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Effect of Disinfection and Accelerated Aging on Color Stability of Colorless and Pigmented Facial Silicone

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Abstract

Purpose: The aim of this study was to evaluate the color stability of a facial silicone with different pigmentations submitted to disinfection and accelerated aging.
Materials and Methods: Sixty replicas were fabricated with the silicone Silastic MDX 4-4210 and divided into three groups: no pigmentation, pigmentation with makeup powder, and pigmentation with ceramic powder. Half the replicas of each group were submitted to disinfection with Efferdent and the other with neutral soap for 60 days (n = 10). After this period, all replicas were inserted in a chamber for accelerated aging of nonmetallic specimens. The color measurements were carried out initially, after disinfection, and after accelerated aging (252, 504, 1008 hours). Color stability was evaluated through spectrophotometry. The values were submitted to ANOVA and the means to Tukey's test ($p < 0.01$).
Results: The specimens disinfected with neutral soap exhibited higher ΔE values regardless of the type of pigmentation. The colorless replicas and the specimens pigmented with ceramic exhibited a statistically significant difference between the methods of disinfection in all periods. The specimens pigmented with makeup powder did not demonstrate a statistically significant difference.
Conclusions: The ceramic pigment presented greater color stability regardless of disinfection and period. On the other hand, the makeup pigment exhibited the highest values of chromatic alteration.

Silicone is used to fabricate maxillofacial prostheses due to resistance, durability, and easy manipulation;[1-4] however, this material presents great chromatic alteration with time,[2-7] and color is an important parameter the patient considers when evaluating the facial prosthesis.[2,6,8-14] Color degradation is a main reason to replace a facial prosthesis. The prostheses fabricated with elastomeric silicones are effective for only 6 months to 1 year.[4,15,16] Prosthesis color alteration results from exposure to ultraviolet light (UV), air pollution, pigments incorporated into the material, and use of solvents for prosthesis hygiene.[3,4,17-21]

In 1969, Cantor et al[22] evaluated the color of materials used for facial prostheses through reflection spectrophotometry. This method has been used to evaluate the color stability of maxillofacial elastomers.[14,23,24] Visual evaluations of the chromatic alteration of facial silicones are also described in the literature.[25]

In 1972, Sweeney et al[26] reported the use of an accelerated aging chamber for evaluation of maxillofacial material color stability. This device exposes specimens to radiation, temperature, and humidity similar to atmosphere.[1,3]

A prosthesis presents appropriate esthetics when the color of the skin is reproduced, and the prosthesis is not noticed surrounding the tissues.[6] According to this, several methods of pigmentation were tested to provide color stability for intrinsic and extrinsic pigmentations exposed to environmental factors.[18,27] Several methods for evaluation of color stability have been suggested; however, there is a lack of information regarding the effect of pigment on physical properties of elastomeric materials.[28]

In addition, deficient facial prosthesis hygiene allows infection on the subjacent tissues. So, facial prosthesis disinfection is essential for maintenance of the surrounding tissues.[1,2,29,30] The routine use of immersion denture cleaners such as Efferdent is recommended as an effective way to minimize biofilm accumulation and reduce bacteria and fungus;[31,32] however, this disinfection may alter the physical properties of the facial silicone.

Table 1 Systems of silicone pigmentation

Pigments	Chemical	Color	Manufacturer	Lot
Silastic MDX 4-4210	Inorganic	Colorless	Dow Corning Co., Midland, MI	0001798623
Makeup powder	Organic	Beige	Avon, São Paulo, Brazil	0021
Ceramic powder	Inorganic	Caramel	Clarart, Brasilia, Brazil	0012

Considering all these factors, the present study aimed to assess the color stability of a silicone used for facial prostheses submitted to chemical disinfection and accelerated aging for 252, 504, and 1008 hours.

Materials and methods

MDX4-4210 silicone (Dow Corning Corporation, Medical Products, Midland, MI,) was used to fabricate the replicas. Makeup and ceramic powder were used for intrinsic pigmentation of the silicone (Table 1).

The ISO specification[33,34] for nonaqueous elastomeric impression materials was used to fabricate the cylindrical metallic matrix (30 mm diameter, 6 mm height). Silicone was manipulated according to the manufacturer's instructions at $23 \pm 2°C$ and relative humidity of $50 \pm 10\%$. Sixty replicas were fabricated: 20 specimens pigmented with ceramic powder, 20 with makeup powder, and 20 colorless.

For the pigmented groups, the pigments were weighed in a digital precision balance, as 0.2%[3,25,35] of the weight of the silicone was necessary to fill the space of the metallic matrix. Each pigment was mixed with the silicone on a glass plate using a stainless steel spatula to obtain a homogeneous mixture.

The silicone, pigmented or not, was inserted in the matrix, and a spatula was passed on the surface to regularize the thickness. The external surface of the silicone Silastic MDX4-4210 in the matrix was exposed to the environment for 72 hours. After this period, each replica was carefully separated from the matrix to avoid distortion.[1–3,29]

The test of color stability of the replicas was carried out initially by a Spectrophotometer of Visible Ultraviolet Reflection, Model UV-2450 (Shimadzu, Kyoto, Japan) according to a method previously described.[2,3,36] Color alterations were calculated by the CIE L*a*b* system established by the *Comission Internacionale de I'Eclairaga--CIE.* The axial "L" represents brightness from 0 (black) to 100 (perfect white). The coordinate "a" represents the amount of red (positive values) and green (negative values), while coordinate "b" represents the amount of yellow (positive values) and blue (negative values). This system allows calculation of the ΔE value (variation of color) between two readings according to the following formula:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}.$$

Half the replicas of each group, pigmented or not, were submitted to disinfection with effervescent tablets (Efferdent, Pfizer Consumer Healthcare, Morris Plains, NJ),[1,2,29] and the other half with neutral soap (Johnson & Johnson, São Paulo, SP, Brazil),[30] three times per week, for 60 days.[1,2,29] For the groups submitted to disinfection with Efferdent, the replicas were immersed in a receptacle with the effervescent tablets dissolved in 250 ml of warm water for 15 minutes.[1,2,29] For the groups submitted to disinfection with water and neutral soap, the replicas were rubbed with soap with digital friction for 30 seconds followed by water washing.[30]

An additional color measurement was carried out after disinfection. The replicas were then submitted to accelerated aging.[37] The specimens were positioned in an accelerated aging chamber (Equilam, Diadema, Brazil) and submitted to alternated periods of UV light and condensation of distilled water. Each cycle of aging was carried out for 12 hours. During the first 8 hours, UV light was applied at $60 \pm 3°C$. Then, a period of condensation without light at $45 \pm 3°C$ occurred for 4 hours. According to this, 1008 hours of aging[3,17] were performed to simulate the deterioration caused by rainwater, dew, and exposure to sunlight UV energy (UVB) (direct and indirect sun energy). Therefore, the replicas were submitted to color measurements initially, after 60 days of disinfection, and after 252, 504, and 1008 hours of aging, totaling five measurements. The data for color change (ΔE) passed the normality test (Kolmogorov–Smirnov test) and were submitted to repeated measures ANOVA followed by Tukey's test ($p < 0.01$).

Results

The test of normality for the comparison of variation demonstrated no statistically significant differences, with resulting homoscedasticity. For values of $p > 0.05$, the null hypothesis was accepted.

All factors (pigment, period, and treatment) and the interaction between them were statistically significant ($p < 0.01$). Color alteration was observed between the materials regardless the period of aging (Table 2). The specimens disinfected with neutral soap exhibited higher ΔE values regardless of the type of pigmentation (Table 2). The colorless replicas and the specimens pigmented with ceramic exhibited statistically significant difference between the methods of disinfection (Efferdent or neutral soap) in all periods (Table 3); however, the specimens pigmented with makeup powder did not demonstrate a statistically significant difference between the methods of disinfection regardless the period of evaluation (Table 3).

Discussion

The results of this study indicate that pigment, disinfection, and environment influence the color stability of silicone MDX 4-4210, similar to that currently used for maxillofacial prostheses. Tables 2 and 3 show that disinfection and accelerated aging generated significant alterations on the chromatic pattern

Table 2 Mean values and standard deviation of color stability (ΔE) of silicone MDX4-4210 initial, after 60 days of disinfection (Efferdent or soap), and accelerated aging of 252, 504, and 1008 hours

Material		ΔE			
			Accelerated aging		
Disinfected	Pigmented	Disinfected 60 days	252 hours	504 hours	1008 hours
Soap	Ceramic	3.42 (0.26) Aa	3.47 (0.32) Aa	3.66 (0.45) Aa	15.77(0.41) Ab
	Colorless	2.82 (0.66) Ba	5.05 (0.49) Bb	5.64 (0.51) Bb	16.60 (0.69) Bc
	Makeup	3.60 (0.26) Aa	5.34 (0.68) Bb	14.59 (0.73) Cc	16.78 (0.46) Bd
Efferdent	Ceramic	2.08 (0.23) Aa	2.81 (0.26) Ab	2.94 (0.32) Ab	14.91 (0.39) Ac
	Colorless	1.70 (0.75) Aa	3.66 (0.50) Bb	7.06 (0.53) Bc	15.19 (0.60) Ad
	Makeup	3.25 (0.81) Ba	5.13 (0.80) Cb	14.23 (0.83) Cc	16.52 (0.68) Bd

Means followed by the same capital letter in the column and same small letter in the line do not differ statistically at 1% level of significance ($p < 0.01$) by Tukey's test.

of the replicas. Additionally, the ΔE values gradually increased with the periods of aging in all groups. The replicas pigmented with ceramic (inorganic pigment) exhibited lower ΔE values while the specimens pigmented with makeup (organic pigment) presented higher values, regardless of disinfection and accelerated aging. These color alterations result from environmental factors[2,3,21,25] and habits of the patient (i.e., smoking) that may pigment the silicones.[2,5,18,19] Furthermore, the continuous release of byproducts during silicone polymerization[2] leads to dimensional alteration of the silicone (shrinkage) as well as alteration of the chromatic pattern. The amount of these factors associated with different types of pollutants, solar radiation, level of humidity, and temperature variation represent an important effect on the materials.

Mancuso et al[3,25] also demonstrated lower values of chromatic alteration for replicas pigmented with ceramic pigments compared to specimens pigmented with makeup. According to the authors, this may be related to the particle size. The silicone presents a low level of cohesive energy, resulting in weak molecular interaction. Therefore, the small particles aggregate to the silicone, while the big particles easily separate.[3,25]

Replicas disinfected with neutral soap had higher ΔE values, with a statistical significance for the colorless specimens and those pigmented with ceramic (Table 3). This may result from removal of pigments that accumulate on the surface of the replicas, increasing the chromatic alteration.

The specimens disinfected with Efferdent presented the lowest ΔE values with statistical significance for the colorless replicas and those pigmented with ceramic. Alkaline peroxides, such as Efferdent and Polident, are commercial products widely used for complete denture hygiene. These products provide oxygen release to allow removal of fragments and staining.[2,31] According to this, although the oxygen-based commercial cleanings of dentures eliminate slight staining, they also whiten the prostheses. This fact has been confirmed by other studies.[2] The colorless and ceramic groups did not present significant whitening with Efferdent, with the lowest ΔE values (Table 2). This result is associated with the composition of the colorless silicone[1] and with the ceramic pigment, which is inorganic and presents greater color stability.[3,25]

The makeup (organic pigment) presents bigger particles that easily separate from the polymeric chain of the silicone,[3,25] which may lead to discoloration with both methods of disinfection (Efferdent or neutral soap). In this case, disinfection dissolved the pigments and generated greater color alteration (Table 3). In addition, the organic pigment exhibited greater degradation with accelerated aging, since these pigments dissolve in contact with UV light.[3,25]

Table 3 Mean values and standard deviation of color stability (ΔE) of silicone MDX4-4210 initial, after 60 days of disinfection (Efferdent or soap), and accelerated aging of 252, 504, and 1008 hours

Material		ΔE			
			Accelerated aging		
Pigmeted	Disinfection	Disinfected 60 days	252 hours	504 hours	1008 hours
Ceramic	Soap	3.42 A	3.47 A	3.66 A	15.77 A
	Efferdent	2.08 B	2.81 B	2.94 B	14.91 B
Colorless	Soap	2.82 A	5.05 A	5.64 A	16.60 A
	Efferdent	1.70 B	3.66 B	7.06 B	15.19 B
Makeup	Soap	3.60 A	5.34 A	14.59 A	16.78 A
	Efferdent	3.25 A	5.13 A	14.23 A	16.52 A

Means followed by the same letter in a column do not differ statistically at 1% level of significance ($p < 0.01$) by Tukey's test.

Considering disinfection with neutral soap, Reisbick and Matyas[4] and Thomas[14] suggested that digital friction on the prosthesis removes the pigments. It is likely that this removal of pigment from silicone generates color alteration.

In this study, accelerated aging resulted in significant chromatic alteration (Table 2). Some authors[17,28] have stated that this adverse response generated by aging results from three factors: solar radiation (clear energy), temperature, and water (humidity).[17,28] It is suggested that exposure to UV light alters the color of elastomers. This color alteration may be caused by inherent chemical alterations in silicone or discoloration of some pigments that are not UV resistant.[3,25]

The effect of accelerated aging on silicone is different from natural aging. The majority of elastomers indicated for facial prostheses are not exposed to the amount of humidity present in the process of artificial aging. Although artificial aging allows greater color alteration than natural aging, there is no definitive study correlating an aging chamber to the color alterations observed clinically during the same period. Additionally, no study demonstrates a minimum acceptable value of color alteration in facial prostheses.[20] Additional research is required to assess this correlation.

Conclusions

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The factors pigmentation, disinfection, and accelerated aging were statistically significant on the color stability of pigmented silicones ($p < 0.01$).
2. The ceramic pigment presented greater color stability, regardless of disinfection and period, statistically significant in comparison with the makeup pigment, which exhibited the highest values of chromatic alteration.

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