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Influence of Pigments and Opacifiers on Color Stability of an Artificially Aged Facial Silicone

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Abstract

Purpose: The aim of this study was to evaluate the influence of two pigments (ceramic powder and oil paint) and one opacifier (barium sulfate) on the color stability of MDX4–4210 facial silicone submitted to accelerated aging.
Materials and Methods: Sixty specimens of silicone were fabricated and divided into six groups—colorless (G1), colorless with opacifier (G2), ceramic (G3), ceramic with opacifier (G4), oil (G5), oil with opacifier (G6). All replicas were submitted to accelerated aging for 1008 hours. The evaluations of chromatic alteration through visual analysis and reflection spectrophotometry were carried out initially and after 252, 504, and 1008 hours of aging. The results were submitted to ANOVA and Tukey's test at 5% level of significance.
Results: All groups exhibited chromatic alteration ($\Delta E > 0$); however, this color alteration was not perceptible through visual analysis of the color. The pigmented groups with opacifier presented the lowest ΔE values, with a statistical difference from the other groups. For the groups without opacifier, the group pigmented with oil paint exhibited the lowest ΔE values in the different aging periods, with a statistical difference. Accelerated aging generated significant chromatic alterations in all groups after 252 hours, except for the colorless and oil groups, both with opacifier (G2 and G6).
Conclusions: The opacifier protects facial silicones against color degradation, and oil paint is a stable pigment even without addition of opacifier.

Maxillofacial deformities are embarrassing for the patient. These defects, which can be congenital or caused by trauma or surgery, generate physical and psychological trauma to the patient.[1-7]

Plastic surgery or autoplasty carried out in live tissue is a treatment choice more suitable than aloplastic or artificial repair when appropriate conditions are present.[8] Even with the development of surgical techniques recently, some congenital and acquired defects are restored with prostheses.[8,9]

Although the aim of a facial prosthesis is to restore esthetics and to improve the quality of life of the patient, it is important to inform the patient about the limitations of the materials to avoid disappointment when the final prosthesis is inserted.[10] Considering the need to use an appropriate material, prosthesis pigmentation has been a challenge to the profession, as external agents influence color stability.[2,3,7,11]

The color stability of several methods of pigmentation has been evaluated for both intrinsic and extrinsic pigmentations exposed to environmental factors.[12-14] The literature has demonstrated that adding some pigments and opacifiers increases the lifetime of the material,[13,15,16] preserving prosthesis esthetics and color stability during a longer wearing period.

The aim of this study was to evaluate the influence of two pigments (ceramic powder and oil paint) and one opacifier (barium sulfate) on the color stability of MDX4–4210 facial silicone submitted to accelerated aging.

Materials and methods

This study evaluated the color stability of MDX4–4210 elastomer (Dow Corning Corporation, Midland, MI) indicated for maxillofacial prostheses. Two inorganic pigments, ceramic powder (Clarart, Brasilia, Brazil) and oil paint (Acrilex, Sao Paulo, Brazil), and one barium sulfate-based opacifier (Wako, Osaka, Japan) were used for pigmentation of this silicone.

Sixty specimens of silicone were fabricated in an aluminum matrix with 10 holes (45-mm diameter, 2-mm thick).

Figure 1 Visual analysis of chromatic stability in the initial period and after 252, 504, and 1008 hours of accelerated aging.

The specimens were divided into six groups (n = 10): G1—colorless, G2—colorless + opacifier, G3—ceramic powder, G4—opacifier + ceramic powder, G5—oil paint, G6—opacifier + oil paint.

The colorless MDX4–4210 silicone, the pigments, and the opacifier were weighed in an analytic balance (Adventurer, Ohaus Corporation, Pine Brook, NJ) for the fabrication of the specimens. The pigments and the opacifier corresponded to 0.2% of the silicone weight.[12,13,15]

The silicones were proportioned and manipulated according to the manufacturer's instructions at a 23 ± 2°C controlled environment. Each pigment and the opacifier were mixed with the silicone using a stainless steel spatula on a glass plate to obtain a homogenous mass. After manipulation, the pigmented silicone and the nonpigmented silicone, with or without opacifier, were inserted into the matrix. The specimens of the MDX4–4210 silicone were kept in the matrix at room temperature for 3 days for polymerization according to the manufacturer's instruction.

Then, the specimens were submitted to the initial chromatic analysis by the Spectrophotometer of Visible Ultraviolet Reflection (Shimadzu, Kyoto, Japan) using the CIE L∗a∗b∗ system to measure the color alteration, as established by the *Comission Internacionale de I'Eclairaga—CIE*.[17] "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 for calculating the ΔE value (variation of color) between two readings according to the following formula

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

Color evaluation was carried out with D65 standard illumination with black background.[18] After the initial color reading, accelerated aging was performed in an aging chamber (Equilam, Diadema, Brazil) for nonmetallic specimens with UVB/condensation according to ASTM standard 53.[19]

Each aging period was carried out for 12 hours. Ultraviolet light at 60 ± 3°C was applied in the first 8 hours. In the remaining 4 hours, the water condensation procedure occurred without light at 45 ± 3°C.[3,20,21] This process is a simulation of the deterioration caused by water, such as rain or dew as well as exposure to ultraviolet light (UVB) and sunlight (direct and indirect). The specimens were exposed to 1008 hours of accelerated aging with measurements of chromatic alteration after 252, 504, and 1008 hours.

The method of visual analysis of color[3] was applied to assess the clinical viability of each material. So, three additional specimens (control) were made for each group. The first was not submitted to the aging process. It was kept in a dark box to avoid light incidence, and it was used to compare the specimens that experienced aging for 252, 504, and 1008 hours. The second specimen was submitted to aging for 252 hours, and it was kept in a dark box for comparison with those that experienced aging for 504 and 1008 hours. The remaining specimen was submitted to aging for 504 hours, and it was kept in a dark box to be compared with those submitted to aging for 1008 hours.

Two calibrated operators carried out the visual analysis among the specimens of the same group. The specimens of each group were placed on a dark metallic plate individually beside the control specimen. Visible color alterations were identified and recorded for posterior analysis of results[3] (Fig 1). The ΔE values were submitted to ANOVA, and the means were compared by Tukey's test at 5% level of significance.

Results

ANOVA revealed a statistically significant difference ($p < 0.05$) for periods and materials factors (Table 1). All materials

Table 1 Two-way ANOVA for color stability (ΔE)

Sources of variation	D.F.	S.S.	M.S.	F	*Prob. > F*
Period	2.0	92.94	18.59	<0.0001	195.8
Materials	5.0	3.751	1.876	<0.0001	34.55
Period × material	10.0	0.9804	0.09804	0.0679	1.806
Replicas (repeated)	54.0	5.127	0.09495	0.0071	1.749
Residue (error)	108.0	5.864	0.05429		
Total	179.0	108.7			

exhibited chromatic alteration regardless of the period of evaluation, $\Delta E > 0$ (Table 2). Color alteration was not perceptible during the visual analysis of the specimens.

The pigmented groups with opacifier (G2, G4, G6) presented the lowest ΔE values with a statistically significant difference when compared to the other groups, regardless of the aging period. In the groups without opacifier (G1, G3, G5), the group pigmented with oil paint (G5) presented the lowest ΔE values during aging, with a statistically significant difference. Accelerated aging generated significant chromatic alterations after 252 hours in all groups, except for the colorless (G2) and oil groups (G6), both with opacifier (Table 2).

Discussion

Although the mechanical and physical properties of the materials used for facial prostheses have improved recently, the color instability of these prostheses remains a challenge for the professional, because it may jeopardize the esthetics.[2,3,7,13,15,16] Facial prostheses made with silicone are effective from 6 months to 1 year and should be replaced due to color instability.[2-7,13-16]

In this study, all groups (Table 2) exhibited color alteration ($\Delta E > 0$) regardless of the period of evaluation, probably due to intrinsic and extrinsic factors.[22] The intrinsic factors include discoloration, resulting from the alteration of the elastomeric matrix[23] to oxidation of the double reactions of carbon that generate peroxide. Extrinsic factors like solar radiation, thermal variations, humidity, absorption, and adsorption of substances may also cause discoloration.[24,25] Nevertheless, this study demonstrated that the color instability of prostheses could be minimized by adding opacifier to the silicone matrix, as groups with opacifier (G2, G4, G6) presented the lowest ΔE values, with statistically significant difference in comparison to those groups without opacifier (G1, G3, G5) (Table 2). Similar results reported by other authors stated that opacifiers might protect facial silicones against color degradation,[13,15,26] can block UVB, and avoid degradation of the elastomeric matrix and other pigments.[26] Inorganic dry pigments, such as ceramic powder, are indicated for pigmentation of facial silicones due to the absence of atoms resulting from hydrogen and carbon in the molecular chain, which increases the color stability.[3,13,15,21]

Table 2 Means of color variation (ΔE) and standard deviation (SD) for each group and aging period

	ΔE (SD)		
Groups	252 hours	504 hours	1008 hours
G1	2.16 (0.25) A a	2.29 (0.31) A ab	2.49 (0.44) A b
G2	0.62 (0.15) B a	0.75 (0.18) B a	0.80 (0.12) B a
G3	2.24 (0.53) A a	2.41 (0.24) A ab	2.65 (0.22) A b
G4	0.62 (0.20) B a	0.96 (0.13) B b	1.06 (0.08) B b
G5	1.03 (0.34) C a	1.48 (0.17) C b	1.64 (0.21) D b
G6	0.66 (0.17) B a	0.71 (0.28) B a	0.80 (0.21) B a

Means followed by the same capital letter in a column and same lowercase letter in a row do not differ statistically ($p < 0.05$) by Tukey's test.

An increase in color stability was observed in this study, as there was no significant difference between the values of color alteration of the ceramic group, with and without opacifier (G3 and G4), and the colorless group, with and without opacifier (G1 and G2) for any aging period (Table 2). This may suggest that the chromatic alteration occurred in the silicone matrix; however, the clinical use of ceramic pigments on facial prostheses is limited, as they present a different shade when compared to human skin. Other widely used inorganic pigments are the oil-based pigments with many tonalities, which improve the pigmentation of the maxillofacial prostheses and provide proper esthetics.[13,15]

Usually, these pigments contain linseed oil that generates a protective film on the particles of the pigment.[13,15] It is probable that this protection was responsible for the results of this study, because among the groups without opacifier (G1, G3, G5) the group pigmented with oil paint (G5) showed the lowest values of chromatic alteration, with statistically significant difference for all aging periods.

Aging after 252 hours generated significant chromatic alterations in all groups (Table 2), except for groups G2 and G6, due probably to the presence of opacifier and linseed oil. To many authors,[20,27] this degradation generated by material aging results from three factors: solar radiation (light energy), temperature, and water (humidity).[20,27] It is suggested that exposure to UVB alters the color of elastomers. This color alteration may result from chemical alterations in the silicone or by discoloration of some pigments that are not UV-resistant.[3,21,28]

Although reflection spectrophotometry has revealed chromatic alterations in all specimens ($\Delta E > 0$), these alterations were not perceptible during the visual analysis regardless of the aging period or pigment types. This result was also observed by Mancuso et al,[3] who demonstrated the maintenance of color stability of facial silicone during 1 year of clinical use.

Conclusion

It was concluded that opacifier protects facial silicone against color degradation, and oil paint is a stable pigment even without adding opacifier.

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