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Studying Water Absorption, Solubility, and UV Absorption of Room Temperature Vulcanized Maxillofacial Silicone after the Addition of Strontium Titanate Nano-Powder

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Abstract

Objective: The study's primary goal is to assess how adding strontium titanate ($SrTiO3$) nanoparticles to VST-50 room temperature-vulcanized silicone elastomer affects water absorption, solubility and UV light absorption.

Materials and Method: Two weight percentages (1% and 1.5% $SrTiO3$) were chosen and incorporated into the VST-50 silicone. Sixty specimens were collected and split in half. There were 30 samples tested for water and solvent solubility and 30 samples tested for UV light penetration. Applying a one-way ANOVA and post hoc $p < 0.05$. Scanning electron microscope and Fourier transform infra-red were also used in the study.

Results: There was an increase in the solubility and amount of water absorbed by the experimental groups (1% and 1.5%). Also, the UV light absorption was significantly increased for the experimental groups.

Conclusion: $SrTiO3$ nanoparticle's addition into the VST-50 silicone increased water absorption, solubility, and UV light absorption.

Keywords: Strontium titanate, Maxillofacial silicone (VST-50), Water absorption, Solubility, UV absorption.

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Introduction

Patients might be affected by facial defects and deformities because of traumatic accidents, congenital diseases, or tumor surgeries. A maxillofacial prosthesis is used to treat such patients with craniofacial and combined intra/extra oral abnormalities [1]. The number of patients needing facial prostheses has increased in recent years, owing to an aging population and rising survival rates among patients with cancers in the craniofacial regions [2]. Different materials can be used in the field of maxillofacial restorations such as chlorinated polyethylene, polymethylmethacrylate, acrylic, polyurethanes, polyvinyl chlorides and silicone elastomers. In recent years, silicone has emerged as the material of choice for maxillofacial prosthetics. The primary reasons for this are its low maintenance requirements, high strength, and extended lifespan., chemical inertness and comfortable to the patient [3].

In clinical use, silicone's physical and mechanical characteristics deteriorate, resulting in textural changes, poorly fitting edges, and color changes [4]. These changes are related to the patient's care and maintenance of the prosthesis' cleanliness and exposure to UV radiation, air pollution, and temperature changes [5,6]. Since the silicone elastomer comes into touch with the wound surface and mucosa, germs from a patient's saliva and blood tend to infect elastomers. So that the washing and cleaning of the silicone prosthetic device is important [7].

In terms of how long a maxillofacial prosthesis will last and how well it will function, there are several aspects to consider. Many researchers have proposed what they believe are the most important aspects over the years-chemical stability, dimensional stability, and little to almost no absorption of water, to name just a few [8]. Elasticity and elongation have also been brought up as important factors in discussions about dimensional stability. On the other hand, the prosthesis may need to be replaced if the material absorbs so much water that it distorts or dissolves. be rendered useless [8]. Water absorption has been demonstrated to influence the look of various silicone compounds in previous research [9]. Water absorption tests would be very helpful in determining the source of the change in appearance. They may be water-soluble if they can take it on.

Since nanotechnology is becoming a key component of dentistry nanomaterials are more efficient than conventional materials. The development of modified nanoparticles would aid in the elimination of many of the flaws in dental materials [10] Over the last several years, research has concentrated on developing a new and better material by fusing nanofillers with silicone material that uses both the rigidity of the polymer matrix and the pliability of the nano-oxides (12). This study used the chemical formula SrTiO3 for strontium titanate oxide.

Hulterström et al. investigated water sorption and solubility of seven silicones and concluded that condensation-type polymers can have significant changes in volume as they exposed to fluids [11]. Salih et al. used a blend consisting of silicone rubber and PMMA as the matrix to which they added several natural and synthetic fibers and nanoparticles (TiO2, Sewak fibers and UHMWPE fibers) [12]. The results showed an increase in water absorption. Water absorption and solubility of MDX10 silicone were also investigated after the addition of pigments and opacifiers. The results showed a non-significant increase in both properties after artificial aging [13].

Material and Methods

Materials

VST-50 is a combination of strontium titanate nano-powder with an average particle size of 80-100 nm and RTV silicone (Factor II Inc., USA) is a vulcanized silicone that may be used at room temperature (Nanoshel, USA). These two materials were utilized in this work. Two weight percentages of Strontium titanate were utilized in the study (1% and 1.5%).

Specimens fabrication

Sixty samples were produced and randomly assigned to one of three groups (group A: control; group B: 1%; and group C: 1.5%). Twenty samples were used for each group, with each sample being tested for solubility and water absorption in water. We tested ten samples for UV absorbance.

Mold fabrication

Acrylic sheets 3 ±0.2 mm (for water absorption and solubility) and 2mm (for UV absorption) in thickness were cut by a laser engraving machine (JL-1612, Jinan Link Manufacture and Trading Co., Ltd., China). The cutting was done by the predetermined standards of the AutoCAD (Computer Aided Design) program. Bolts and nuts hold the mold's three components—the base, the matrix, and the cover—together. In addition, G-clamps utilized around the edges to tighten things up even further.

Mixing

According to VST-50 silicone is blended per VST-50 silicone manufacturer's recommendations. a 10:1 ratio (ten parts base to one part catalyst). To avoid air entrapment, a vacuum mixer was utilized to mix the silicone. The VST-50 silicone base and catalyst were weighed to an accuracy of 0.0000 on an electronic scale

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before being combined in a vacuum mixer at a speed of 360 rpm and a pressure of 10 bar for 5 minutes.

For 1% and 1.5% specimens, the appropriate SrTiO3 concentration is measured on a digital balance and then the base part is added. In the vacuum mixer, the SrTiO3 and the base were mixed for three minutes, without air evacuation to prevent the suction of nanoparticles. After that, While the room is being sucked dry of air, the nano-powder and the base are combined for 7 minutes. The catalyst was introduced after the liquid had cooled for 5 minutes. was subjected to a 5-minute vacuum mixing [14].

Preparation and Storage of Specimens

The silicone mixture was applied gently and slowly metal spatula until all matrix specimen regions were filled; specimens were somewhat overloaded to prevent deficiency. After placing the matrix section on top of the cover, we applied moderate, continuous hand pressure to the cover's center until the bolts and nuts were tightened at the corners and the cover was secured in place. secured around the mold boundaries with the G-clamps. The pressure force of bolts and G clamps should eliminate the air bubbles and excess silicone material after mold is closed. Specimens with included bubbles were excluded.

After 24 hours at room temperature (23°C ⍰ 2°) the molds were removed gently, and the specimens were placed in a storage box (the same one used for the vaccination). The specimens were stored for 16 hours at 20-25°C, 50 10 humidity, and in the storage box [15].

Testing Procedures

Water Absorption

Specimens for Water absorption test were made according to ASTM 570: 2018 [16]. The specimen dimensions are 50.8mm in diameter and 3.2mm in thickness as shown in Figure 1 and Image 1. The specimen is first conditioned in a drying oven for 24 hours at 50 ±3 °C, cooled inside a desiccator and then weighed immediately on 0.0001 g balance (Image 2A, B, C).

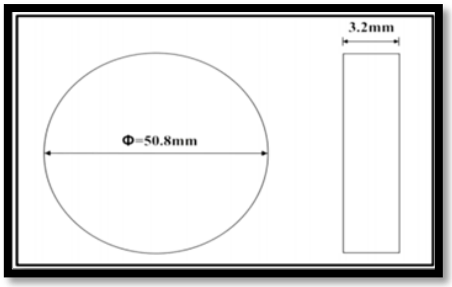

Figure 1. Specimen dimensions for water absorption and solubility test.

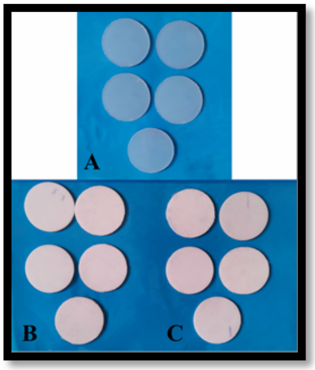

Image 1. Specimens for water absorption and solubility tests.

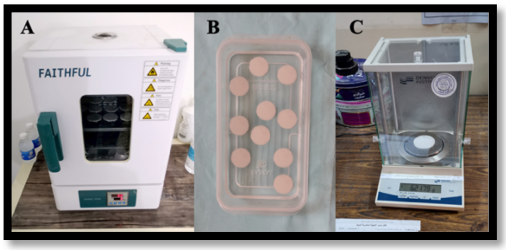

Image 2. A, Drying inside oven. B, Specimens placed inside distilled water. C, weighing on a four-digit electronic balance.

A long-term immersion procedure was used to measure the water absorption of the specimens. The conditioned specimen is placed in distilled water maintained at 23 ±1 °C and should be immersed entirely for 24 hours (Image 2B). At the end of 24 hrs. The specimen is taken from the distilled water and wiped from surface water with clean and dry cloth, weighed on 0.0001g balance and replaced immediately inside distilled water. These weightings are repeated at the end of 7 days and every 2 weeks until the specimen is considered saturated when no more change in weight is achieved. This is to measure the increase in weight.

The increase in weight is calculated using the following formula:

Increased in weight, %=(wet weight-conditioned weight)/(conditioned weight)*100

For the solubility test the specimens, after immersion in

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distilled water, were weighed again, and then reconditioned for another drying session at the same temperature and duration as the first. The samples were weighed again after being chilled in a desiccator. Water solubility was determined by doing an immersion test and subtracting the reconditioned weight from the conditioned weight. Solubility is calculated using the following formula:

Solubility = (conditioned weight-reconditioned weight)/(conditioned weight)*100

According to ASTM 570: 2018, the water-absorption value for such materials shall be taken as the sum of the increase in weight on immersion and the weight of the water-soluble matter.

UV absorption

The specimen's absorption of UV light was measured using a UV Vis spectrophotometer. A disk-shaped specimen with 2mm in thickness and 20mm in diameter was fabricated [17] as shown in Image 3. The device measured the amount of UV light absorption as a function of wavelength.

The disk-shaped specimens were located over the light source and exposed to light, then the readings of the absorbed light were captured from the computer's screen attached to the spectrophotometer, as shown in images 4A, B, C, D.

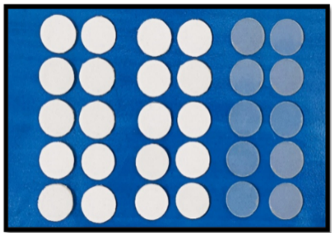

Image 3. Specimens to be tested inside spectrophotometer.

Image 4. (A) UV spectrophotometer setup; (B) Specimen placement inside the device; (C) Closer look at the specimen inside the device; D, UV probe software.

1.

SEM

The dispersion of SrTiO3 nanoparticles inside the VST-50 silicone matrix was analyzed using a scanning electron microscope[2.] (TESCAN MIRA3, France).

FTIR

FTIR device (SHIMADZU, Japan) was used to distinguish any[3.] chemical reaction among the silicone material and nanosized SrTiO3 nanoparticles.

The statistical analysis: Done using Tukey's HSD for post hoc testing after a one-way ANOVA.

Results

SEM

The results obtained for the control group revealed the lack of nanoparticles, while the 1% SrTiO3 group exhibited a random distribution with little aggregation of SrTiO3 nanoparticles. However, nanoparticles cause the 1.5% SrTiO3 cluster within the silicone matrix to grow into bigger aggregates as shown in Images 5A, B, and C.

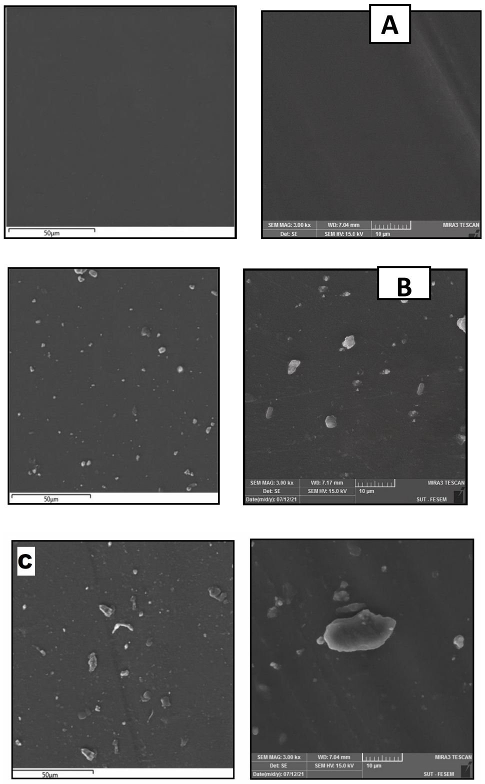

Image 5. SEM Picture of (A) VST-50 silicone, (B) control specimen at 10 m magnification. B, a sample of 1% SrTiO3 and, (C) SrTiO3 sample with 1.5% purity.

FTIR

The absence of new peaks in the silicone elastomers microstructure, suggesting that nanoparticle addition did not cause chemical changes as showed in Figure 2A, B.

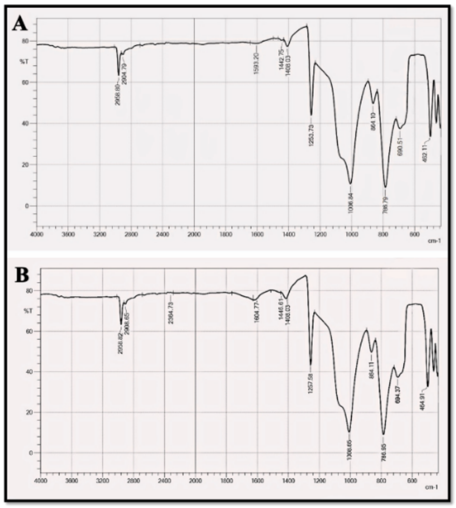

Figure 2. A, FTIR analysis of the standard sample. B, FTIR analysis of the sample after 1% SrTiO3 nanoparticles were added.

Water Absorption

The tested group (C) showed the highest mean value (0.2656) followed by (B) group with a (0.2470) mean value while the lowest mean value was for the group (A) with (0.1229) as shown in Table 1.

Table 1. Descriptive statistics, one-way ANOVA and Tukey's HSD of water absorption test.

Water absorption					ANOVA		Tukey HSD	
Group	Min	Max	Mean	±SD	F	P-value	Groups	P-value
Control(A)	0.0917	0.1772	0.1229	0.0248	120.676	0.000	A B	0.000
1 % (B)	0.2027	0.2831	0.2470	0.0247			A C	0.000
1.5 % (C)	0.2432	0.2912	0.2656	0.0162			B C	0.171
Levene's statistics=0.751, p-value=0.482								

To compare the mean values among all study groups, post-hoc Tukey's test was conducted. A highly significant difference was found between group (A) and groups (B and C) while a non-significant mean difference was found between group (B) and group (C).

Solubility

Group C had the highest average (0.0303), group B had the second highest average (0.0288), and Group A had the lowest average (0.0217) as shown in Table 2.

Table 2. Descriptive statistics, one way ANOVA and Tukey's HSD of solubility test.

Solubility					AVOVA		Tukey HSD	
Group	Min	Max	Mean	±SD	F	P-value	Groups	P-value
Control(A)	0.0129	0.0354	0.0217	0.00675	6.829	0.004	A B	0.000
1 % (B)	0.0209	0.0386	0.0288	0.00600			A C	0.000
1.5 % (C)	0.0255	0.0356	0.0303	0.00338			B C	0.014
Levene's statistics=1.590, p-value=0.222								

Group (A) was significantly different from Group (B), while Group (A) was significantly different from Group (C). The difference in mean scores between groups B and C was not statistically significant. between group (B) and group (C). was not statistically significant.

UV Absorption

The experimental group (1.5%) showed the highest UV absorption (3.1796) followed by group (1%) with (3.14913), followed by the control group with (1.06509) as shown in Table 3. There was a significant difference between the control group and groups (1% and 1.5% $SrTiO_3$). Also, a significant difference between group (1%) and group (1.5%) was shown by Tukey's HSD post-hoc test.

Table 3. Descriptive statistics, one-way ANOVA and Tukey's HSD of UV absorption.

UV absorption					ANOVA		Tuckey HSD	
Group	Min	Max	Mean	±SD	F	P-value	Groups	P-value
Control(A)	16.98	19.21	1.06509	0.01865	91174.274	0.000	A B	0.000
1 % (B)	23.56	26.64	3.14913	0.00622			A C	0.000
1.5 % (C)	21.23	24.27	3.17960	0.00983			B C	0.000
Levene's statistics =1.6440, p-value=0.212								

Discussion

None of the commercially available silicones may provide the desirable properties (19). Thus, efforts are always being made to better silicone materials by refinement of their formulation or the addition of fillers. [18].

Since maxillofacial prosthetic material is cleaned by the patient with saliva, water, or other liquids, water absorption is an essential physical feature. The look, mechanical strength, and dimensions of a material may all be affected by the amount of liquid it absorbs [16].

The literature [21] suggests that prolonged storage of silicone materials that allow water absorption due to both the load component in their composition and a low degree of adhesion among the silicone polymers may account for the higher water absorption rates observed for (1% and 1.5%) SrTiO3 specimens compared to control specimens. Furthermore, this might owing to the fact that nano particles are dry, causing the silicone to absorb more water [19]. This is likely related to the type of filler and the degree to which the filler is attached to the silicone rubber. This agreed with Braden and Wright who stated that the nature of filler may influence the rubber's water absorption [20].

Dos Santos et al. in 2012 [13] discovered that MDX4-4210 face silicone absorbed and dissolved more water after 502 hours of storage than it did after 252 hours of storage. It was also mentioned that the little improvements in water solubility and water absorption readings seen after 502 hours could not indicate a clinical issue. Since silicone rubbers are closed-cell materials and naturally hydrophobic, this low water absorption rate makes sense. The fact that VST-50 silicone is just another kind of silicone, and not a condensation silicone. The addition silicone curing occurs without byproduct formation. Condensation silicone cures with byproducts that later exit from the structure of the polymer leading to more porous structure than the additional silicone [11]. This agreed with Canay et. al. and Parker et. al. who found that the silicone–type materials absorbed less water than plasticized acrylics because of their highly hydrophobic nature [21,22]. In addition, the high number of cross-linking agents in the silicone can minimize absorption owing to a strong association between the load and the elastomeric material molecules decreasing the space among the polymer chains where water could penetrate [23,24].

For solubility, the results showed significant increase in the amount of soluble matter lost. This increase in solubility could be related to the release of formaldehyde over time, a peculiar characteristic of elastomeric materials polymerized at room temperature. The loss of alcohol generated as a reaction by-product and extraction of the metallic salt catalyst, which is left unchanged in the reaction, are thought to be responsible for the water solubility of silicones cross-linked at room temperatures [20]. It should be emphasized that silicone-based materials generally exhibit much lower sorption and solubility than acrylic-based lining materials because they do not contain components such as plasticizers that are rinsed out by water and consequently allow absorption and solubility [25].

The UV absorption test results revealed a highly significant increase in the amount of UV light absorbed by the reinforced specimens (1 % and 1.5% SrTiO3) when compared to the control groups. Currently, titanium oxide and zinc oxide nanoparticles are used widely in sunscreen applications because they are more effective than microparticles [26]. The UV light absorbing ability of SrTiO3 can be related to the wide band gap of the material which is 3.25 eV (in the typical range of semiconductors) [27]. Wide band gap materials are known for their ability to absorb light because their electrons need to absorb more photon energy to transfer from the valance band (h) to the conduction band (e). It has shown that SrTiO3 had a peak at 354 nm wavelength with the absorbance of 0.86, which means that it exhibits good absorbance at the UV region [28].

Conclusion

The addition of 1% and 1.5% of SrTiO3 nanoparticles into VST-50 increases water absorption, solubility, and UV absorption.

Conflicts of interest

The authors declare no competing interest.

Source of funding

Completely self-funded.

Ethical clearance

None.

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