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Research / Araştırma Makalesi

Evaluation of Surface Properties of A Recently Introduced Maxillofacial Silicone Elastomer After Aging

Güncel Bir Maksillofasiyal Silikon Elastomerin Yaşlanma Sonrası Yüzey Özelliklerinin Değerlendirilmesi

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ABSTRACT

Background: Silicone elastomer has been the most widely used material in the production of maxillofacial prostheses. Although silicone has some advantages, the degradation of the material over time is still a problem. Investigating the properties of recently used materials is crucial for practitioners to expand the possible choice of materials. One of these properties is surface roughness (Ra), which causes microbiological colonization, color instability, and accelerated degradation. This study aimed to evaluate Ra after artificial aging of newly introduced high-consistency elastomers.

Materials and Methods: A total of 150 specimens were fabricated using four high-consistency silicones (HCS) having different hardness options and one commonly used liquid silicone rubber. Each silicone group consisted of two colored subgroups and a nonpigmented subgroup as a control group. Ra values of the specimens were measured by a profilometer before and after the artificial aging. Ra change after aging was compared between all silicone groups using Wilcoxon signed-rank test (α=.05).

Results: There was no significant difference between pre- and post-aging Ra values for all main silicone groups except for the lowest hardness option of HCS silicone (*P*<05). Ra change after aging was significantly different for the main silicone groups (*P* =.001).

Conclusions: The HCS silicone tested in the study had similar surface roughness with the commonly used liquid silicone rubber after artificial aging.

Keywords: Silicone elastomers, Surface properties, Maxillofacial prosthesis, Aging

ÖZ

Amaç: Silikon elastomer, maksillofasiyal protez yapımında en çok kullanılan malzemedir. Silikonun bazı avantajları olmasına rağmen materyalin bozunması hala bir problemdir. Son zamanlarda kullanılan materyallerin özelliklerinin araştırılması, hekimlerin olası malzeme seçeneklerini genişletmeleri için önemlidir. Bu özelliklerden bir tanesi mikrobiyolojik kolonizasyon, renk değişimi ve bozunmanın hızlanmasına neden olan yüzey pürüzlülüğüdür (Ra). Bu çalışma, yakın zamanda tanıtılmış yüksek yoğunluklu elastomerlerin suni yaşlandırma sonrası yüzey pürüzlülüğünü değerlendirmektir.

Gereç ve Yöntemler: Dört adet farklı sertlik seçeneklerine sahip yüksek yoğunluklu silikon (HCS) ve bir adet sıkça kullanılan sıvı silikon kullanılarak toplam 150 adet örnek üretildi. Her silikon grubu iki adet renkli alt gruba ve kontrol grubu olarak renksiz bir alt gruba sahipti. Suni yaşlandırma öncesi ve sonrasında profilometre ile örneklerin Ra değerleri ölçüldü. Tüm silikon gruplarında yaşlandırma sonrası Ra değişimleri Wilcoxon signed-rank testi kullanılarak karşılaştırıldı (α=.05).

Bulgular: En düşük sertlik seçeneğine sahip HCS silikon dışında tüm temel silikon gruplarında yaşlandırma öncesi ve sonrası arasında belirgin farklılık bulunmadı (*P*<05). Yaşlandırma sonrası temel silikon grupları arasında Ra değişimi belirgin olarak farklıydı (*P* =.001).

Sonuçlar: Çalışmada test edilen HCS silikonun, sık olarak kullanılan sıvı silikon ile yaşlandırma sonrası benzer yüzey pürüzlülüğüne sahip olduğu bulunmuştur

Anahtar Kelimeler: Silikon elastomerler, Yüzey özellikleri, Maksillofasial protez, Yaşlandırma

Introduction

Maxillofacial prostheses are used to improve aesthetics and comfort by replacing missing or damaged structures in the head and neck.[1] Silicone elastomer is the most frequently used for fabrication of maxillofacial prosthesis. The major disadvantage of the silicone elastomer is degradation of the material, which affects the physical and mechanical properties and results in a shortened prosthesis life of up to 24 months.[2] Several factors including climate conditions, sunlight, humidity, disinfectants, and body fluids contribute to the degradation of the silicone elastomer.[3-6] Weather conditions lead to chemical alterations in polymer matrix of the silicone such as crosslinking, chain fragmentation, and formation of radicals, resulting in degradation.[7] Besides external factors, the physical and mechanical properties of silicones also depend on molecular weight of the material, type and concentration of fillers and pigments, polymerization temperature and time, and grade of cross-linking.[8] One of the physical properties is surface roughness (Ra) and this property affects mechanical properties and performance of the material. Ra is an indicator of the fine irregularities on the surface layer of a material. The Ra value represents the average deviation of surface peaks and valleys. In the presence of large deviations, so-called rough surfaces, there is a high risk of bacterial adhesion and colonization, the formation of microcracks or corrosion.[9,10] Colonization of microorganisms on maxillofacial prosthesis may lead to skin irritation.[5] The cracks may reduce ability of the material to withstand aging conditions which aggravate all other deterioration effects.[11]

There are two types of silicone elastomers according to the polymerization temperature; high-temperature vulcanized (HTV) and room-temperature vulcanized (RTV) silicones.[1]

In a recent comprehensive review, Annamma et al.[12] reported MDX4-4210, A-2186, M511, A-2000, Z004 (BU HTV), Cosmesil and Silastic 732 RTV as the most studied silicones, respectively. M511, one of these widely used silicones, was used in the study to compare with a recently introduced HCS. HCS has mostly been used in manufacturing finger, hand, and partial foot prosthesis.[13-15]. The literature on the use of HCS in maxillofacial prostheses appears to be limited.[16,17]

The aim of this study was to evaluate the Ra value of HCS, which has recently been used in maxillofacial prostheses, and to compare it with the Ra value of a commonly used silicone after an aging process. The null hypothesis was that there would be no difference between Ra values of HCS and M511 after aging.

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Materials and Methods

Two maxillofacial silicones were tested in the study: a HTV silicone (M511; Technovent Ltd) and a RTV silicone (Derma-sil; Spectromatch Ltd). The HCS silicone had several base options based on different hardness values. Base compounds having Shore A hardness 5, 20, 55, and 70 were used for the experiment. For fabrication of M511 specimens, the components of the product were mixed in a vacuum mixer (EasyMix; BEGO GmbH & Co KG) and for HCS, components were mixed by using a 2-roll mill device (Polymix; Servitec Maschinenservice GmbH) as recommended by the manufacturers. The mixtures were poured into dental stone molds. M511 mixtures were polymerized at 100 °C for 1 hour and HCS for 30 minutes in a dry heat oven (Mikrotekdental; Mikrotek Ltd). The specimens were evaluated for internal and surface porosity under magnification (Dental Loupe opt-on; Orange Dental GmbH & Co KG) after polymerization. A total of 150 specimens (Ø13x3 mm) were fabricated for the study. Main silicone groups M511 and HCS consisted of 3 subgroups according to pigmentation: fair-skinned (FS), dark-skinned (DS), and nonpigmented (NS). Every subgroup consisted of 10 specimens. As a result, 6 silicone groups (M511, HCS5, HCS20, HCS50 and HCS70), each with 3 color subgroups (FS, DS, and NS), were included in the study. Intrinsic pigmentation method was used for coloring the groups FS and DS. Group FS consisted of light grey (1.27% by weight), cream (1.11%), white (0.98%), pink (0.74%), and light dapple (0.45%) pigments. Group DS included ochre (1.85%), dark dapple (0.91%), orange-brown (0.82%), white (0.67%), and olive (0.29%) (QuickWeigh LSR; Spectromatch Ltd).

Ra values of the specimens were measured using a contact stylus profilometer (Marsurf M 300 C, MarSurf RD 18 C, stylus PHT 6-350/2 µm; Mahr GmbH). The device was calibrated by using a calibration plate supplied by the manufacturer. A total of three measurements were taken from three different areas of each specimen and the average of the three values was recorded as the mean Ra value of the specimen. The profilometer was set to a length of 1.75 mm, a cut-off of 0.25 mm, and a measurement speed of 0.5 mm/s. Ra test was carried out before and after artificial aging.

A UV aging chamber (BGD 856; Biuged Laboratory Instruments Co Ltd) was used to evaluate the effects of sunlight, moisture, and temperature on the specimens. Sunlight was simulated with fluorescent ultraviolet (UV) lamp and rain, dew, and water cleaning was simulated with condensation and water spray system. Calibration of the UV chamber was performed by using a radiometer (BGD 8118; Biuged Laboratory Instruments Co Ltd). Aging cycles consisted of UVA light at 340 nm wavelength and UVB light at 313 nm wavelength at a temperature of 60 ±20 °C for 8 hours, water spray for 18 minutes, and condensation at a temperature of 50 ±20 °C for 4 hours. The light had a radiation intensity of 1.55 W/m^2. The specimens were subjected to aging for 168 hours.

Statistical analyses were performed using a statistical software program (IBM SPSS Statistics, v23.0; IBM Corp). Distribution of data was tested by Shapiro-Wilk test. Data for before and after aging were not normally distributed, therefore nonparametric analysis were performed. Difference values observed in each silicone in Ra following aging were compared by independent-samples Kruskal-Walli's test. Significance values were adjusted by Bonferroni corrections for multiple tests. The differences between Ra values before and after aging in different silicone groups were tested by related samples Wilcoxon signed-rank test (α=.05).

Results

Table 1 shows comparison of change in Ra values between all silicone groups and subgroups after aging. Ra values were significantly different between the silicone groups both before (*P*<.001) aging and after aging (*P*<.001). Change of Ra values were also statistically different between 5 silicon groups (*P* =.01). HCS5 was the only group that had a significantly different Ra value after aging (*P* =.001). The Ra value of HCS5 increased after the aging process. Although not statistically significant, the mean Ra value of HCS20, HCS55, and HCS70 decreased after aging, while the mean Ra value of M511 increased. There was no significant change in Ra value in any of the color subgroups.

Table 1. Comparison of surface roughness values of silicone groups.

Silicone	Ra (µm) Before aging	Ra (µm) After aging	P (color groups)	P (silicone groups)
M511	0.969 ±0.58	1.036 ±0.49	.893	.01
	P=.191			
NS	0.851 ±0.79	0.947 ±0.74		
	P=.260			
FS	0.816 ±0.31	0.878 ±0.41		
	P=.508			
DS	1.240 ±0.49	1.283 ±0.33		
	P=.646			
HCS5	0.632 ±0.23	0.741 ±0.99	.535	
	P =.001			
NS	0.681 ±0.28	0.793 ±0.34		
	P =.022			
FS	0,650 ±0.15	0.789 ±0.31		
	P =.074			
DS	0.563 ±0.13	0,640 ±0.18		
	P =.028			
HCS20	1.169 ±0.26	1.144 ±0.39	.520	
	P=.551			
NS	1.031 ±0.11	0.978 ±0.00		
	P=.475			
FS	1.300 ±0.05	1.318 ±0.09		
	P=.575			
DS	1.162 ±0.41	1.137 ±0.32		
	P=.508			
HCS55	1.095 ±0.58	1.071 ±0.44	.170	
	P=.711			
NS	1.029 ±0.55	0.981 ±0.38		
	P=.575			
FS	1.128 ±0.71	1.052 ±0.63		
	P=.333			
DS	1.127 ±0.78	1.180 ±0.74		
	P=.093			
HCS70	1.294 ±0.45	1.286 ±0.46	.998	
	P=.504			
NS	1.183 ±0.08	1.164 ±0.08		
	P=.721			
FS	1.478 ±0.40	1.468 ±0,36		
	P=.799			
DS	1.204 ±0.24	1.207 ±0.19		
	P=.285			

Ra: surface roughness, HCS: high consistency silicone, NS: non-pigmented silicone, FS: faired-skinned silicone, DS: dark skinned silicone.
Bonferroni corrections; 5-70 p= 0.01, 5-20 p=0.005
Unadjusted p values for the differences of mean differences among groups;
5-55 p=0.12, 5-70 p= 0.002, 5-20 p= 0.001, 5-M p=0.174; 55-70 p=0.842, 55-20 p=0.994, 55-M p=0.249; 70-20 p=0.894, 70-M p=0.154; 20-M p=0.174

Discussion

The null hypothesis that there would be no difference between Ra values of HCS and M511 after aging was rejected. The surface roughness of maxillofacial prostheses is important because of its relationship with mechanical properties, adhesion of microorganisms, and color deterioration.[9,11] Shihab[11] reported that Ra increased for both nonpigmented and pigmented RTV silicone groups after 75 h and 150 h of aging. Abdalqadir[20] reported different Ra results for different color groups of HTV silicone after 750 h of artificial aging and concluded that the type and distribution of pigments in the matrix affect Ra changes. In this study, HCS5 was the only silicon whose Ra value increased after aging. The color types used in the study seem not to affect the Ra values. Some studies on nonpigmented RTV and HTV silicones reported an increase in Ra for both types after outdoor

weathering.[10,20] Ra change may not only be related to color pigments and aging. Indeed, a study comparing Ra changes in RTV and HTV silicones reported Ra increases without an aging process.[21] In the present study none of silicone groups and color subgroups had significantly different Ra value after aging except HCS5. This may indicate stability of chemical structure of the silicone materials. HCS5 seems to be more sensitive to surface degradation compared to other groups.

Ra values of the silicones tested were significantly different between silicone groups both before and after the aging process. HCS70 had the highest Ra before and after aging. This may be explained by higher filler concentration.[6] Although Ra value of HCS5 increased after aging, it was the lowest among other groups before and after aging. This raises the question that there is no Ra threshold for silicone elastomer. Ra above a threshold value of 0.2 µm is known to cause more biofilm accumulation on dental materials.[22] Ra of HCS5 was below this threshold.

Hydrophobicity is another property related to the rough surface of a material. Hydrophilic features of additives have been reported to be responsible for rougher surface.[9,23] Further studies on the hydrophobicity of the silicones tested, would be enlightening to explain roughness characteristics of the materials. Although there was no significant difference between the Ra values of the groups before and after aging, Ra of M511 had increased and Ra of HCS silicones decreased. Smoother surface of HCS silicones may be because of complete polymer chains.[24]

In this study, the surface roughness of high viscosity silicone with different hardness and color options before and after aging was tested. The major limitation of the study was that only the surface roughness was investigated. More research is needed for this recently used silicone, especially on mechanical and optical properties. According to the results of this study, high viscosity silicones may be an option for the fabrication of maxillofacial prostheses, especially when hardness close to that of the defect tissue is required.

Conclusion

There is a lack of research in the literature on the high-consistency silicone tested in this study. Given its surface roughness like that of commonly used liquid silicone rubber, this high-consistency silicone should be the primary starting point for further research. Further studies on mechanical and optical properties followed by in-vivo studies seem to be a necessity at this time to increase material options for physicians.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

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Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

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Çıkar Çatışması / Conflict of interest

Çıkar çatışması beyan edilmemiştir.

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Yazar Katkıları / Author Contributions

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Veri Analizi | Data Analysis: NÖ (%40), SKN (%20), MK (%20), GU (%20)
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