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Effect of Chemical Disinfection and Accelerated Aging on Color Stability of Maxillofacial Silicone with Opacifiers

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Abstract

Purpose: The purpose of this study was to evaluate the color stability of MDX4-4210 maxillofacial elastomer with opacifier addition submitted to chemical disinfection and accelerated aging.
Materials and Methods: Ninety specimens were obtained from Silastic MDX4-4210 silicone. The specimens were divided into three groups (n = 30): Group I: colorless, Group II: barium sulfate opacifier, Group III: titanium dioxide opacifier. Specimens of each group (n = 10) were disinfected with effervescent tablets, neutral soap, or 4% chlorhexidine gluconate. Disinfection was conducted three times a week for 2 months. Afterward, the specimens were submitted to different periods of accelerated aging. Color evaluation was carried out after 60 days (disinfection period) and after 252, 504, and 1008 hours of accelerated aging, using a reflection spectrophotometer. Color alterations were calculated by the CIE L*a*b* system. Data were analyzed by three-way ANOVA and Tukey test ($\alpha = 0.05$).
Results: Group II exhibited the lowest color change, whereas Group III the highest ($p < 0.05$), regardless of the chemical disinfection and accelerated aging periods.
Conclusion: Opacifier addition, chemical disinfection, and accelerated aging procedures affected the color stability of the maxillofacial silicone.

Several factors including shape, volume, position, texture, and transparency of the patient's features must be precisely reproduced during maxillofacial prosthesis fabrication. Although prosthetic technicians usually choose good materials to manufacture prostheses, they often have great difficulty in reproducing the color of a patient's skin.[1] Due to external agents, changes in color occur, resulting in prostheses that do not match the patient's skin, hence compromising the dissimulation of the facial defect.[2]

Silicone elastomers are the material of choice[3] because of their chemical inertness, strength, durability, and ease of manipulation.[4] Nevertheless, silicone elastomers and pigments present color change over time.[5,6] Color instability of the prosthesis may be attributed to ultraviolet (UV) light exposure, air pollution, cosmetics, and the use of strong solvents to clean the prosthesis, such as benzene and xylene.[7,8]

In this context, several methods of both intrinsic and extrinsic color pigmentation have been tested for color stability when the material is exposed to external factors.[5,9,10] Some authors stated that using opacifiers[10-12] could protect the color degradation of silicone elastomers. Titanium dioxide is an opacifier used in cosmetics, and paper and plastics manufacture, since it can promote whiteness and protection against the chromatic alterations caused by UV-B radiation. This opacifier has been added to facial elastomers to promote color stability over time.[10,12] Barium sulfate is a white powder used to help doctors to examine the esophagus, stomach, and intestine using x-rays or computed tomography. Also, it is added to root-end filling material to confer higher radiopacity to be visualized radiographically.[13] Barium sulfate is used in sunscreen lotions to create a physical barrier against UV rays and to provide better appearance of the product.[11] However, few scientific investigations in the dental literature concern opacifiers and maxillofacial materials.

Effervescent tablets, neutral soap, and chlorhexidine gluconate are used for disinfection of impressions,[14,15] dental prostheses,[16] and maxillofacial prostheses.[6,8,17] However, no study that investigated the interactions of both opacifiers and chemical disinfectant substances on the color stability of MDX4-4210 has been identified.

The purpose of this investigation was to evaluate the effect of chemical disinfection methods and accelerated aging on the color stability of MDX4-4210 facial silicone colored with titanium dioxide and barium sulfate opacifiers. The hypothesis of the present study was that the addition of these opacifiers promotes color stability of the facial silicone even after disinfection and accelerated aging.

Materials and methods

Silastic MDX4-4210 (Dow Corning Corporation, Midland, MI) was used to fabricate the specimens. Barium sulfate (Wako, Osaka, Japan) and titanium dioxide (Homeofar, Catanduva, Brazil) were added intrinsically to silicone.

A metallic cylindrical matrix (30-mm diameter, 3-mm thick) was used to obtain the specimens.[6] A total of 90 specimens were fabricated, and they were divided into three groups ($n = 30$), according to opacifier: GI—colorless, GII—barium sulfate opacifier, and GIII—titanium dioxide opacifier.

Both the opacifiers and the silicone were weighed using a precision digital scale (BEL Analytical Equipments, Piracicaba, Brazil). The opacifier weight was equivalent to 0.2% of the total weight of the silicone.[9,18-21]

The silicone was manipulated according to manufacturer's instructions. Each opacifier was incorporated to silicone on a glass slab with a stainless steel spatula until a homogenous mixture was obtained. The silicone was then inserted in the master mold, and the excess was removed with a spatula to maintain a regular thickness. Silastic MDX4-4210 material was confined in the matrix with the external surface exposed to the environment for 3 days, according to the manufacturer's instructions. The material is partially cured after 24 hours, allowing its handling, but final cure following the release of formaldehyde occurs within approximately 3 days, according to the manufacturer.[6,18,19] After this period, each specimen was carefully removed from the metallic matrix.[6,8,17-21]

All the test specimens obtained were submitted to initial chromatic analysis by means of a Visible Ultraviolet Reflection Spectrophotometer, Model UV-2450 (Shimadzu, Kyoto, Japan). The color alterations were calculated using the CIE L*a*b* system, established by the Commission Internationale de l'Eclairage—CIE.[6,19,20-22] This system allows calculation of the mean value of ΔE (color variation) between two readings by the formula:

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

After the initial color test, all specimens were stored in a black box without light.[6,8,17] The specimens were disinfected three times per week for 2 months.[6,8,17] Specimens of each group ($n = 10$) were disinfected with effervescent tablets (Efferdent, Pfizer Consumer Health, Morris Plains, NJ),[6,8,17] neutral pH soap (Johnson & Johnson, Sao Jose dos Campos, Brazil)[6,8,17] or with 4% gluconate chlorhexidine (Cl—Naturativa, Araçatuba, Brazil).[16]

Specimens were immersed in a solution of warm water and an Efferdent effervescent tablet for 15 minutes and rinsed in running water at an initial temperature of 37°C.[6,8,17] Specimens were cleaned with neutral soap and rubbed with the fingertips for 30 seconds, then rinsed with water for 30 seconds.[6,8,17] Specimens immersed in a solution of 4% chlorhexidine gluconate were immersed in this solution for 10 minutes and rinsed in running water.[15]

Table 1 Results of three-way repeated measures ANOVA

Source	df	SS	MS	F	*p*
Disinfection	2	14.3	7.2	21.2	< 0.0001*
Opacifier	2	300.5	150.3	444.4	< 0.0001*
Disinfection × opacifier	4	30.6	7.6	22.6	< 0.0001*
Between subjects	81	27.4	0.3		
Aging	3	67.9	22.6	221.4	< 0.0001*
Aging × disinfection	6	3.0	0.5	4.9	0.0001*
Aging × opacifier	6	34.3	5.7	56.0	< 0.0001*
Aging × disinfection × opacifier	12	11.2	0.9	9.1	< 0.0001*
Within subjects	243	24.8	0.1		

*$p < 0.05$ denotes statistically significant difference.

After simulated disinfection, a new chromatic analysis was performed. Afterward, the accelerated aging was carried out using an aging chamber (Equilam, Diadema, Brazil). The test specimens were submitted to periods of alternating UV light and condensation of distilled water saturated with oxygen under conditions of heat and 100% humidity. Each aging cycle was performed for 12 hours. In the first 8 hours, UV light was irradiated at a temperature of 60 ± 3°C. In the next 4 hours, a period of condensation took place without light at a temperature of 45 ± 3°C. This process simulated the deterioration caused by rain water, as well as dew and UV energy (UV-B) from direct and indirect sunlight.[18-21]

The chromatic analysis was performed after 252, 504, and 1008 hours of accelerated aging.[20,21] The chromatic change (ΔE) values were analyzed by three-way ANOVA, and means were compared by Tukey's test ($p < 0.05$).

Results

Silastic MDX4-4210 mean color alteration (ΔE) values are shown in Tables 1 and 2 and in Fig 1. Three-way ANOVA (Table 1) showed that the disinfection, opacifier, aging factors, and their interactions were statistically significant ($p < 0.05$).

Table 2 Mean values (SD) of ΔE for Silastic, in the groups with different chemical disinfections

		Groups		
Period	Disinfectant	GI	GII	GIII
60 days	Ef	0.55(0.22)	0.89(0.03)	1.22(0.59)
	Ns	1.01(0.5)	0.58(0.24)	1.84(0.32)
	Cl	1.14(0.44)	0.93(0.29)	2.53(0.2)
252 hours	Ef	1.39(0.11)	1.29(0.24)	2.56(0.3)
	Ns	2.04(0.31)	0.65(0.21)	3.67(0.45)
	Cl	0.8(0.39)	1.74(0.32)	3.99(0.47)
504 hours	Ef	1.39(0.38)	0.91(0.2)	3.18(0.43)
	Ns	1.97(0.5)	1.12(0.47)	3.96(0.45)
	Cl	1.17(0.32)	1.45(0.32)	4.13(0.61)
1008 hours	Ef	1.57(0.24)	1.36(0.27)	3.32(0.42)
	Ns	2.07(0.47)	1.27(0.46)	4.23(0.53)
	Cl	1.63(0.5)	1.3(0.16)	4.11(0.44)

Ef = Efferdent; Ns = neutral soap; Cl = chlorhexidine.

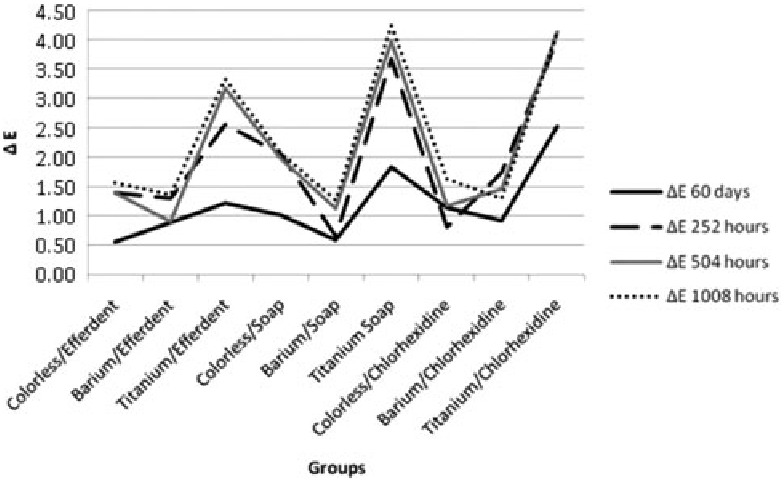

Figure 1 Mean ΔE values of Silastic for measurement periods.

The color alteration level increased after each accelerated aging period (Fig 1). In general, GII group disinfected with effervescent tablets and neutral soap presented the lowest color alteration, whereas the GIII group disinfected with neutral soap and chlorhexidine exhibited the highest color change (Fig 1, Table 2).

Discussion

The research hypothesis was rejected since all groups presented color change after chemical disinfection and accelerated aging. Opacifiers are incorporated in facial silicone during the intrinsic pigmentation of the prosthesis. Some studies reported that the association of opacifiers and facial silicones increases prosthesis longevity, since the prosthesis' color stability is maintained for a long time.[10,12,21,23]

Among the different types of opacifiers, titanium dioxide has shown the best results.[12,23] The use of barium sulfate promoted satisfactory results regarding the color stability of facial prostheses,[21] but this method was not associated with chemical disinfection.

The results of the present study showed that both colorless and opacifier-pigmented silicone treatments exhibited color alteration ($\Delta E > 0$) after simulated chemical disinfection and accelerated aging (Fig 1, Table 2). Therefore, the colorless silicone (GI group) underwent changes when exposed both to different substances commonly used for cleaning prostheses, and to extreme weather conditions such as UV-B radiation and cycles of water condensation in the accelerated aging chamber.[20,24] These results are in accordance with other studies[20,24] that colorless silicone exhibited chromatic alteration regardless of the addition of pigments and opacifiers.

The specimens with barium sulfate presented the lowest color alteration, mainly those disinfected with effervescent tablets and neutral soap (Fig 1, Table 2). The use of alkaline peroxide effervescent tablets to clean facial prostheses should be avoided because this substance can promote color alteration of prostheses by removing pigments from the superficial layer of the silicone using the oxygen release mechanism.[6,26] Others have claimed that neutral soap can also remove pigments from the superficial layer of the silicone since this technique is based on mechanical methods such as finger friction and brushing.[6,27]

Therefore, it can be assumed that the results of the present study are justified by the linking between the barium sulfate and the silicone. The smaller the pigment particle, the higher its interaction with the polymeric chain of the silicone.[18,19] We believe that the present opacifier presents extremely small load particles, which strongly link with the colorless silicone, and they are not removed either by the action mechanism of the hydrogen peroxide in effervescent tablets or by the mechanical action of the neutral soap disinfection technique.[20]

Considering that the polymers used to fabricate the facial prostheses exhibit the greatest color change in the first days after curing,[20] it can be considered that the alterations resulted from accelerated aging. Since the opacifier was not removed during the chemically simulated disinfection procedure, its protective action against UV-B radiation is expected. This fact supports the present result after accelerated aging, considering that opacifiers act as a physical barrier reflecting the UV rays that reach the prosthesis and preventing deterioration of the silicone,[27-29] as observed in the ΔE values of the GI group.

On the other hand, greater color alteration was observed in the GIII group, mainly after disinfection with neutral soap and chlorhexidine (Fig 1, Table 2). The titanium dioxide particles may be larger than those from barium sulfate,[18,19] and may promote a weak link with the silicone. Therefore, the repeated disinfection procedure by digital friction removes the pigments from the superficial layer of the silicone, promoting color alteration of the specimens, since some pigments remain in the superficial layer and deteriorate when exposed to these procedures.[2]

Chlorhexidine can cause dental staining[30] and color alteration of lining materials of complete dentures.[31] After 60 days of disinfection, the groups disinfected with chlorhexidine did not exhibit the highest color change, but after the accelerated aging, significantly greater color instability was observed in this group compared to the other groups (Fig 1, Table 2). Therefore, the repeated disinfection procedure with chlorhexidine may expose the opacifiers, particularly titanium dioxide, which presented the highest color change after accelerated aging. The exposed opacifier is more susceptible to color changes caused by UV radiation from the accelerated aging chamber.

The accelerated aging chamber simulates the exposure of the prosthesis to severe weather, UV rays, and temperature changes.[12,18-20] The period of 1008 hours of accelerated aging corresponds to 1 year of clinical use of the prosthesis.[18]

Color measurement by spectrophotometry is a reliable, sensitive, and repeatable method; however, some color changes detected by this method can not be observed visually.[31] Only ΔE values higher than 3 can be detected by the human eye.[31] Therefore, only the GIII group exhibited visual color alteration.

Further studies to evaluate the mechanism of interaction between the opacifier particles and the polymeric chain of the silicone are required. In addition, the interaction among both barium sulfate and titanium dioxide opacifiers with pigments and disinfectants should be analyzed, since this is a clinical condition of maxillofacial prostheses.

Conclusion

Considering the limitations of the present in vitro study, the following conclusions can be drawn.

(1) Chlorhexidine promoted the greatest color alteration of the facial silicone compared to the other disinfectants.
(2) Accelerated aging affected the color stability of all groups.
(3) The barium sulfate opacifier was more stable in all periods.

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