in fabricating these prostheses fail to consistently meet the necessary standard; their functional lifespan is relatively short, typically lasting only around six months, as they undergo alterations in physical characteristics and exhibit color instability. (11)

The inherent restrictions of conventional silicone, like poor tear resistance and vulnerability to deterioration, impose the investigation of advanced reinforcement techniques. Different reinforcement techniques, including the addition of polymeric additives, filler modifications, and surface treatment, have been studied to improve the sturdiness and effectiveness of the material. (12) Nanotechnology has acquired considerable importance because of many properties of nanomaterials, such as high reinforcing potency, which can improve the thermal, mechanical, antibacterial, and antiviral merits of polymeric matrices while maintaining their bio-inertness. (13) The suitable physical and mechanical characteristics gained by reinforcing the polymer with nanoparticles could be attributed to the special features of the nanofillers, like their large surface area, high surface energy, and polarity or high chemical reactivity. These features permit the nanofillers to interact with the polymer chains, forming a composite with a three-dimensional arrangement and distinct properties. (14)

Magnesium oxide (MgO) NPs are one of these nanoparticles, which are eco-friendly and show many beneficial properties, including less toxicity, bio-inertness, biodegradability, strong antimicrobial properties, and biomedical implementations; they are also affordable and simply accessible. (15). In the latest research, researchers have been focused on MgO Nps as a good nanoparticle and reinforcing material for polyethylene (PE) (16,17), and other polymers (18,19), because of non-toxicity and high mechanical strength. (20,21). Previous findings indicated that reinforcing glass ionomer cement (GICs) with MgO NPs yields a marked improvement in surface hardness (22). In removable prosthodontics, the addition of MgO NPs to polymethylmethacrylate (PMMA) denture base resin showed an increase in the flexural strength (23)

Studies on the addition of MgO NPs as a mechanical reinforcing agent within maxillofacial silicone elastomers were limited, so this research aims to evaluate the effect of adding different concentrations of MgO nanoparticles on the tear strength, tensile strength, and surface hardness of RTV maxillofacial silicone elastomers, aiming to enhance their clinical durability. The null hypothesis assumed that incorporating

MgO nanoparticles would not alter the mechanical properties of RTV maxillofacial silicone in a concentration-dependent manner.

MATERIALS AND METHODS

In this study, MgO nanofiller 50 nm, purity 99.5% (US Research Nanomaterial's, USA) and VST-50F (RTV) room temperature vulcanized silicone (Technovent, UK) were used,120 specimens were manufactured,40 specimens for each test (tear, tensile and hardness), and each test group further classified into four subgroups which are control group (0% MgO Nps) and three experimental groups (1%,2% and 3%) MgO Nps,10 specimens for each one.

Acrylic molds were designed using computer software AutoCAD 2015 (Autodesk Inc., San Rafael, CA, USA), then acrylic sheets were cut by a digitally controlled CNC machine (Boye Laser Application Technology, China) to construct the molds into which the maxillofacial silicone is to be flowed. (24)

Every mold was fabricated from three pieces: base, frame, and lid. The mold pieces are joined tightly with nuts and bolts; for more security, G-clamps were also utilized at the edges. The VST-50F(RTV) silicone was prepared using a standard 10:1 base to catalyst mixture following the factory instructions. Control specimens were prepared by measuring the RTV silicone base and catalyst on a high-precision electronic balance with 0.001 g accuracy (China). After that, blending was performed in a vacuum mixer (Multivac 4, Degussa, Germany) at 360rpm under -10 bar pressure for 5 minutes to prevent air from flowing into the mixture. For 1%, 2%, and 3% specimens, the intended concentration of MgO Nps was weighed on an electronic balance; the weight of nanoparticles was subtracted from the weight of the base; the base was then added, and the mixture of base and MgO nanoparticles was blended in the vacuum mixer for 3 minutes without applying a vacuum, to prevent the nanoparticles from being drawn out. (25) The nanofiller and base were then vacuum mixed for 7 minutes. After that, the mixture was permitted to cool for 5minutes because the rotation of the mixer led to heat generation, which lessened the working

time of the material. (12), subsequently, the catalyst was introduced and thoroughly mixed for 5 minutes under vacuum to ensure the formation of a bubble-free mixture. (26) After that, the mixture was poured into the prepared molds for every test, then the cover was applied; bolts and nuts were used to tighten the closure of the lids over the specimens, applying G-clamps, then the silicone mixture was allowed to cure for 24 hours at ambient temperature (23°C ± 2°C). After curing, the specimens were removed carefully, then placed inside the storage box at 20-25°C, 50 ±10% humidity, for 16 hours according to ISO 23529:2016. (27). A hygrometer and thermometer with a digital screen were secured on the storage box cover, which had a sensor probe that was placed inside the box to monitor relative humidity and ambient temperature inside and outside the specimen conditioning box (28).

Testing procedures

Attenuated Total Reflectance-Fourier Transform Infrared spectroscopy (ATR-FTIR) analysis

It was performed using an ATR-FTIR device (Bruker, Germany) (four specimens were tested, one from each group (0%,1%,2%,3%) MgO NPs); the test was performed according to ASTM E1252-98(2021). (29) Each specimen was placed directly onto a diamond crystal of an Attenuated Total Reflectance (ATR) sampling accessory, ensuring uniform contact pressure. Spectroscopic scans were recorded within an infrared wavenumber range of 4000 cm-1 to 400cm^{-1} at a spectral resolution of 4 cm-1, to check if there was any alteration in the chemical composition of maxillofacial silicone after the addition of MgO Nps.

Tear strength

Specimens were constructed and tested following ASTM D624-00(2020) (30). Specimens (type C) were utilized to test the tear strength with an un-nicked, one apex (90 °) angle on one side, with two-tab ends. The thickness of the specimens is 2±0.2mm as shown in Figure 1A. The testing was performed utilizing a universal testing machine (HSA-UT-5PC, China). The ends of the specimens were fixed symmetrically in the universal testing machine's grips so that the specimens were strained evenly

along their length. The upper arm was raised upward, but the lower arm was fixed; the cross-head speed of the machine was 500mm/min. The tear strength test was determined by measuring the peak force at break per unit thickness(N/mm). The calculation was performed using the tear strength equation (T_s) =F/D, where F is the maximum breaking force in Newtons, and D is the thickness of each specimen in millimeters (mm). Figure 2A.

Tensile strength

The specimens were prepared and evaluated in accordance with (ISO 37:2017) (31), utilizing type 2 dump-bell-shaped specimens as shown in Figure 1B. Each specimen was secured between the grips of a universal testing machine (HSA-UT-5PC, China). Testing was conducted at a crosshead speed of 500mm/min, and the maximum fracture stress was calculated. Tensile strength was calculated by using the following equation: Tensile strength=Fm/Wt, tensile strength is measured in (MPa), where Fm is the maximum force in Newtons; W is the width in Millimeters, and t is the thickness in millimeters. Figure 2B

Shore A hardness

The test was made following ASTM D2240-15(2021) (32). The dimensions are 25 mm length × 25 mm width × 6 mm thickness, Figure 1C. Five points were tested on the surface, six mm away from one another. Shore A durometer LAC-YJ (LOYKA, Turkey) with a 1.25 mm blunt indentor was used for testing. The specimen was positioned on a smooth, straight surface. Hardness values were recorded at each test point, and the average of these readings was taken as the overall hardness of the specimen. Figure 2C.

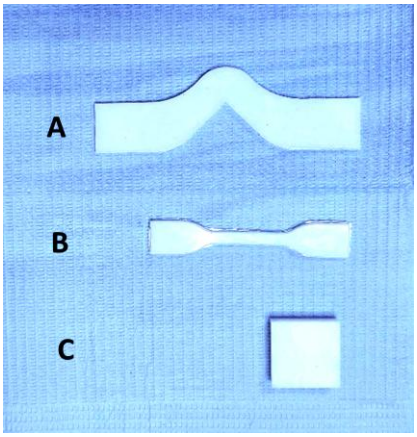


Figure (1): Sample shapes: (A)tear test, (B) tensile test, (C) hardness test

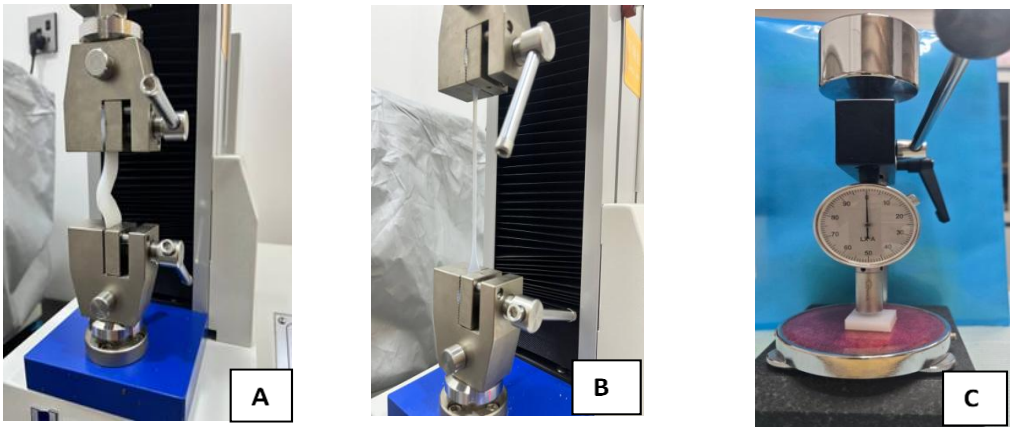


Figure (2): Testing apparatus: (A)tear test, (B) tensile test, (C) hardness test

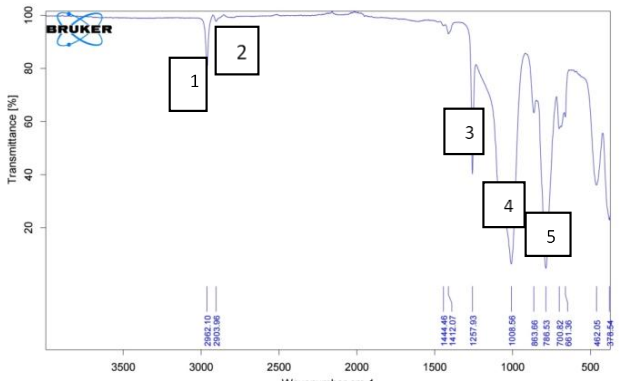
Statistical analysis

The data were compiled and analyzed using IBM SPSS version 30. Descriptive statistics, mean, and standard deviation (SD) were calculated for all groups. Subsequently, the test of normality (Shapiro-Wilk test) was done to assess the distribution of data; since the data demonstrate a normal distribution ($p > 0.05$), parametric tests were considered appropriate. Consequently, a one-way analysis of variance (one-way ANOVA) was used to compare the tested groups. Tukey honestly significant difference HSD post hoc was conducted for multiple pairwise comparisons whenever ANOVA showed a significant difference; statistical significance was set at $p \leq 0.05$.

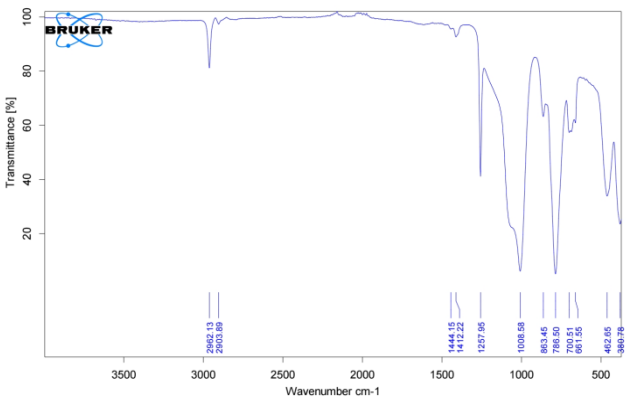
RESULTS

Attenuated total reflectance, Fourier transform infrared spectroscopy (ATR-FTIR) test:

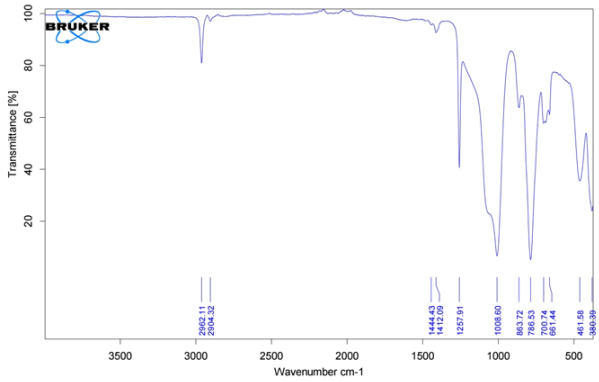
FTIR test revealed the main absorbance peaks in the control, which were (1) 2962cm $^{-1}$ which represents CH3, (2)2903 cm^{-1}, which represents C-H, (3)1257cm^{-1} represents Si-CH3, (4) 1008cm^{-1} represents Si-O-Si, and (5) 786 cm $^{-1}$ represents Si-C. (33) The FTIR test of the three experimental groups showed the same peaks as in the control group, which means that the addition of MgO Nps did not affect the chemical bonds in VST-50F(RTV) silicone, governed solely by physical interactions, such as hydrogen bonding or Van der Waals bonding, as shown in Figure 3 (A, B, C, and D).



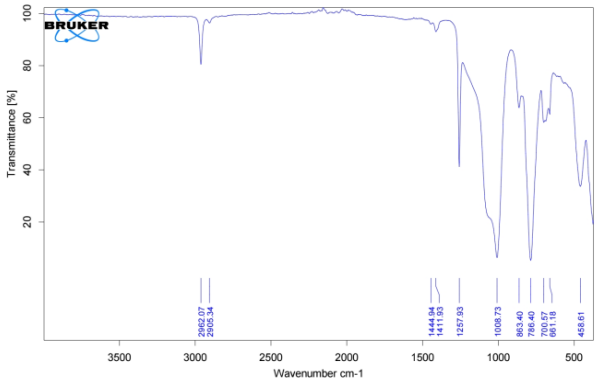
(A) Control



(B) 1%MgO Nps



(C) 2% MgO Nps



(D) 3%MgO Nps

Figure (3): FTIR of (A) Control (B) 1% MgO Nps (C) 2% MgO Nps (D) 3% MgO Nps

Tear strength test

Descriptive statistics showed that the highest mean belonged to MgO Nps 2% group followed by MgO Nps 1% group then MgO Nps 3% group, the least mean belonged to control group, one way analysis of variance (ANOVA) test showed that there was a highly significant difference at ($p < 0.001$), to compare means among experimental groups, tukey HSD test was performed and showed that all groups differed from one another significantly except between MgO Nps 1% and MgO Nps 3% which showed non-significant difference between them as shown in table1 and Figure 4.

Table (1): Descriptive statistics, one-way ANOVA, and Tukey HSD test of tear strength (N/mm)

Groups	N	Mean±SD	F value	P value	Tukey
Control	10	23.19 ±1.39			C
MgO Nps 1%	10	25.83±0.97	26.348	< 0.001	B
MgO Nps 2%	10	27.42±1.07			A
MgO Nps 3%	10	25.63±0.77			B

*ANOVA showed a statistically highly significant difference at P <0.001, the Tukey HSD test described that different letters mean statistically significant differences, while the same letters mean non-significant differences between groups.

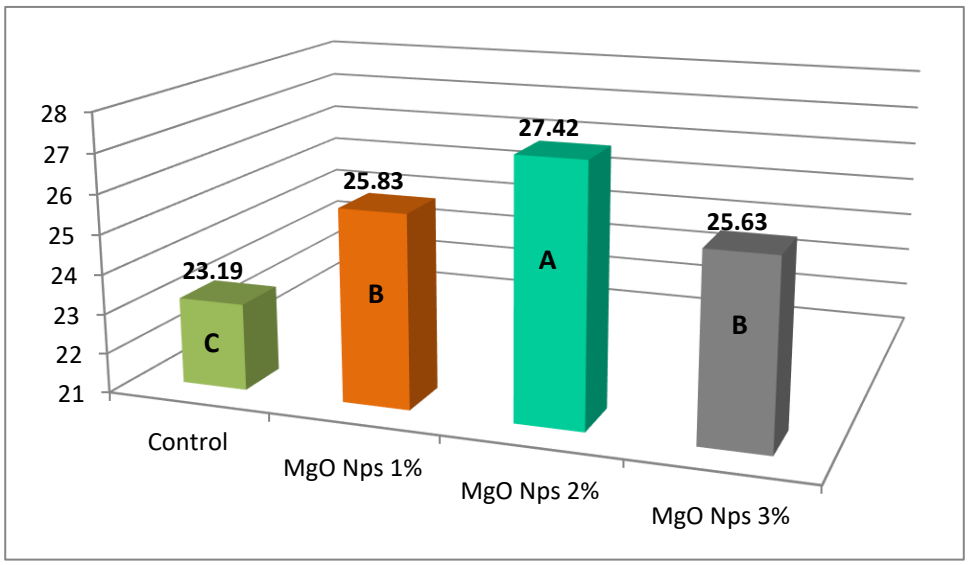


Figure (4): Shows the mean and Tukey HSD test of tear strength

Tensile test

Descriptive statistics showed that the highest mean belonged to MgO Nps 2% followed by MgO Nps 1% group then control group, the least mean belonged to MgO Nps 3% group, one way analysis of variance (ANOVA) test showed that there was a highly significant difference at ($p < 0.001$), to compare mean among experimental groups, tukey HSD test was performed which showed a significant difference among all groups except between control and MgO Nps 3% groups which showed non-significant difference between them as expressed in Table 2 and Figure 5.

Table 2: Descriptive statistics, one-way ANOVA, Tukey HSD test of tensile strength (MPa)

Groups	N	Mean±SD	F value	P value	Tukey test
Control	10	4.72±0.13			C
MgO Nps 1%	10	5.24 ±0.18	271.411	< 0.001	B
MgO Nps 2%	10	6.51±0.20			A
MgO Nps 3%	10	4.57±0.16			C

*ANOVA showed a statistically highly significant difference at P <0.001, the Tukey HSD test indicated that different letters mean statistically significant differences, while the same letter means a non-significant difference between groups.

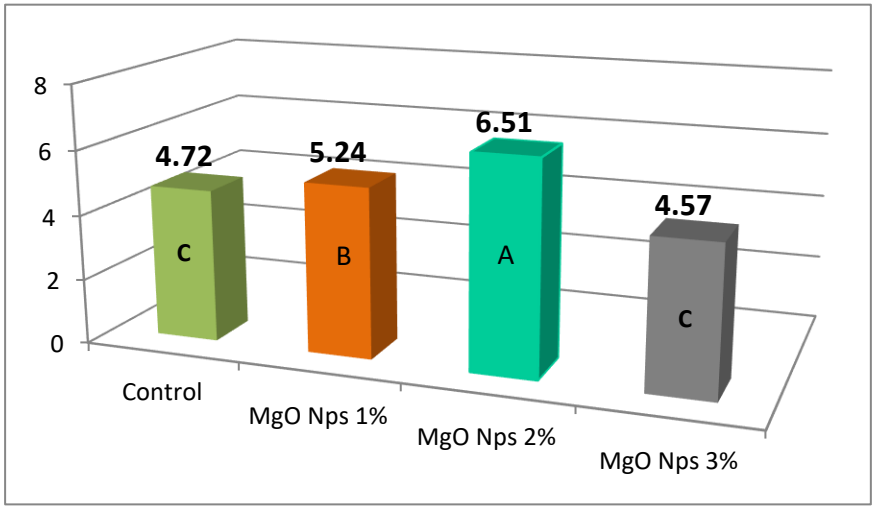


Figure (5): Shows the mean and Tukey HSD test of tensile strength

Shore A hardness test

Descriptive statistics showed that the highest mean belonged to MgO Nps 3%, followed by the MgO Nps 2% group, then the MgO Nps 1% group; the lowest mean was the control group. Analysis of variance (ANOVA) test showed that there was a highly significant difference ($p < 0.001$) comparing means among experimental groups; the Tukey HSD test was performed, which showed that all groups differed significantly from one another, as shown in Table 3 and Figure 6.

Table 3: Descriptive statistics, one-way ANOVA and Tukey of hardness test

Groups	N	Mean ±SD	F value	P value	Tukey test
Control	10	26.66±0.66			D
MgO Nps 1%	10	28.36±0.69	65.978	<0.001	C
MgO Nps 2%	10	29.48±0.71			B
MgO Nps 3%	10	31.18±0.88			A

*ANOVA showed a statistically highly significant difference at P <0.001, Tukey HSD test indicated that different letters mean statistically significant differences, while the same letter means a non-significant difference between groups.

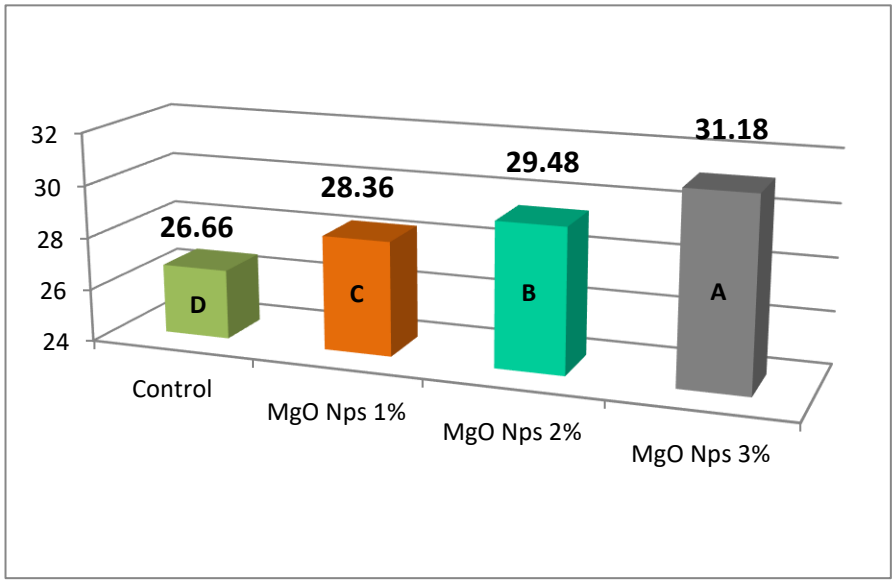


Figure (6): Shows the mean and Tukey HSD test of hardness

DISCUSSION

Maxillofacial specialists still have problems associated with the serviceability and durability of maxillofacial prostheses. (34) The results of this study showed an increase in tear strength and tensile strength at certain concentrations, while the hardness value increased as the concentrations of MgO NPs increased, so the null hypothesis, which suggested that there is no effect of MgO NPs on (RTV) VST-50F silicone, was rejected. This study showed significant increase in tear strength of (RTV) silicone after the addition of MgO Nps to it at concentration of 1% and became higher at 2% compared to control group, this may be owing to creation of three dimensional scaffold inside the polymer framework, the enhancement in tear strength can also be theoretically clarified based on the established literatures by capability of the polymer to dissipate strain energy near the advancing crack tip, as tearing transmits, nano fillers will disperse the energy inside the polymer framework improving tear tolerance and a greater force will be required to totally disrupt the polymer framework. (35,36)

Tensile strength is an essential property of a maxillofacial material since the prosthesis is commonly exposed to tensile load when the patient takes it off for cleansing and nightly before sleeping. (37) The current study showed an improvement in the tensile property, the highest mean tensile strength at 2%, followed by 1%, in comparison to the control group. The enhancement in the tensile strength may be attributed to the reinforcing effects of MgO NPs within the silicone matrix, fillers increase the mechanical strength of the elastomer by allowing its polymer chains to uncoil, consequently inhibiting rupture of polymer chains, the FTIR test showed that no new bands or significant peak shifts after MgO NPs addition which indicated that no chemical change has occurred therefore the enhancement in tear and tensile strength is more likely associated with physical reinforcement and this agrees with Hussein and Hasan (2021) who studied the effects of adding (1% and 1.5%) concentration of ZrO2 NPs to RTV maxillofacial silicone, they stated an increase in tear and tensile strength at both 1% and 1.5% ZrO2 NPs, their study also mentioned that there was no chemical reaction has occurred between silicone and nanoparticles. (28)

At 3% concentration, both tear and tensile strength declined; this may be due to the higher concentration of MgO Nps may lead to aggregation and coalescence of the nanofillers inside the silicone matrix. These aggregates act as stress concentration points, thereby decreasing the efficacy for transferring the stress and enabling instigation of flaws and propagation under tensile and tearing loads. (38,39) However, the tear strength at 3 % concentration was higher to those of the control specimens, suggesting that MgO NPs continue to provide the reinforcing effect, but became less effective beyond the optimum concentration. For the hardness test, the current study exhibited that the hardness value increased significantly in direct proportion to the concentration.

The hardness of the maxillofacial silicone elastomers increased as MgO Nps loading was raised from 1% to 3%. This result may be attributed to the fact that unreinforced silicone has microscopic structural intermolecular spaces; the MgONPs have the ability to fill these spaces within the polymer, so the compactness and density of the overall silicone will increase; consequently, the consolidated polymers will resist the compression force and thus increase hardness. The increase in the Shore A hardness may be due to the increase in the silicone elastomers' toughness after incorporation of nanoparticles, as the nanoparticles limit chain movement by increasing the crosslink density. (40) or probably as a result of that, the high modulus of nanoparticles influences the elastic modulus of the silicone elastomer; thus, the hardness of the composites rises. (41) An elevated hardness is regarded as a detrimental quality of maxillofacial silicone, since it induces excessive rigidity and compromises the biomimetic fidelity of the prosthesis.

The preferred hardness value of elastomeric maxillofacial silicone is generally between 25 and 35 to provide sufficient durability and, at the same time, mimic the natural skin. (42) The hardness value in the current study is within the normal range. The results of the present study are consistent with the previous study done by Han *et al*. (2008) (43), who showed that incorporating titanium, zinc, and Cerium nano-oxides at 2-2.5 wt.% into A-2186 silicone elastomer enhanced its overall mechanical

properties. However, their findings indicated that increasing concentration to 3% resulted in decreased tear and tensile strength, while hardness value increased with increasing concentration from 0.5% to 3%. It is also consistent with Alsamaraay *et al.* (2021) (44), who investigated the effects of CaCO3-SiO2 nanoparticles at 1%,2%, and 3% on tear strength and hardness; they found that tear strength was best improved at 2% and started to decrease at 3%, while the hardness was directly increased with increasing concentration of CaCO3-SiO2 fillers from 1 to 3%.

This study also agrees with Ahmed and Ali (2021) (45), who found an increase in hardness with increasing concentration of Strontium Titanate (SrTiO3), but within the acceptable range of the material's hardness, and agrees with Bunyan *et al*. (2022). (38), who added 1%, 2%, and 3% of nanosilica and nanoalumina to maxillofacial silicone, they concluded that tear and tensile strength were best increased at 2% and started to decrease at 3%, while hardness increased with increasing concentration.

The results of this study disagree with Khanna *et al.* (2024)(46), who concluded that the addition of 2% ZnO nanoparticles decreased the tear strength value; this discrepancy may be due to differences in the type of silicone used in their study, which is heat-temperature vulcanized silicone, or may be attributed to the difference in nanoparticle distribution, particle surface characteristics, and processing techniques. It 's also disagree with Srinivasan *et al*.(2025*)(*12*)* who found that shore A hardness test exhibited a gradual decline with increasing graphene oxide concentrations, this reduction in hardness is indicative of alterations in the polymer cross-linking density, at lower concentrations graphene oxide restricts silicone chain mobility, contributing to increased rigidity, but at higher concentrations, excessive filler incorporation disrupts the polymer network, leading to reduced cross-linking density and, consequently, lowered hardness values.

This observation aligns with studies on graphene-based silicone composites, where controlled filler concentrations were shown to improve mechanical properties while excessive additions led to network disruption and diminished performance. The FTIR test showed that no new bands formed after the incorporation of MgO NPs,

thereby indicating that there is no chemical propensity to react with RTV silicone. This is because MgONPs are chemically stable ceramic oxides that serve as passive reinforcing agents, physically distributed within the polymer matrix rather than forming covalent bonds with the polymeric chains of the silicone elastomer. (43)

Implications of the study

The incorporation of magnesium oxide nanoparticles as a reinforcing filler may offer a practical approach for enhancing the clinical performance of maxillofacial prostheses. Optimized nanoparticle loading could improve material durability, thereby promoting longer prosthesis life, minimizing the need for frequent repair or refabrication, and enhancing the overall cost-effectiveness of prosthetic rehabilitation. In addition to these findings, it may also guide manufacturers in the development of next -generation maxillofacial silicone material with superior mechanical properties.

Limitation of the study

Regarding the present study limitations, it is important to note that this research was conducted in vitro, meaning it cannot completely simulate the dynamic and harsh conditions of the oral and facial environments, like constant exposure to ultraviolet radiation and human sweat. Moreover, presenting MgO nanoparticles into the silicone matrix imposes practical challenges, mainly concerning even distribution of the filler and avoiding the agglomeration of nanoparticles at certain percentages, which might limit the material performance. One more limitation is that a scanning electron microscope (SEM) was not conducted; consequently, the nanoparticle distribution, the incidence of nanoparticle aggregation, and the morphology of the fractured sample could not be viewed. Future researches incorporated SEM analysis is required to approve the mechanical results.

CONCLUSIONS

Within the limitations of this study:

The FTIR test showed that no chemical interaction has occurred between MgO NPs and silicone, only physical interaction. It is also stated that the addition of MgO Nps to RTV maxillofacial silicone material significantly affects its mechanical

properties in a concentration-dependent manner; both tear and tensile strength were increased at 1% and 2%, with 2% concentration providing the best result. At 3% concentration, both tear and tensile strength were decreased, but tear strength stayed higher than that of the unmodified silicone, demonstrating that the reinforcing effects of MgO NPs were still maintained. In contrast, the hardness value was increased as the concentration of MgO Nps increased from 1% to 3%. The findings of this study supposing that 2% concentration of MgO NPs represents the best concentration for improving the tested mechanical properties of the investigated maxillofacial silicone material, whereas a higher concentration may compromise some reinforcing effects. Further studies are required to estimate the long-term aging behavior of the material, color stability, antimicrobial properties, biocompatibility, and clinical performance of MgO NPs reinforced maxillofacial silicone before its clinical use.

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Authors' Contribution
Al-Taee NW contributed to conceptualization, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, validation, visualization, writing–original draft, writing–review and editing.

Ethical statement:
This research was conducted in compliance with ethical standards and received approval from the Research Ethics Committee and Scientific Committee of the College of Dentistry, University of Mosul. Record reference no. **UoM.Dent.24/1040.**

Conflict of interest
The author declares that there are no conflicts of interest regarding the publication of this manuscript.

Availability of data and materials: All data generated or analyzed during this study are included in this published article and its supplementary information files.

Declaration of Generative AI and AI-assisted technologies
During the preparation of this work, the authors used grammar tools to improve certain statements. The authors reviewed and edited the content as needed and take full responsibility for the content.

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تأثير إضافة جسيمات أكسيد المغنيسيوم النانوية على بعض الخواص الميكانيكية لسيليكون الوجه والفكين المتصلب في درجة حرارة الغرفة

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الملخص

الهدف :هدفت هذه الدراسة إلى تقييم تأثير إضافة تراكيز مختلفة من جسيمات أكسيد المغنيسيوم النانوية (MgO NPs)على بعض الخواص الميكانيكية لسيليكون التعويضات الوجهية والفكية المتصلب في درجة حرارة الغرفة Room Temperature Vulcanized(RTV). **المواد وطرائق العمل** :شملت الدراسة تصنيع (120) نموذجًا من مادة السيليكون، وُزعت بواقع (40) نموذجًا لكل من اختبارات مقاومة التمزق، ومقاومة الشد، والصلادة. وقُسِّمت كل مجموعة إلى أربع مجموعات فرعية تبعًا لتركيز جسيمات أكسيد المغنيسيوم النانوية المضافة (0%، 1%، 2%، و3%)، بحيث ضمت كل مجموعة فرعية عشرة نماذج. خُلِطت مادة السيليكون مع جسيمات أكسيد المغنيسيوم النانوية وفق التراكيز المحددة، ثم أُجريت عملية التصلب وفق البروتوكول القياسي المعتمد. قُيِّمت مقاومة التمزق ومقاومة الشد باستخدام جهاز الاختبار الشامل(Universal Testing Machine) ، في حين قِيسَت صلادة Shore A باستعمال جهاز قياس الصلادة (Durometer) .كما استُخدم مطياف الأشعة تحت الحمراء بتحويل فورييه (Fourier Transform Infrared Spectroscopy, FTIR)للتحقق من سلامة التركيب الكيميائي والكشف عن أي تفاعلات جزيئية محتملة بين مادة السيليكون وجسيمات أكسيد المغنيسيوم النانوية.**النتائج** :أظهر تحليل التباين الأحادي (One-way ANOVA) أن إضافة جسيمات أكسيد المغنيسيوم النانوية أحدثت تأثيرًا معنويًا في الخواص الميكانيكية لسيليكون التعويضات الوجهية والفكية .($P\leq0.05$) وسجلت كل من مقاومة التمزق ومقاومة الشد أعلى قيمها عند تركيز 2%، تلتها مجموعة 1%، ثم انخفضت القيم عند تركيز 3%. وبينت اختبارات المقارنات البعدية الزوجية (Post-hoc pairwise comparisons) عدم وجود فروق ذات دلالة إحصائية بين مجموعتي 1% و3% في مقاومة التمزق، وكذلك بين مجموعة السيطرة ومجموعة 3% في مقاومة الشد. وفي المقابل، أظهرت صلادة Shore A زيادة تدريجية متناسبة مع ارتفاع تركيز جسيمات أكسيد المغنيسيوم النانوية من 1% إلى 3%، مع وجود فروق ذات دلالة إحصائية بين جميع المجموعات. كما أظهرت نتائج تحليل FTIR تطابقًا في مواقع وشدات القمم الطيفية بين مجموعة السيطرة والمجموعات التجريبية، مما يشير إلى عدم حدوث أي تغيرات في التركيب الكيميائي أو تفاعلات جزيئية بين السيليكون والجسيمات النانوية. **الاستنتاجات** :أسهمت إضافة جسيمات أكسيد المغنيسيوم النانوية في تحسين الخواص الميكانيكية المدروسة لسيليكون التعويضات الوجهية والفكية المتصلب في درجة حرارة الغرفة، وكان تركيز 2% هو التركيز الأمثل لتحقيق أعلى قيم لمقاومة التمزق ومقاومة الشد. أما زيادة التركيز إلى 3% فقد أدت إلى تعزيز صلادة المادة، إلا أنها اقترنت بانخفاض في خواصها الميكانيكية المرتبطة بالمتانة، مما يشير إلى أن الإفراط في إضافة الجسيمات النانوية قد يحد من كفاءة التعزيز الميكانيكي للمادة.

الكلمات المفتاحية: سيليكون الوجه والفكين، جزيئات أكسيد المغنيسيوم النانوية، قوة التمزق، قوة الشد، صلابة شور أ