MDJ

Estimation Of Color Change Of Maxillofacial Silicone Elastomer After Artificial Aging

***Nebras Fadhil Alwan, BSc**
****Mohammed Abdul Hussein Hamid, MSc,**
*****Saja Ali Muhsin MSc, PhD**
*, **, *** Department of Prosthetic Dental Technology, College of Health and Medical Technology, Middle Technical University, Iraq.
* nebrasalalwan@gmail.com mobile no. 07717440776
** Dmoh.arob@yahoo.com mobile no. 07708885548
*** dr.sajaali79@gmail.com mobile no. 07702787470

Abstract

Background: Silicone elastomers are the most widely used maxillofacial materials, however, it is far away from ideal and still progresses through many improvements for replacing the facial defect, maxillofacial prostheses need renewed as early as six months and can last up to 24 months. The color change is the most essential cause for remaking new prostheses.
Aim: The purpose of this study was to assess the color stability of maxillofacial elastomers throughout aging of about one year.
Materials and methods: Ten specimens were prepared from Room Temperature Vulcanazation (RTV) VerSilTal (VST-06) maxillofacial silicone and pigmented using rayon the flocking, the specimens were tested using the color-ometer device before and after subjecting to 46,146, and 317h accelerated weathering. The data were collected, analyzed, and compared using SPSS (V-18) via t-test, accomplished in confidence % 95 and significant P-Value of ($p \leq 0.05$).
Results: Statistical t-test showed that the values of color changes differed among the tested groups ($P \leq 0.05$). The red wave value increased throughout weathering progress while the green and blue waves were decreased.
Conclusions: This study presented that the color degradation may take place in VST-06 VerSilTal (room temperature vulcanization) silicone elastomers after it was exposed to 46h accelerated weathering and this degradation increased over time.

Keywords: Maxillofacial Silicone Elastomer, Color Change, after Artificial Aging.

Introduction

Maxillofacial prosthesis exhibited discoloration and deformation throughout service life as a result of external or internal factors, these alterations in the quality of prosthesis require frequent replacement and increase treatment costs, **(Kiat-amnuay et al., 2009; Zarrati et al., 2020).**

Color stability is the first property of maxillofacial prosthetic silicone elastomer which deteriorates over time and involving the reconstruction of a new prosthesis, **(Bishal et al., 2019; Mohan et al., 2021; Al-Harbi et al., 2015).** Silicone materials like other Polymers absorb the UV photons energy initiating breakdown of polymeric chains, creating new radicals that can cause extra degradation of the polymer network, resulting in loss of flexibility, cracking, molecular weight reduction, weakening of mechanical properties, surface dullness, discoloration, and fading, **(Al-Harbi et al., 2015; Guiotti et al., 2016; Zayed, 2018).** Other factors causing color changes of silicone prostheses involve the intrinsic capacity of elastomer and pigments to degrade over time, **(Goiato et al., 2010, Han et al., 2010).**

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).**

Artificial accelerated weathering is a practical way to assess the durable effect of outdoor weathering conditions, by using intensive elements of the weathering conditions, such as heat, UV, moisture, and water spray, **(M Shihab and M Abdul-Ameer, 2018).**

The color change is the most vital consideration used by patient's acceptance of facial prostheses. The color fading is the first of the requests of substitution, which unluckily occurs due to the inevitable aging, use of disinfectants or additives, **(Mancuso et al., 2009b; Goiato et al., 2009b; Bankoglu et al., 2013; Zarrati et al., 2020).**

A study in 1999 approved that the outdoor weathering for one year of the silicone elastomer may cause the visually detectable color change, **(Polyzois, 1999)**. Each of weathering and degradations of silicones itself and pigments attributing in color changes of silicone elastomers, **(Haug et al., 1999; Hatamleh et al., 2010; Li et al., 2017)**.

Abdullah and Abdul-Ameer in 2018, described three types of color changes that might occur in the silicone elastomers. Firstly is the type of the inherent color degradation of silicone ingredients themselves, then second color change type may take place during the vulcanization phases, while the third type resulted from external conditions for occurrence, like the patient's daily habits, cleaning processes, the weather, and integral chemical alterations in the elastomer, **(Cifter et al., 2019)**. In addition to absorption and adsorption from the silicone surfaces which are responsible for color degradation occurrence, **(Mancuso et al., 2009a; Kheur et al., 2016; Bishal et al., 2019)**.

The main objective of prosthetic rehabilitation of facial defects in the aesthetic restoration and reestablishment of confidence of the patients is the color fading, **(Goiato et al., 2009a; Bankoglu et al., 2013)**.

The clinician decided to choose an appropriate colorant that ensures aesthetics used in coloring maxillofacial prostheses as well as must has color stability and resists the degradation from any of its properties, **(Al-Dharrab et al., 2013; Chandan Sengupta et al., 2019)**.

A study by **Al-Harbi et al. (2015**), involving six samples, evaluated the effect of outdoor weathering on color stability of three silicone materials over six months. The color change was examined at the baseline and after outdoor weathering with a spectrophotometer. They found that the color change significantly take place in all tested silicones elastomers when subjected to weathering.

In addition, Bunyan and Abood (2019) evaluated the effect of (75h, 150h, 300h) periods of artificial weathering on color changes of RTV silicone maxillofacial material pigmented with 0.2wt.% of dry pigment (Burnt sienna). The pigmented (Tech-Sil25) silicon specimens divided into two groups control and study group (n=10), the control group specimens was tested for color change and the study group were tested after each period of (75, 150, and 300 h) of artificial weathering ultraviolet. They found that no significant color change after 75 hours of artificial weathering. However, they approved that the color change in pigmented silicone elastomer is increase significantly with increasing the aging period. **Therefore,** the aim of this study is to evaluate the effects of artificial weathering on color change of VST-06 maxillofacial silicone elastomers.

Material and Method

VST-06 platinum Room Temperature Volcanazation silicone elastomer (Factor II Inc., Lakeside, USA), Rayon flocking tan, flesh, and yellow colors (Factor II Inc., Lakeside, USA), were used in this study to prepare the study samples (n=10) **(Al-Harbi et al., 2015**; **Bunyan and Abood, 2019)** with 25×25×6mm dimensions, this dimensions accommodated with the size of the sensor and the light distribution of the LEDs and plastic black box size of color-ometer, **(Al Mamun et al., 2017)**. The abbreviations A, B, C and D reffered to the reading at the baseline and after 46,146, and 317h accelerated weathering applied on the same specimens respectively.

According to the manufacturer's instructions, 59.1g from the base and 6g from the catalyst were used in this study, as the mixing ratio of final silicone platinum room temperature vulcanization (RTV) VST-06 was 10:1. According to the pilot study, three colors of rayon fibers were prepared earlier from mixing of 0.6, 0.3, and 0.05 (±0.001)g of tan, flesh, and yellow rayon fibers respectively, these fibers were mixed mechanically for about one hour using an amalgamator device, 0.9g from this homogenous color such as human skin crony tone were used for silicone coloration**.**

Specimens preparation, finishing, and storage:

To ensure homogeneous mixing, shak the base and catalyst proberly before use, the base and catalyst were pre-weighed using digital electronic weight balance of (0.000) digits as shown in table (1).

The pre-weighed rayon flocking was positioned inside the mixing container of the vacuum mixer machine then the silicone base was added into the container gradually to avoid fibers dispersion, **(Jebur et al., 2018).** Manual mixing was done for 1min (±1sec) with a clean spatula followed by 2min (±1sec) mechanical mixing as the speed of 360 rpm without vacuum to prevent suction of the fibers, then this colored mixture was left to stand for 2min because the rotation of the mixer generated heat which reduces the working time of the material, **(Jebur et al., 2018; Abdullah and Abdul-Ameer, 2018)**. Then the pre-weighed catalyst was added to the mixture of rayon fiber and silicone base, when adding the catalyst distribute it in more than one place in addition to the center,**(Tukmachi and Moudhaffer, 2017; Jassim and Hussain, 2019)**.

This homogeneous mixture of free air bubbles poured gently into the customized acrylic mold over a dental vibrator to avoid air entrapment within the material, a fine needle used to expose any air bubbles that formed on the material surface before covering the material and mold matrix, (**Al-Harbi et al., 2015**). Gentl adjustment for the cover over the matrix to drift any excess material and trapped air out of the mold. After that, a constant load of 1kg applied over the mold cover and tightened using six G-clamps with nuts. According to the manufacturer's, VST-06 silicone vulcanization takes about 16h. However, the load then removed leaving the mold fixed firmly until the specimens compeletly hardened, figure (1), **(Abdullah and Abdul-Ameer, 2018; Shakir and Abdul-Ameer, 2018).**

Keeping the elastomer at a regular laboratory

temperature at 23(±2)̊C and relative humidity (RH) of 50(±10)% during preparation, and vulcanization of silicone elastomers, **(Shakir and Abdul-Ameer, 2018).**
After the specimens were conditioned, left at least 3h before flashes removal, **(Shakir and Abdul-Ameer, 2018; Abdullah and Abdul-Ameer, 2018)**. Specimens were placed away from light exposure through the period from vulcanization to testing and it was kept in a bag of tight sealing, care must be taken also to avoid lay the specimens one over another. The specimens were preserved in a modified box of light proofing united with digital thermometer and hygrometer device. This to display the temperature and humidity in and out the box. The inner box chamber was an air-conditioned with relative humidity (RH) of 50(±10)% and controlled temperature at 23(±2)̊C, to avoid any undesirable change that occurs in temperature and/or humidity**(Alsmael and Ali, 2018; Abdullah and Abdul-Ameer, 2018)**.
All flashes of the specimens were removed with a scalpel and sharp surgical blade no.11**, (Jebur et al., 2018).** The specimens were inspected visually for intact borders, free from air bubbles, and clear from irregularities within and at the of each specimens The specimens were kept in a standard condition for 24h before the test procedure, **(Abdullah and Abdul-Ameer, 2018).**

Artificial weathering:
Figure (3) shows a Weather-Ometer device (QUV) that promotes the same conditions as outdoor weathering but at a faster rate, with many hours in the device chamber comparable to many days outside weathering depending on the research site. The weathering standardization used in this study according to cycle 7 of ASTM G154 the specimens exposed to 25 cycles, each weathering cycle was accomplished in 12h. The first 8h (light cycle) included irradiance of (340nm) of (1.55 W/m^2) and temperature of 60(±3̊C). The subsequent 4 hours represented the dark cycle, which included (340nm) (1.55 W/m2) irradiance, 15 minutes of water spray system to cause thermal shock, and ultimately a condensation period at 50(3C) temperature.
The timing of Weather-Ometer differs depending on both the place and the device. Even though within the same device because it depends on many factors such as the site of the study, age of the lamplight, presence or absence of filters inside the Weather-Ometer. The condition in Baghdad city considers that every 100h inside the Weather-Ometer chamber are equivalent to three months of outdoor weathering or clinical use of the prosthesis, **(Atta-Allah and Muddhaffer, 2017).**
According to previous information, the periods of 46, 146 and 317h inside the Weather-ometer chamber are equivalent to outdoor weathering or clinical use of the prosthesis for about 6.2, 19.69 and 42.74 weeks or 1.45, 4.59 and 9.97 months, or 43.4, 137.8 and 299.18 days respectively.

Testing procedures:
The color-ometer device was used in this study as shown in figure (4), (TCS230, China). The set up of color ometer according to the Arduino microcontroller system. The sensor in device consists of four LED lights at the corners of the PCP, and an RGP color sensor located at the center. This device system was programmed to be responsible to read the red, green, and blue wave colors.
The first step of testing after 24h of specimen finishing that kept in a standard condition according to **(Al-Harbi et al., 2015; Abdullah and Abdul-Ameer, 2018).** These initial readings were analyzed and compared as with the same specimens that were subjected to artificial weathering after each of accelerated weathering periods 46, 146, and 317h.

Results: The data were calculated with descriptive statistics includes the means, standard deviation, minimum, and maximum values, and t-test for comparing red, green, and blue colors waves changes, at a confidence level of 95% and a significant P-value of ($P \leq 0.05$).

As regards the three colors red, green, and blue waves as in tables (1) and (2), and figure (4) show the result of the wave color change for the VST-06 RTV. After comparing the results, generality significant differences presented between the groups, ($P \leq 0.05$). 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 in group D, (212) and (168) for green and blue waves in control group.

Discussion

The color change is one of the first mandate of facial prosthesis replacement, the color deterioration unfortunately occurs throughout the aging process, and use of disinfectants. Color is the most important factor used by patients in the assessment of facial prostheses, **(Bankoglu *et al*., 2013; Zarrati *et al*., 2020)**.

In the present study, color-ometer device was used, this digital technology is simple and easily used apparatus, accurate method, and low cost, it analyze the color of the material through three-filtered that match the human eye response to light and color according to the RGB system for (Red, Green, and Blue) colors analysis. This system presents the output in the computer by Arduino IDE software, **(Al Mamun et al., 2017).**

The results in the present study showed the effect of 46, 146, and 317h of artificial weathering on pigmented VST-06 silicone material. As presented in tables (1) and (2), and figure (4), throughout artificial accelerated weathering a negligible decrease 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, The exceptional least mean value was after 146h. Also, the blue wave color was decreased conversely with the increase of aging hours. The color changes results of this study may supported by (**Al-Harbi et al., 2015)**, they approved that outdoor weathering in a hot and humid climate adversely affected the color stability of silicone elastomer, they explicated the color change as 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 followed by changes in the amount of light diffusion through the material along with degradation of the polymer color shade, **(Al-Harbi,2015**)

Also the results of the current study supported with **(Bishal et al., 2019)**, they found that all pigmented specimens observed a great color change after 120h of artificial weathering, the they attributed these color deteriorations to both the intrinsic (self-discoloration of the material) and extrinsic factors (adsorption or absorption of different substances),**(Bishal et al., 2019**).

In the current study the specimens showed color deteriorations after 46h of artificial weathering, this diagreed with **(Bunyan and Abood, 2019)**, they approved color change of elastomers upon aging, but after period more than 75h of artificial weathering. This may be explained as a result of UV radiation effects in the elastomers such as reducing the polymerization process, improving cross-linking, breaking down of bonds of the polymer chain, elastomer decomposition, and accelerated interface of fatty acids with silicone, all these factors terminated in color change, **(Haug et al., 1999; Hatamleh et al., 2010; Li et al., 2017; Zayed, 2018).** In addition, 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).**

However, this study has a limitation of using artificial weathering because aging chambers reproduce greater environmental conditions than that occur when daily routine use by patients. Such phenomena are less obvious in the clinical presentation of silicone prostheses. In outdoor weathering, there are differences in weathering test results at different geographic locations, despite the climatological data seems to be the same. The elements of the atmosphere, like nitrogen, oxide sulfur dioxide, and ozone or rain and/or wind may also affect the photo-oxidative process, **(Goiato et al., 2009b; 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, **(Han et al., 2010)**.

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).**

Further in-depth studies are warranted to investigate the influence of outdoor weathering or cleaning solutions treatment on color stability of VST-06 silicone elastomers. Investigating of different types of oxide nanocoatings on the color stability of pigmented silicone elastomers recommended to decrease the inevitable color change.

Conclusions

Within the limitation of this study, it was concluded that the color deterioration of maxillofacial silicone elastomer occurred after 46h of accelerated weathering, however, it is directly and proportionally increased with artificial aging.

Acknowledgement

Special gratitude is to our messenger Mohammed and his pure family (Peace and Pray upon them).

Conflicts of Interest

The author reported that there is no conflictof interest

References:

1. 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.
2. AL-DHARRAB, A. A., TAYEL, S. B. & ABODAYA, M. H. J. I. S. R. N. 2013. The effect of different storage conditions on the physical properties of pigmented medical grade I silicone maxillofacial material. 2013.
3. 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.
4. 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.
5. Atta-ALLAH, J. A. & MUDDHAFFER, M. 2017. Influence of artificial weathering on some properties of nano silicon dioxide incorporated into maxillofacial silicone. *International Journal of Science and Research,* 6**,** 423-428.
6. 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.

7. BANKOGLU, M., ORAL, I., GUL, E. B. & YILMAZ, H. J. J. O. C. S. 2013. Influence of pigments and pigmenting methods on color stability of different silicone maxillofacial elastomers after 1-year dark storage. 24**,** 720-724.

8. 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.

9. BUNYAN, S. F. & ABOOD, A. Z. 2019. Color Changes in Dry Pigmented Tech-Sil25 Maxillofacial Elastomer after Artificial Weathering. Indian Journal of Forensic Medicine & Toxicology, 13.

10. CHANDAN SENGUPTA, PRAKASH NIDAWANI, HARSHA RH, VINAY UMALE, ROHIT KULSHRESTHA & CHANDURKAR, K. 2019. Evaluation and Comparison of Tensile Strength, Water Absorption, Hardness and Colour Stability of Three Commercially Available Maxillofacial Silicone Elastomers. *Advanced Research in Dentistry and Oral Hygiene,* 1.

11. CIFTER, E. D., OZDEMIR-KARATAS, M., CINARLI, A., SANCAKLI, E., BALIK, A. & EVLIOGLU, G. J. B. O. H. 2019. In vitro study of effects of aging and processing conditions on colour change in maxillofacial silicone elastomers. 19**,** 1-10.

12. FERREIRA, A., ARAS, M., CHITRE, V., COUTINHO, I. & RAJAGOPAL, P. J. T. J. O. T. I. P. S. 2018. Effect of the simulated Indian and Mediterranean climates on the Shore A hardness of maxillofacial silicone. 18**,** 305.

13. GOIATO, M. C., PESQUEIRA, A. A., DA SILVA, C. R., GENNARI FILHO, H., DOS SANTOS, D. M. J. J. O. P., RECONSTRUCTIVE & SURGERY, A. 2009a. Patient satisfaction with maxillofacial prosthesis. Literature review. 62**,** 175-180.

14. GOIATO, M. C., PESQUEIRA, A. A., SANTOS, D. M. D., ZAVANELLI, A. C., RIBEIRO, P. D. P. J. J. O. P. I., ESTHETIC & DENTISTRY, R. 2009b. Color stability comparison of silicone facial prostheses following disinfection. 18**,** 242-244.

15. GOIATO, M. C., SANTOS, D. M. D., HADDAD, M. F. & PESQUEIRA, A. A. J. B. O. R. 2010. Effect of accelerated aging on the microhardness and color stability of flexible resins for dentures. 24**,** 114-119.

16. 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. J. T. J. O. P. D. 2016. Comparison of conventional and plant-extract disinfectant solutions on the hardness and color stability of a maxillofacial elastomer after artificial aging. 115**,** 501-508.

17. 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.

18. 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.

19. 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.

20. JASSIM, A. L. & HUSSAIN, M. A. 2019. The effect of aging on tensile strength of two maxillofacial silicone materials before and after pigmentation. *Journal of Oral and Dental Research,* 6.

21. 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.

22. KHEUR, M., KAKADE, D., SETHI, T., COWARD, T., RAJIKUMAR, M. J. J. O. D. R. & DEVELOPMENT, S. 2016. Evaluation of the effect of UV stabilizers on the change in colour of a silicone elastomer following ageing by three different methods-An In-Vitro Study. 3**,** 18-23.
23. KIAT-AMNUAY, S., BEERBOWER, M., POWERS, J. M. & PARAVINA, R. D. J. J. O. D. 2009. Influence of pigments and opacifiers on color stability of silicone maxillofacial elastomer. 37**,** e45-e50.
24. 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.
25. 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.
26. MANCUSO, D. N., GOIATO, M. C., DE CARVALHO DEKON, S. F. & GENNARI-FILHO, H. J. I. J. O. D. R. 2009a. Visual evaluation of color stability after accelerated aging of pigmented and nonpigmented silicones to be used in facial prostheses. 20**,** 77.
27. MANCUSO, D. N., GOIATO, M. C. & SANTOS, D. M. D. J. B. O. R. 2009b. Color stability after accelerated aging of two silicones, pigmented or not, for use in facial prostheses. 23**,** 144-148.
28. MOHAN, A. S., MANJU, V., BABU, A. S. & KRISHNAPRIYA, V. J. I. J. P. 2021. Effect of Particle Size of Nano-Oxides on Color Stability and Mechanical Properties of Maxillofacial Silicone Elastomers: An In Vitro Study. 54-60.
29. MOUSA, M. A. J. D. P. 2020. Influence of Weather on Hardness and Surface Roughness of Maxillofacial Elastomeric Materials. 21**,** 678-682.
30. POLYZOIS, G. L. J. T. J. O. P. D. 1999. Color stability of facial silicone prosthetic polymers after outdoor weathering. 82**,** 447-450.
31. 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.
32. 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.
33. ZARRATI, S., SAFI, M., REZAEI, S. M. M. & SHADAN, L. J. T. J. O. P. D. 2020. Effect of nano-oxides on the color stability of maxillofacial silicone elastomers.
34. ZAYED, S. 2018. Mechanical Properties of Maxillofacial Silicone Elastomer and Approaches for their Improvement: A Literature Review. *EC Dental Science,* 17**,** 1293-1303.'

Table (1): The descriptive statistic of the color waves of the tested groups

Wave Color		N	Mean	Std. Deviation	Min.	Max.
Red	**A**	10	156.7	6.992	146	167
	B	10	155.4	4.402	151	165
	C	10	150.8	3.794	146	158
	D	10	167.8	2.7406	164	172
Green	**A**	10	204.3	6.929	193	212
	B	10	188.6	7.027	178	201
	C	10	178.3	5.618	172	189
	D	10	187.5	5.968	182	198
Blue	**A**	10	178.5	4.972	172	185
	B	10	171.5	6.519	163	184
	C	10	160.5	4.927	155	168
	D	10	165.5	2.718	161	169

Table (2): T-test of the color waves changes among tested groups (n=10)

Wave Color			Mean Difference	t-test	P-value	Sig
Red	**A**	**B**	1.30000	0.539	0.603	**NS**
		C	5.90000	2.054	0.070	**NS**
		D	-11.10000	-5.410	0.000	**S**
	B	**C**	4.60000	2.815	0.020	**S**
		D	-12.40000	-6.146	0.000	**S**
	C	**D**	-17.00000	-9.964	0.000	**S**
Green	**A**	**B**	15.70000	4.916	0.001	**S**
		C	26.000	8.820	0.000	**S**
		D	16.80000	4.672	0.001	**S**
	B	C	10.30000	3.425	0.008	**S**
		D	1.10000	0.335	0.746	**NS**
	C	D	-9.20000	-2.872	0.018	**S**
Blue	**A**	**B**	7.000	2.753	0.022	**S**
		C	18.000	8.603	0.000	**S**
		D	13.00000	7.619	0.000	**S**
	B	**C**	11.000	5.626	0.000	**S**
		D	6.00000	2.328	0.045	**S**
	C	**D**	-5.00000	-2.507	0.033	**S**

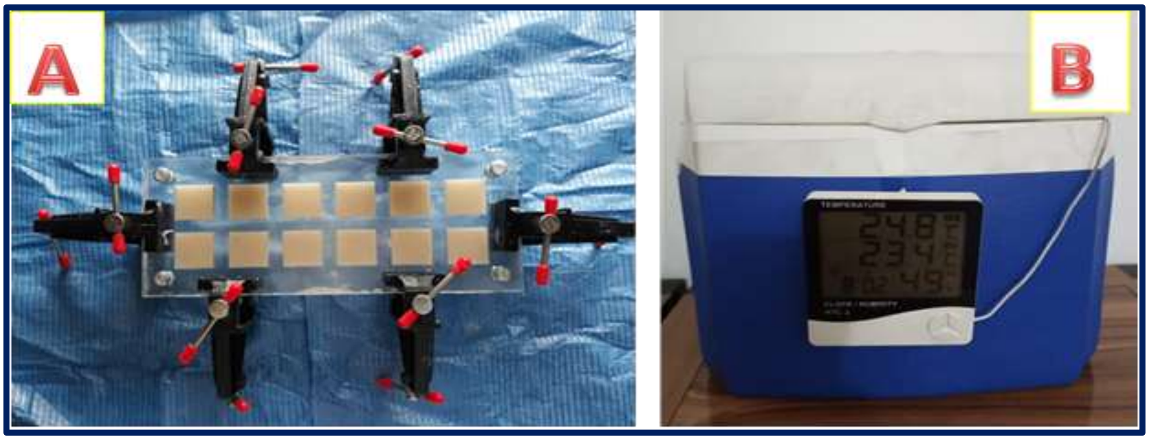

Figure (1): A, specimens at the set period; B, a modified box of light proofing combined with digital thermometer and hygrometer device

Figure (2): A, Weather-Ometer device; B, Weather-Ometer system (cycle 7)

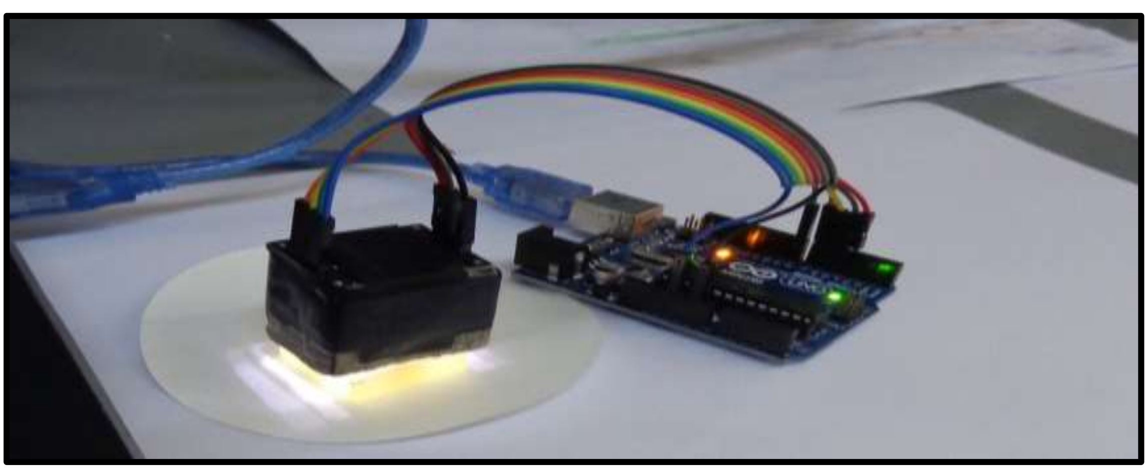

Figure (3): Specimens tested in color ometer device

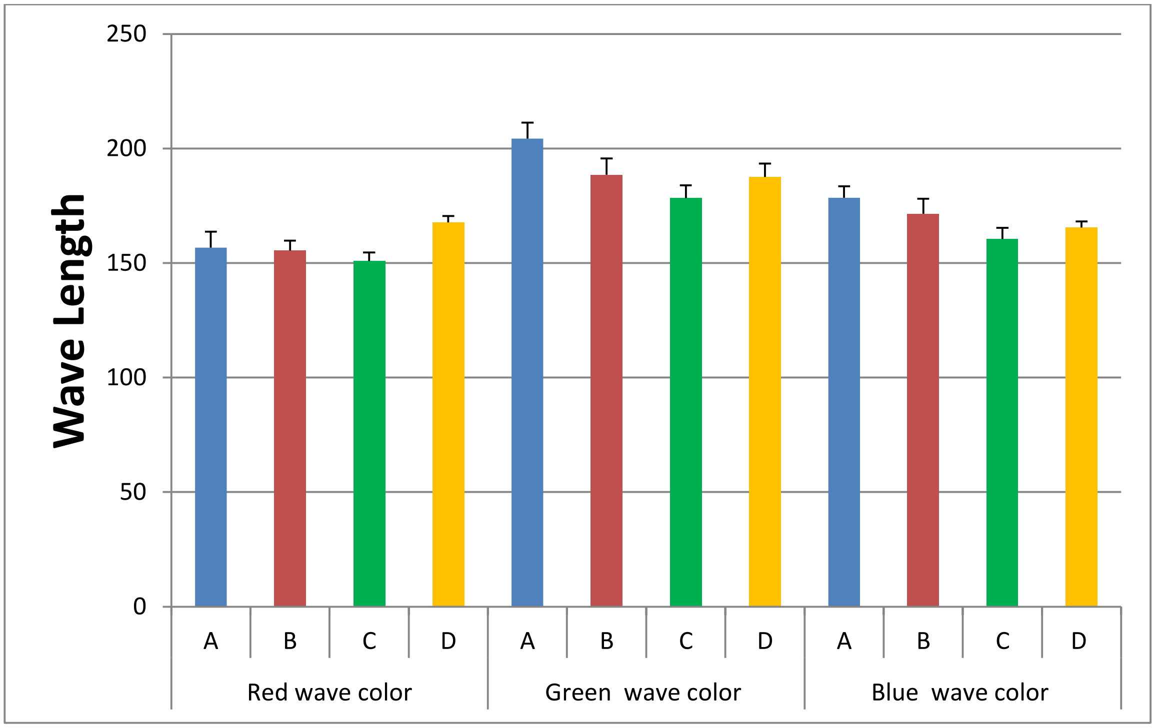

Figure (4): Bar-chart showing the mean distribution of the tested groups