JODR
Volume 9, Issue 1, 2022

Aging Effect on the Surface Roughness and Color Stability of VST-06 Maxillofacial Silicone

[1]Nebras Fadhil Alwan, BSc, [2]Mohammed Abdul Hussein Hamid, MSc, and [3]Saja Ali Muhsin MSc, PhD
[1, 2, 3] Department of Prosthetic Dental Technology, College of Health and Medical Technology, Middle Technical University, Iraq.
Corresponding author: Saja Ali Muhsin
E-mail: dr.sajaali79@gmail.com

Received September 22, 2021.
Accepted for publication on October 18, 2021.
Published February 22, 2022.

Abstract
Background Silicone elastomer is used commonly for the construction of maxillofacial prostheses. However, it is possessing inferior physical and mechanical properties alongside clinical longevity of the prostheses; rough silicone material may lead to several problems like bacterial accumulation, tissue irritation to the surrounding soft tissue, and even lead to some micro-sites propagation into mechanical failure, color deterioration of the maxillofacial prostheses is the most common cause of its reconstruction. **Objectives** This study aim to investigate the role of the accelerated weathering on the surface roughness and color wave change of the VST-06 silicone elastomer.**Materials and Methods** 10 silicone specimens were prepared at room temperature vulcanization (RTV) VST-06. They were tested before being subjected to an accelerated artificial weathering period (at the baseline), then after being exposed to 46, 146 and 317h of artificial weathering. The surface roughness was measured using TR-200 and the color change measured using the color-ometer device. Statistical One-Way ANOVA test used to analyze the results, the significant confidence was set to $p \leq 0.05$. **Results** ANOVA showed that the values of surface roughness were different among the tested periods ($p \leq 0,05$). The lowest surface roughness value is represented after 317h accelerated weathering of 0.10µm, while the highest value was at the initial baseline 3.95µm. As well as the (red, green, and Blue) wave color values were decreased overtime of accelerated weathering with the lowest value that represented after 146h of accelerated weathering. **Conclusion** Within this study limitation, it was concluded that the lowest surface roughness was noticed as the aging period increased, and the color deterioration was initiated after 46h of accelerated weathering, but it increased directly in proportional to accelerated aging.

Keywords: Aging; color; weathering; silicone; surface roughness.

Introduction

Many synthetic materials have been introduced with various advantages and drawbacks for the reconstruction of maxillofacial defects. Silicone elastomer is considered the best choice among them for making maxillofacial prostheses, this may be related to biocompatibility, durability, chemical inertness, and being easily manipulated and colored especially when need to replace movable tissues, (Mahajan and Gupta, 2012; Salih et al, 2018). The extraoral prosthesis may be affected by different weather factors such as sunlight, moisture, and the air polluted with dust irradiation to to other variables that may damage the prosthesis materials include chewing tobacco, smoking, and household cleaning

ISSN 6417-2310

agents, (Güngör et al, 2021). Artificial accelerated weathering is a practical way to assess the durable effect of outdoor weathering conditions, by using intensive elements of the weathering condition, such as heat, UV, moisture, and water spray, (Rosa et al, 2005; M Shihab and M Abdul-Ameer, 2018; Babu et al, 2018; Rahman et al, 2021). Other reasons may affect the silicone prosthesis may include pigments› fibers which inherent ability to degrade over time, (Goiato et al, 2009; Goiato et al, 2010; Shakir and Abdul-Ameer, 2018;Jebur et al, 2018). Environmental elements such as processing temperature, molding-stone color, adsorption and absorption, adhesive use, even exposure to cosmetic additives and human secretions, as well as the influence of cleaning methods, are all aspects to consider, (Mohan et al, 2021). The fine irregularities on the surface texture of any materials refer to material roughness. The average for surface roughness (Ra) is the deviation of the surface valleys in microinches or micrometers, the rough surface denotes great deviations while the minor deviation denotes less surface roughness, (Ali, 2017; Darvell, 2018; Al-Mohammad and Abdul-Ameer, 2019; Mousa, 2020). The color change is mainly attributed to both intrinsic and extrinsic aging factors that lead to fading of silicones color. The intrinsic physiochemical environments such as humidity and thermal instabilities may cause a change in the materials› matrix that leads to discoloration. Added to the silicone surface absorb and adsorb of various substances which considered extrinsic factors. Also, the color instability may result from other factors such as extrinsic stains accumulation, continuous formation of pigments due to degradation, material degradation from use; water absorption, dehydration, infiltration, superficial roughness, and oxidation, (Farage and 2008; Mancuso et al, 2009; Haddad et al, 2011; Wang and Line Ahm Mielby; 2019). The silicone elastomers were transparent to UV radiation and moisture added to absorb many gases, this fact may be cause degradation to its intrinsic colors, (Kantola, 2014).

Materials and Methods

10 specimens were prepared from VST-06 (RTV) Platinum silicone elastomer (Factor II Inc, Lakeside, USA). The Specimens were prepared with a dimension of 25×25×6mm, according to the ISO specifications (23529, 2010) and ASTM (D624, 2012), (ISO-23529, 2010, ASTM-D624-00, 2012).

Materials ratio preparation

The final silicone platinum RTV mixing ratio was according to the manufacturer›s recommendations (VST-06) was 10:1; for the base 60g and the catalyst 6g. According to the pilot study, the total used quantity of rayon flocking was 0.9g using a digital electronic balance (0.000digits, China) as in Table (1).

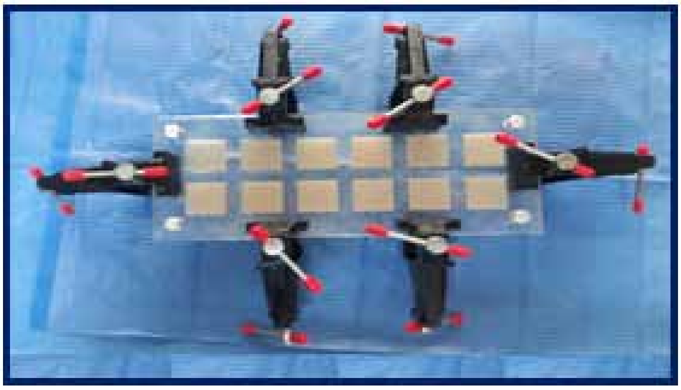

Figure (1): Study specimens at the setting period using G-jig clamp.

Figure (2): Weather-Ometer device.

JODR
Volume 9, Issue 1, 2022

Table (1): Showing the study material ratio by weight.

Material	Weight
Rayon (Tan, Flesh, Yellow)	0.9g (±0.001)
Silicone Base	51.1 (g±0.001)
Silicone Catalyst	6g (±0.001)

Table (2): ANOVA-test (LSD) showing the surface roughness of different weathering intervals.

Study Groups (Red Wave Change)	Weathering	Mean Difference	*p*-value	Sig.
Base-line	After 46h	1.30000	0.603	NS
	After 146h	5.90000	0.070	NS
	After 317h	-11.10000	0.000	S
After 46h weathering	After 146h	4.60000	0.020	S
	After 317h	-12.40000	0.000	S
After 146h weathering	After 317h	-17.00000	0.000	S

Figure (3): Surface roughness tester device (TR-200).

Figure (4): Color-Ometer device.

Table (3): ANOVA-test (LSD) showing the red wave color change of different weathering intervals.

Study groups	Weathering	Mean Difference	*p*-value	Sig.
Base-line	After 46h	-0.81620	0.000	S
	After 146h	-1.18680	0.000	S
	After 317h	-1.75530	0.000	S
After 46h weathering	After 146h	-0.37060	0.037	S
	After 317h	-0.93910	0.000	S
After 146h weathering	After 317h	-0.56850	0.002	S

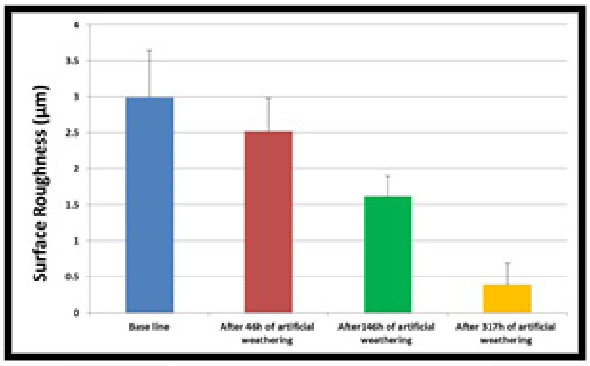

Figure (5): Bar-chart showing the mean distribution of the surface roughness of the tested groups.

ISSN 6417-2310

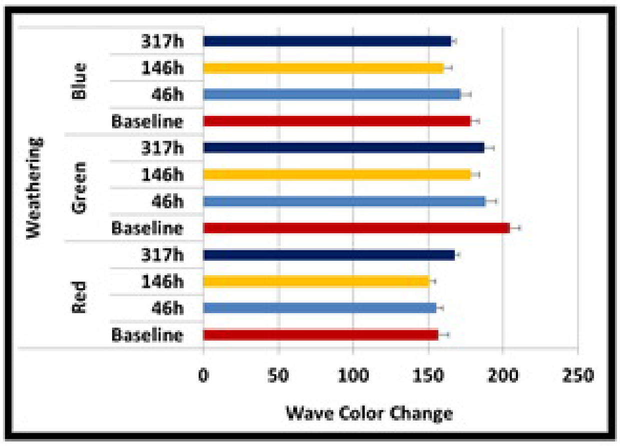

Figure (6): Bar-chart showing the mean distribution of the red, green, and blue wave color of tested groups.

Table (4): ANOVA-test (LSD) showing the green wave color change of different weathering intervals.

Study Groups (Green Wave Change)	Weathering	Mean Difference	*p*-value	Sig.
Base-line	After 46h	15.70000	0.001	S
	After 146h	26.000	0.000	S
	After 317h	16.80000	0.001	S
After 46h weathering	After 146h	10.30000	0.008	S
	After 317h	1.10000	0.746	NS
After 146h weathering	After 317h	-9.20000	0.018	S

Table (5): ANOVA-test (LSD) showing the blue wave color change of different weathering intervals.

Study Groups (Blue Wave Change)	Weathering	Mean Difference	*p*-value	Sig.
Base-line	After 46h	7.000	0.022	S
	After 146h	18.000	0.000	S
	After 317h	13.00000	0.000	S
After 46h weathering	After 146h	11.000	0.000	S
	After 317h	6.00000	0.045	S
After 146h weathering	After 317h	-5.00000	0.033	S

Specimens preparation

The pre-weighed rayon flocking was placed in the mixing container of the vacuum mixer device, then the base of silicon elastomers was added to it gradually to avoid dispersion of fibers, (Jebur et al, 2018). Firstly it mixed manually for 1min (±1sec) with a clean spatula followed by mechanical mixing at a speed of 360rpm for 2min (±1sec) without vacuum to prevent fibers suction. Second, the colored mixture was left to stand for 2min because the mixer›s rotation generated heat and that reducing the material›s working time, (Jebur et al, 2018; Abdullah and Abdul-Ameer, 2018). Then, the pre-weighed catalyst was added to the mixture of rayon fiber and the silicone base. When the catalyst is added the mixture should be mixed all over the directions, (Tukmachi and Moudhaffer, 2017; Jassim et al, 2019). The final silicone mixes should be made at a relative humidity (RH) of 50(±10)% and the temperature should be controlled at 23(±2)°C, (Shakir and Abdul-Ameer, 2018). The homogeneous mixture of (free air bubbles) poured gently into the customized acrylic mold using a dental vibrator to avoid air entrapment within the material. A fine needle may be used also to expose any air bubbles that formed on the material surface before covering the material and mold matrix, (Al-Harbi et al, 2015). The cover was gently lowered onto the matrix to allow any excess material or trapped air to escape the mold. A constant load of 1kg was applied over the mold cover center and tightened, using 6 nuts and 6 G-clamps. According to the manufacturer›s, the specimens were secured firmly until the specimens hardened for about 16h, Figure (2), (Abdullah and Abdul-Ameer, 2018; Shakir and Abdul-Ameer, 2018).

Finishing and storage specimens

After the complete vulcanization period, the specimens were kept at a constant laboratory temperature of 23(±2)°C for at least 3 hours before flashes removal, (Shakir and Abdul-Ameer, 2018; Abdullah and Abdul-Ameer, 2018). Specimens were kept away from light exposure through the period of vulcanization in a bag of tight sealing and care must be taken to avoid lay the specimens one over another, The specimens were preserved in a modified box of light proofing united with a digital thermometer and hygrometer device used to show the inside and outside temperature and humidity of the box. The box chamber was an air-conditioned room with RH of 50(±10)% and controlled temperature at 23(±2)°C, to remove any undesirable change that occurs in temperature and/or humidity, (Al-Dharrab et al, 2013; Alsmael and Ali, 2018; Abdullah and Abdul-Ameer, 2018). With a scalpel and a sharp surgical blade no.11, all flashes on the specimens were eliminated, (Jebur et al, 2018). The specimens were inspected visually for intact borders, free of air bubbles, and irregularities at the surface and inside of the specimens. The specimens were kept in a standard condition for 24h before the testing procedure, (Abdullah and Abdul-Ameer, 2018).

Artificial weathering

The weather-ometer device (QUV) raises the same outdoor weathering state but at a faster rate, Figure (2). As a result, many hours spent in the device chamber are similar to many days spent weathering outdoors. According to ASTM G154 weathering cycle standardization was used in this study. Each outdoor weathering cycle was equivalent to 12h in the chamber. Irradiance at (340nm) of (1.55 W/m2) and a temperature of 60(±3C) were used for the first 8 hours (light cycle). The subsequent 4 hours represented the dark cycle, which contained 1.55 W/m2 of irradiance at (340 nm), 15 minutes of a water spray system to cause thermal shock, and lastly the condensation period at 50(±3°C) temperature. The timing of the Weather-ometer differs from citation to another, a device to another, and even within the same device. This may depend on many factors related to the weather conditions, site of the study, age of the lamplight, presence or the absence of filters inside the Weather-ometer. Based on the conditions of Baghdad›s capital city, every 100 hours inside the Weather-ometer chamber are equivalent to 3 months of external weathering or clinical use of the prosthesis, (Ali, 2017; Cifter et al, 2019). According to the present study information, the weathering intervals 46h, 146h, and 317h inside the Weather-ometer chamber are equivalent to 6, 20 and 43 weeks, about 1.5, 5 and 10 months, 43, 138 and 299 days of outdoor weathering or clinical use of the prosthesis.

Testing procedures

The testing specimens after 24h weathering treatment were finished and kept in a standard condition (Al-Harbi et al, 2015; Abdullah and Abdul-Ameer, 2018). These initial readings compared to that obtained after subjecting the same group to accelerated weathering periods 46h, 146h, and 317h. Surface Roughness Optical Tester (TR-200) device with (0.001µm) accuracy, Figure (3) used for the initial and after weathering measurements procedure. The sensor moved linearly along the measured length when the specimen was put on a flat solid surface. The moves in accordance with the surface profile. These movements are converted into electric signals which are amplified, filtered, and converted into digital signals by an A/D converter, (Goiato et al, 2009; Guiotti et al, 2016). The primary processor refines these signals into Ra values, which are subsequently displayed on the screen. This device drawing the irregularities on the sample surface by a surface analyzing probe and the 3 readings were recorded for each specimen in (µm), then the average value of the reading is considered as a roughness result, (Jebur et al, 2018; Shen et al, 2021; Rahman et al, 2021). The color-ometer device was used in this study as shown in figure (4), (TCS230, China). The set up of the color ometer according to the Arduino microcontroller system. The sensor in the device consists of four LED lights at the corners of the PCP and the red-green-blue (RGB) color sensor located at the center, (Al Mamun et al, 2017).The current study›s findings were examined and evaluated with the use of the statistical package (SPSS) version (18), One-Way ANOVA test (LSD) post hoc test at a significant p-value ($p \leq 0.05$).

Results

A statistically significant decrease in the surface roughness of the VST-06 RTV silicone material was observed among study groups (P≤0.05), as demonstrated in table (2) and figure (5). The group subjected to 317 hours of accelerated weathering has the lowest mean value of surface roughness (0.10μm), while the baseline non-weathered specimens had the greatest mean value (3.95μm). And as regards the three colors red, green, and blue waves as in tables (3 to 5), and figure (6) show the results of the wave color change for the VST-06 RTV silicone elastomers. After comparing the results, generality significant differences were presented between the groups, (p≤0.05). However, non-significant differences were noticed between the non-weathered group and after being subjected to 46h and 146h of artificial weathering, (p>0.05). The lowest mean value is represented after 146h artificial weathering at 146, 172, and 155 for red, green, and blue waves respectively. While the highest mean value was (172) for red wave after 317h artificial weathering, (212), and (168) for green and blue waves at the baseline.

Discussion

Both heat temperature vulcanization (HTV) and room temperature vulcanization (RTV) types of maxillofacial prosthetic materials seem to undergo degradation due to changes in the material›s mechanical and physical properties including surface Topography, (Jebur et al, 2018; Cifter et al, 2019; Mousa, 2020). The mechanical properties of silicone elastomers are affected by several factors such as the cross-link density, filler incorporation, and polymer chain molecular weights, (Shakir and Abdul-Ameer, 2018). VST-06 is a platinum-catalyzed vinyl terminated type of RTV maxillofacial silicone introduced by Factor II Inc. This study material was selected as it has common applications for good mechanical properties and with minimum bubbles forming during specimens fabrication with an adequate working and setting time make, (Jassim et al, 2019). Generally, the maxillofacial elastomer element cannot resist high thermal change and less withstand to sunlight and irradiation, (Rosa et al, 2005). Less surface roughness could help to sustain the mechanical qualities of any maxillofacial material, as rough material contains finer surface flaws that can lead to cracks, bacterial contamination, and corrosion. (Al-Dharrab et al, 2013; Mousa, 2020). As in Figure (5) and table (2) the increased surface smoothness values over time of artificially accelerated weathering were noticed, these results could be agreed with the outcomes of Atta-Allah and Ali 2017, Mousa 2020, (Ali, 2017; Mousa, 2020). and may disagree with that of Al-Mohammad and Abdul-Ameer, 2019, (Al-Mohammad and Abdul-Ameer, 2019). The decrease in the surface roughness may be related to continual polymerization impact that stimulates extra arrangement and augmentation of polymer chain resulting in finer and smoother silicone surface overtime, (Goiato et al, 2009; Guiotti et al, 2016; Ali, 2017; Darvell, 2018; Mousa, 2020; Shen et al, 2021). Moreover, surface smoothness was might be attributed to the fact that the aging progression was achieved in a weather-ometer chamber, but not in actual clinical use when the absence of mechanical irritations or wearing influence the prosthesis. Furthermore, the water spray effect through the artificial aging cycle may increase the smoothness by water adsorption to the polymer surface resulting in surface swelling by stretching the resin matrix, (Darvell, 2018). In performing the smoothness property of VST-06 a prediction in reducing plaque accumulation upon use when the material replaces facial cavity defects. The results were analyzed using the color-ometer device in this study to show the effect of 46, 146, and 317h of artificial weathering on the color stability of VST-06 silicone material. As presented in tables (3 to 5), and figure (6), a negligible increase in a red wave color with considered increase after 317h. While a significant decrease in a green wave color conversely with the increase of weathering, excepted after 146h that showed least mean value. Also, the blue wave color was decreased conversely with the increase of aging hours. These unacceptable color changes results may be supported by Al-Harbi et al, (2015) as they attributed the color change to the postpolymerization cross-linking which is caused by energy from light irradiation, producing modifications in the polymer network structure. This could be like the polymer chains number, the bonding between these chains, or their angular arrangement in space. The probability is followed by changes in the amount of light diffusion through the material along with degradation of the polymer color shade, (Al-Harbi et al, 2015). The elastomer›s color was changed as an effect of UV radiation which resulting in reduce the polymerization process, breaking down of bonds of the polymer chain, improving cross-linking, elastomer decomposition. Also, the accelerated interface of fatty acids with silicone, (Haug et al, 1999; Hatamleh et al, 2010; Li et al, 2017). The causal environmental factors like solar radiation, moisture, routine cleaning, airborne pollutants, and temperature, UV radiation was stated to have the greatest influence on the degradation of facial prostheses color, (Han et al, 2010; Hatamleh et al, 2010; Al-Harbi et al, 2015; Bishal et al, 2019). The deterioration is primarily caused by a photo-oxidative occurrence for most polymeric materials which may be described as the oxygen action and combined with sunlight, on their chemical structure, (Bishal et al, 2019). The alterations in the chemical structure are generally photooxidation of the polymers, with the formation of free radicals (polymer oxy- and peroxy-radicals) that lead to chain scission. Added free radicals might react with each other, producing cross-linking, (Al-Harbi et al, 2015; Guiotti et al, 2016). Han, et al, 2010, stated that the maximum significant color changes can be attributed to the fact that the elastomers have a fundamental ability to lose color with weathering progression.

Conclusion

Within the limitation of the present study, it was concluded that the surface smoothness of Room Temperature Vulcanized VST-06 maxillofacial silicone elastomer was increased directly proportional to the increase of artificial accelerated weathering. Also, the color deterioration of VST-06 Room Temperature Vulcanized maxillofacial silicone elastomer started after 46h accelerated weathering and it increased as the artificial aginghours increasesd.

Conflict of interest

We are the authors (Nebras Fadhil Alwan, Assist. Prof. Mohammed Abdul-Hussein Hamid, and Assist. Prof. Dr. Saja Ali Muhsin) state that the submitted manuscript for this paper is original. It has not been published previously, and it's part of the MSc. dissertation and is not under consideration for publication elsewhere, and that the final version has been seen and approved by all authors.

References

ABDULLAH, H. A. & ABDUL-AMEER, F. M. 2018. Evaluation of some mechanical properties of a new silicone elastomer for maxillofacial prostheses after addition of intrinsic pigments. The Saudi dental journal, 30, 330-336. https://doi.org/10.1016/j.sdentj.2018.05.006

AL-DHARRAB, A. A., TAYEL, S. B. & ABODAYA, M. H. 2013. The effect of different storage conditions on the physical properties of pigmented medical grade I silicone maxillofacial material. International Scholarly Research Notices, 2013. https://doi.org/10.1155/2013/582051

AL-HARBI, F. A., AYAD, N. M., SABER, M. A., ARREJAIE, A. S. & MORGANO, S. M. 2015. Mechanical behavior and color change of facial prosthetic elastomers after outdoor weathering in a hot and humid climate. The Journal of prosthetic dentistry, 113, 146-151. https://10.1016/j.prosdent.2014.09.008

AL-MOHAMMAD, Y. N. & ABDUL-AMEER, F. M. J. I. J. O. P. H. 2019. Effects of Artificial Aging on Some Properties of Room-Temperature-Vulcanized Maxillofacial Silicone Elastomer Modified by Yttrium Oxide Nanoparticles. 10. https://10.5958/0976-5506.2019.02389.1

AL MAMUN, M. A., ALI, M. H. & FERDOUS, M. S. Design, construction and performance test of a color detective device. International Conference on Mechanical, Industrial and Materials Engineering, 2017.

ALI, J. A.-A. 2017. Influence of Artificial Weathering on Some Mechanical Properties of SiO2 Nano Silicone Dioxide Reinforced Maxillofacial Silicone. University of Baghdad.

ALSMAEL, M. A. & ALI, M. M. M. 2018. The effect of nano titanium silicate addition on some properties of maxillofacial silicone material. Journal of Research in Medical and Dental Science, 6, 127-132.

ASTM-D624-00 2012. Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers. ASTM International, West Conshohocken, PA.

BABU, A. S., MANJU, V. & GOPAL, V. K. 2018. Effect of chemical disinfectants and accelerated aging on maxillofacial silicone elastomers: an in vitro study. Indian Journal of Dental Research, 29, 67.

BISHAL, A. K., WEE, A. G., BARÃO, V. A., YUAN, J. C.-C., LANDERS, R., SUKOTJO, C. & TAKOUDIS, C. G. J. T. J. O. P. D. 2019. Color stability of maxillofacial prosthetic silicone functionalized with oxide nanocoating. 121, 538-543. https://10.1016/j.prosdent.2018.06.007

CIFTER, E. D., OZDEMIR-KARATAS, M., CINARLI, A., SANCAKLI, E., BALIK, A. & EVLIOGLU, G. 2019. In vitro study of effects of aging and processing conditions on colour change in maxillofacial silicone elastomers. BMC oral health, 19, 1-10. https://10.1186/s12903-019-0798-1

DARVELL, B. W. 2018. Materials science for dentistry, Woodhead publishing.

FARAGE, M. A. & , K. W. M., P ELSNER, H I MAIBACH 2008. Intrinsic and extrinsic factors in skin ageing: a review. International Journal of Cosmetic Science, 30, 87–95. • https://doi.10.1111/j.1468-2494.2007.00415.x

GOIATO, M. C., PESQUEIRA, A. A., SANTOS, D. M. D. & DEKON, S. F. D. C. 2009. Evaluation of hardness and surface roughness of two maxillofacial silicones following disinfection. Brazilian oral research, 23, 49-53. https://doi.org/10.1590/s1806-83242009000100009

GOIATO, M. C., SANTOS, D. M. D., HADDAD, M. F. & PESQUEIRA, A. A. 2010. Effect of accelerated aging on the microhardness and color stability of flexible resins for dentures. Brazilian oral research, 24, 114-119. https://doi.org/10.1590/S1806-83242010000100019

GUIOTTI, A. M., GOIATO, M. C., DOS SANTOS, D. M., VECHIATO-FILHO, A. J., CUNHA, B. G., PAULINI, M. B., MORENO, A. & DE ALMEIDA, M. T. G. 2016. Comparison of conventional and plant-extract disinfectant solutions on the hardness and color stability of a maxillofacial elastomer after artificial aging. The Journal of prosthetic dentistry, 115, 501-508. https://doi.org/10.1016/j.prosdent.2015.09.009

GÜNGÖR, M. B., NEMLI, S. K., BAL, B. T. & ARıCı, Y. K. 2021. Effect of ultraviolet protective agents on maxillofacial silicone elastomer, part 2: Mechanical properties after artificial aging. The Journal of Prosthetic Dentistry. https://doi.org/10.1016/j.prosdent.2021.06.032

HADDAD, M. F., GOIATO, M. C., DOS SANTOS, D. M., MORENO, A., PESQUEIRA, A. A. & D›ALMEIDA, N. F. J. J. O. B. O. 2011. Color stability of maxillofacial silicone with nanoparticle pigment and opacifier submitted to disinfection and artificial aging. 16, 095004. https://doi.org/10.1117/1.3625401.

HAN, Y., ZHAO, Y., XIE, C., POWERS, J. M. & KIAT-AMNUAY, S. J. J. O. D. 2010. Color stability of pigmented maxillofacial silicone elastomer: effects of nano-oxides as opacifiers. 38, e100-e105. https://doi.org/10.1016/j.jdent.2010.05.009

HATAMLEH, M. M., WATTS, D. C. J. J. O. P. I., ESTHETIC & DENTISTRY, R. 2010. Effect of extraoral aging conditions on color stability of maxillofacial silicone elastomer. 19, 536-543. https://doi.org/10.1111/j.1532-849X.2010.00627.x

HAUG, S. P., ANDRES, C. J. & MOORE, B. K. J. T. J. O. P. D. 1999. Color stability and colorant effect on maxillofacial elastomers. Part III: weathering effect on color. 81, 431-438. https://doi.org/10.1016/s0022-3913(99)80010-9

ISO-23529 2010. Rubber — General procedures for preparing and conditioning test pieces for physical test methods. https://doi.org/10.1016/j.dib.2019.104166

JASSIM, A. L., HUSSAIN, M. A. J. J. O. O. & RESEARCH, D. 2019. The effect of aging on tensile strength of two maxillofacial silicone materials before and after pigmentation. 6.

JEBUR, A., FATALLA, A. & ALJUDY, H. 2018. The Effect of Polyester Fibers Addition on Some Mechanical Properties of Room Temperature Vulcanized Maxillofacial Silicon Elastomers. J. Pure Appl. Microbiol, 12, 165-176. https://doi.org/10.22207/JPAM.12.1.21

KANTOLA, R. J. T. Y. U. O. T. T. 2014. Use Of Fiber-Reinforced Composite Framework And Thermochromic Pigment In Facial Prostheses.

LI, Q., HUANG, X., LIU, H., SHANG, S., SONG, Z. & SONG, J. 2017. Properties enhancement of room temperature vulcanized silicone rubber by rosin modified aminopropyltriethoxysilane as a cross-linking agent. ACS Sustainable Chemistry & Engineering, 5, 10002-10010. https://doi.org/10.1021/acssuschemeng.7b01943

M SHIHAB, N. & M ABDUL-AMEER, F. 2018. Studying some mechanical properties of maxillofacial silicone elastomer before and after incorporation of intrinsic pigments and artificial aging. Future Dental Journal of Egypt, 4, 244-252. https://doi.org/10.1016/j.fdj.2018.06.002

MAHAJAN, H. & GUPTA, K. 2012. Maxillofacial prosthetic materials: A literature review. Journal of Orofacial Research, 87-90. https://10.5005/jp-journals-10026-1020

MANCUSO, D. N., GOIATO, M. C., DE CARVALHO DEKON, S. F. & GENNARI-FILHO, H. J. I. J. O. D. R. 2009. Visual evaluation of color stability after accelerated aging of pigmented and non-pigmented silicones to be used in facial prostheses. 20, 77. httpa://10.4103/0970-9290.49073

MOHAN, A. S., MANJU, V., BABU, A. S. & KRISHNAPRIYA, V. 2021. Effect of Particle Size of Nano-Oxides on Color Stability and Mechanical Properties of Maxillofacial Silicone Elastomers: An In Vitro Study. Int J Prosthodont, 54-60. https://10.11607/ijp.6593

MOUSA, M. A. 2020. Influence of Weather on Hardness and Surface Roughness of Maxillofacial Elastomeric Materials. The Journal of Contemporary Dental Practice, 21, 678-682. https://10.5005/jp-journals-10024-2853

RAHMAN, A. M., JAMAYET, N. B., NIZAMI, M. M. U. I., JOHARI, Y., HUSEIN, A. & ALAM, M. K. 2021. Effect of tropical outdoor weathering on the surface roughness and mechanical properties of maxillofacial silicones. The Journal of prosthetic dentistry. https://doi.org/10.1016/j.prosdent.2020.07.026

ROSA, D., ANGELINI, J., AGNELLI, J. & MEI, L. 2005. The use of optical microscopy to follow the degradation of isotactic polypropylene (iPP) subjected to natural and accelerated ageing. Polymer Testing, 24, 1022-1026. https://10.1088/1757-899X/454/1/012086

SALIH, S., OLEIWI, J. & ALI, H. Study the Mechanical Properties of Polymeric Blends (SR/PMMA) Using for Maxillofacial Prosthesis Application. IOP Conference Series: Materials Science and Engineering, 2018. IOP Publishing, 012086.
https://10.1016/j.polymertesting.2005.07.009

JODR
Volume 9, Issue 1, 2022

SHAKIR, D. A. & ABDUL-AMEER, F. M. 2018. Effect of nano-titanium oxide addition on some mechanical properties of silicone elastomers for maxillofacial prostheses. Journal of Taibah University Medical Sciences, 13, 281-290. https://doi.org/10.1016/j.jtumed.2018.02.007

SHEN, C., RAWLS, H. R. & ESQUIVEL-UPSHAW, J. F. 2021. Phillips› Science of Dental Materials E-Book, Elsevier Health Sciences.

TUKMACHI, M. & MOUDHAFFER, M. 2017. Effect of nano silicon dioxide addition on some properties of heat vulcanized maxillofacial silicone elastomer. IOSR-JPBS, 12, 37-43. https://10.9790/3008-1203063743

WANG, Q. J. & LINE AHM MIELBY, J. Y. J., 1 ANNE SJOERUP BERTELSEN,1 ULLA KIDMOSE,1 CHARLES SPENCE,2 AND DEREK VICTOR BYRNE1 2019. The Role of Intrinsic and Extrinsic Sensory Factors in Sweetness Perception of Food and Beverages: A Review. https://10.3390/foods8060211

ISSN 6417-2310