Clinical study on the maxillofacial prosthodontic treatment using dental implant: Part I-Color stability of maxillofacial elastomeric materials

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I. INTRODUCTION

Maxillofacial defects can be divided into congenital defects such as cleft palate and acquired defects from traumatic accident and disease. Acquired maxillofacial defects are tend to increase by various kinds of accidents and by results of cancer surgery for maxillofacial region. In early age, the treatment for maxillofacial defects is only for restoration of defects area, but today, the treatment is more complex and elaborate according to the development of reconstructive surgical treatment and rehabilitation.

And according to the lengthening of the life span, the desire for improvement of the quality of the life gave the new goal to the prosthodontic field. So the prosthetic rehabilitation should be developed toward the goal for better esthetics and function.

Modern materials for external prostheses include vinyl plastisols, poly(methyl methacrylate), polyurethanes, latex and silicone polymers[1]. Following the introduction of silicones into facial prosthetics in 1960, there was a rapid development and introduction into the market-place of various types of silicones for facial prosthetic applications[2,3].

The properties of the ideal facial prosthetic material may be listed as follows[4]: nonirritant, pliability, weight, color, hygiene, durability, thermal conductivity, manipulation, texture and availability. From a practical point, the material requirements for a prosthesis can be translated into final appearance, durability, ease of processing, and safety in both processing and wearing[5].

Silicone elastomers were first used for external prostheses by Barnhart in 1960 and have since become the material of choice because of their chemical inertness, strength, durability, and ease of manipulation[1].

Many investigations have been performed studies on the materials for maxillofacial prostheseses. Pigno et al.[6] studied on the efficacy of antifungal agents incorporated into a fa-

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cial prosthetic silicone elastomer. Haug et al.[7] investigated on the physical properties of the maxillofacial elastomers. Lemon et al[8]. studied on the color stability of facial prostheses. The limited service of facial prostheses is a result of the rapid degradation of the elastomer and its color instability[8].

The purpose of this study was to investigate the the color stability of the silicone elastomers that were tinted with dry pigments for maxillofacial prostheses under various environments. Color changes were measured with colorimeter(Model TC-6FX, Tokyo Denshoku Co., Japan) using CIE-Lab system.

II. MATERIAL AND METHODS

1. sample preparation and material manipulation

The elastomers used in this study were MDX 4-4210 Elastomer(Dow Corning, Midland, Mich.) and A-2186 Silicone elastomer(Factor II, Lakeside, Ariz.). The Dry Pigments used in this study were Mars violet, Golden yellow as dry pigments, and Red yellow, Raw sinna as cosmetic pigments(Table 1). For preparation of specimens, one of four dry or cosmetic pigments was mixed into the MDX4-4210 or A-2186 base elastomer at 0.2% by weight[9]. The base and catalyst of elastomers were combined in a 10:1 ratio by weight, placed in container and mixed in vacuum mixer to remove any bubble. The mixture was poured into ready made brass mold which was precoated with a Silicone mold release(A-416, Factor II Inc., Lakeside, Az)as separating agent. Lid was placed and to extrude excess material, a load of 1 Kg was applied. Disc shaped specimens with dimensions 15mm X 1.5mm thickness were produced. After polymerization the specimens were removed from the mold and trimmed carefully with scissors. The number of specimens for each group was twenty five. After samples were prepared, the baseline color measurement were recorded and regarded it as control group, and all specimens were divided into five groups as experimental group: the first group that was therocycycled between 5°C to 55°C for 24 hours(700 times), a second group that was thermocycled in 10% soap solution for 24hours(700 times), a third group that was to be soaked in 10% soap solution in room temperature, and fourth group that was to be kept in darkness for 75 days, and the last fifth group that was to be exposed to sun light for 75 days.

2. color measurement

The color measuring system used in this study was colorimeter(Model TC-6FX, Tokyo Denshoku Co., Japan). Color changes(ΔE^*) were calculated by measuring tristimulus values at several wavelengths in the visual spectrum with the use of the Commision

Table 1. Elastomers and dry pigments used in this study

Material	Type	Manufacturer
MDX 4-4210	Silicone elastomer	Dow Corning, Midland, Mich.
A-2186	Silicone elastomer	Factor II, Lakeside, AZ
Mars violet	Dry pigment	Factor II, Lakeside, AZ
Golden yellow	Dry pigment	Factor II, Lakeside, AZ
Red yellow	Cosmetic pigment	Factor II, Lakeside, AZ
Raw sienna	Cosmetic pigment	Factor II, Lakeside, AZ

International de l'Eclairge L* a* b* (CIE-LAB) uniform color scale. This system represents a three dimensional color space having components of lightness(L*), red-green(a*), and yellow-blue(b*). An important aspect of the CIE-LAB system is that color differences between specimens can be given a single parameter, ΔE^*ab.

The formula of color difference is calculated as follows:

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

Mean values were calculated for each material and group and compared statistically with one way analysis of variance and calculating Scheff'e intervals at 0.95[10].

III. RESULTS

Color changes that occured for all specimens are presented in Table2-9. There were statistical significance among the control group and five experimental groups in all specimens($P<0.01$). The L* values of all experimental group were reduced compared with control group, so that they got darkness(Table 2,6). In most specimens the a* values were increased, but there were no statistical difference between control group and some of experimental group 3,5,6(Table 3,7). The values of b* were decreased in experimental group 1,2,3, but increased in most of group 4,5(Table 4,8). There were no statistical differences between control group and most of group 3,4,5(Table 5,9).The color changes(ΔE^*)

Table 2. Mean and S.D. of L* value

Pigment	Silicone	Control	Group 1	Group 2	Group 3	Group 4	Group 5
Golden Yellow	A 2186	56.88(0.45)	55.38(0.37)	55.60(0.57)	545.47(0.74)	54.99(0.37)	54.81(0.40)
	MDX4-4210	55.15(0.94)	53.73(0.53)	54.11(0.81)	54.16(0.35)	52.78(1.13)	53.47(0.41)
Red Yellow	A-2186	39.20(0.43)	37.57(0.48)	38.01(0.43)	37.56(0.34)	36.50(0.63)	37.73(0.46)
	MDX4-4210	37.64(0.87)	36.81(0.21)	36.92(0.54)	36.49(0.55)	34.80(1.17)	36.58(0.24)
Raw Sienna	A-2186	37.29(0.43)	35.45(0.36)	35.98(0.48)	35.60(0.29)	34.38(0.54)	34.97(0.65)
	MDX4-4210	37.20(0.37)	35.93(0.29)	36.05(0.42)	35.75(0.65)	35.41(0.27)	36.03(0.29)
Mars Violet	A-2186	26.78(0.46)	24.95(0.55)	25.07(0.46)	24.85(0.49)	23.25(0.33)	25.25(0.47)
	MDX4-4210	26.14(0.97)	24.69(0.39)	25.95(0.45)	25.01(0.45)	23.45(0.40)	24.32(0.49)

Table 3. Mean and S.D. of a* value

Pigment	Silicone	Control	Group 1	Group 2	Group 3	Group 4	Group 5
Golden Yellow	A 2186	-4.69(0.51)	-1.39(0.45)	-1.27(0.57)	-2.15(0.54)	-1.53(0.53)	-2.19(0.47)
	MDX4-4210	-4.09(0.52)	-1.10(0.41)	-1.12(0.45)	-2.65(0.29)	-2.90(0.66)	-2.78(0.43)
Red Yellow	A-2186	24.82(0.64)	27.92(0.45)	27.59(0.42)	26.00(0.66)	27.46(0.65)	25.89(0.63)
	MDX4-4210	22.65(0.56)	24.93(0.33)	24.26(0.41)	23.02(0.53)	22.80(0.71)	22.78(0.41)
Raw Sienna	A-2186	2.67(0.60)	6.23(0.40)	5.94(0.75)	3.52(0.61)	4.09(0.52)	3.55(0.70)
	MDX4-4210	3.56(0.50)	5.73(0.60)	5.82(0.46)	3.27(0.43)	2.99(0.53)	2.83(0.43)
Mars Violet	A-2186	13.35(1.08)	17.49(1.34)	17.20(1.01)	13.29(0.79)	14.91(1.48)	13.45(0.91)
	MDX4-4210	12.90(1.09)	15.89(1.16)	13.94(0.99)	11.82(1.10)	12.76(1.15)	12.11(0.84)

were greater in MDX4-4210 materials pigmented with Red yellow and with Mars Violet in group 2 as 2.07 and 2.54(Table 9).

In order to get the differences of color change in MDX4-4210 and A-2186 regardless of pigments and experimental condition, the

Table 4. Mean and S.D. of b* value

Pigment	Silicone	Control	Group 1	Group 2	Group 3	Group 4	Group 5
Golden Yellow	A 2186	42.03(0.70)	40.40(0.65)	39.21(0.80)	39.40(0.94)	42.05(2.53)	41.33(0.82)
	MDX4-4210	39.07(0.77)	37.82(0.80)	36.99(0.83)	38.57(0.63)	38.86(0.36)	39.25(0.74)
Red Yellow	A-2186	30.78(0.90)	29.38(1.07)	28.97(1.18)	30.68(1.05)	32.43(2.01)	30.70(1.09)
	MDX4-4210	25.83(0.88)	24.76(0.69)	23.82(0.54)	25.59(0.95)	27.17(0.90)	28.87(0.77)
Raw Sienna	A-2186	17.90(0.66)	16.87(0.57)	17.31(5.82)	17.35(0.50)	18.27(1.04)	18.21(0.94)
	MDX4-4210	15.72(0.61)	15.07(0.49)	13.95(0.62)	15.61(0.54)	16.11(0.61)	16.07(0.46)
Mars Violet	A-2186	9.83(0.93)	8.31(0.83)	8.18(0.87)	10.06(1.08)	10.39(1.10)	10.33(0.89)
	MDX4-4210	7.45(0.68)	6.10(0.62)	5.59(0.79)	6.76(0.66)	7.99(0.76)	8.64(0.81)

Table 5. Mean and S.D. of ⊿E* value

Pigment	Silicone	Control	Group 1	Group 2	Group 3	Group 4	Group 5
Golden Yellow	A 2186	57.61(0.56)	57.16(0.60)	56.34(0.56)	56.56(0.84)	58.62(0.63)	57.95(0.67)
	MDX4-4210	57.58(0.64)	56.52(0.31)	56.15(0.65)	56.83(0.54)	57.58(0.91)	57.38(0.35)
Red Yellow	A-2186	72.93(0.87)	72.08(0.72)	71.31(0.75)	71.68(0.73)	73.58(1.53)	71.06(0.79)
	MDX4-4210	71.21(0.75)	69.83(0.33)	69.14(0.57)	69.65(0.74)	70.87(0.91)	69.46(0.32)
Raw Sienna	A-2186	64.37(0.40)	63.77(0.42)	63.19(0.55)	63.64(0.34)	64.91(0.74)	63.81(1.13)
	MDX4-4210	63.76(0.43)	62.90(0.36)	62.54(0.37)	63.07(0.71)	62.72(0.28)	62.15(0.38)
Mars Violet	A-2186	75.15(0.57)	74.64(0.80)	74.44(0.43)	73.98(0.59)	75.79(0.45)	73.22(0.59)
	MDX4-4210	75.11(0.45)	74.42(0.56)	72.57(0.55)	73.31(0.59)	74.40(0.53)	73.59(0.50)

Table 6. Difference between control and experimental group in L* value

Pigment	silicone	Group 1	Group 2	Group 3	Group 4	Group 5	Total
Golden Yellow	A 2186	1.50 *	1.28 *	1.41 *	1.89 *	2.07 *	8.15
	MDX 4-4210	1.42 *	1.04 *	0.99 *	2.37 *	1.68 *	7.50
Red Yellow	A-2186	1.63 *	1.19 *	1.64 *	2.70 *	1.47 *	8.63
	MDX 4-4210	0.83 *	0.72 *	1.15 *	2.84 *	1.06 *	6.60
Raw Sienna	A-2186	1.84 *	1.31 *	1.69 *	2.91 *	2.32 *	10.07
	MDX 4-4210	1.27 *	1.15 *	1.45 *	1.79 *	1.17 *	6.83
Mars Violet	A-2186	1.83 *	1.71 *	1.93 *	3.53 *	1.53 *	10.53
	MDX 4-4210	1.45 *	0.19 NS	1.13 *	2.69 *	1.82 *	7.28
Subtotal	A-2186	6.80	5.49	6.67	11.03	7.39	37.38
	MDX4-421010	4.97	3.10	4.72	9.69	5.73	28.21
Total		11.77	8.59	11.39	20.72	13.12	65.59

* : Significant between control and experimental group($p<0.05$)

NS: not significant between control and experimental group total amount of changes were put together. And in order to compare the difference of change among five experimental group, the amount of change of all specimens were put together also.

The sum of amount of change of L* and that of a* value in MDX4-4210 was lesser than that of A-2186(Table 6,7), the sum of amount of change of ΔE* in MDX4-4210 was greater than that of A-2186(Table 9), and those of b* values of MDX4-4210 and A-2186 were similar(Table 8).

The sum of amount of change of L* value regardless of type of silicone materials and pigments was the greatest in experimental group 4(Table 6), and that of change of a* value was the greatest in experimental group 1(Table 7), and that of change of b* and ΔE* values were the greatest in experimental group 2(Table 8,9).

Table 7. Difference between control and experimental group in a* value

Pigment	silicone	Group 1	Group 2	Group 3	Group 4	Group 5	Total
Golden Yellow	A 2186	3.30 *	3.42 *	2.54 *	3.16 *	2.50 *	14.92
	MDX 4-4210	2.99 *	2.97 *	1.44 *	1.19 *	1.31 *	9.90
Red Yellow	A-2186	3.10 *	2.77 *	1.18 *	2.64 *	1.07 *	10.76
	MDX 4-4210	2.28 *	1.61 *	0.37 NS	0.15 NS	0.13 NS	4.54
Raw Sienna	A-2186	3.56 *	3.27 *	0.85 *	1.42 *	0.88 *	9.98
	MDX 4-4210	2.17 *	2.17 *	-0.29 NS	-0.57 *	-0.73 *	5.93
Mars Violet	A-2186	4.14 *	3.85 *	-0.06 NS	1.56 *	0.10 NS	9.71
	MDX 4-4210	2.99 *	1.04 *	-1.08 *	-0.14 NS	-0.79 NS	6.04
Subtotal	A-2186	14.1	13.31	4.63	8.78	4.55	45.37
	MDX4-4210	10.43	7.79	3.18	2.05	2.96	26.41
Total		25.53	21.10	7.81	10.83	7.51	71.78

* : Significant between control and eperimental group($p<0.05$)

NS: not significant between control and experimental group

Table 8. Difference between control and experimental group in b* value

Pigment	silicone	Group 1	Group 2	Group 3	Group 4	Group 5	Total
Golden Yellow	A 2186	-1.63 *	-2.82 *	-2.63 *	0.02 NS	-0.70 *	7.80
	MDX 4-4210	-1.25 *	-2.08 *	-0.50 NS	-0.21 NS	0.18 NS	4.22
Red Yellow	A-2186	-1.40 *	-1.81 *	-0.10 NS	1.65 *	-0.08 NS	5.04
	MDX 4-4210	-1.07 *	-2.01 *	-0.24 NS	1.34 *	3.04 *	7.70
Raw Sienna	A-2186	-1.03 *	-0.59 *	-0.55 NS	0.37 NS	0.31 NS	2.85
	MDX 4-4210	-0.65 *	-1.77 *	-0.11 NS	0.39 *	0.35 NS	3.27
Mars Violet	A-2186	-1.52 *	-1.65 *	0.23 NS	0.56 NS	0.50 NS	4.46
	MDX 4-4210	-1.35 *	-1.86 *	-0.69 *	0.54 NS	1.19 *	5.63
Subtotal	A-2186	5.58	6.87	3.51	2.60	1.59	20.15
	MDX4-4210	4.32	7.72	1.54	2.48	4.76	20.82
Total		9.90	14.59	5.05	5.08	6.35	40.97

* : Significant between control and eperimental group($p<0.05$)

NS: not significant between control and experimental group

Table 9. Difference between control and experimental group in ΔE^* value

Pigment	silicone	Group 1	Group 2	Group 3	Group 4	Group 5	Total
Golden Yellow	A 2186	-0.45 NS	-1.27 *	-1.05 *	1.01 *	0.34 *	4.12
	MDX 4-4210	-1.06 *	-1.43 *	-0.75 *	-0.00 NS	-0.20 *	3.44
Red Yellow	A-2186	-0.85 *	-1.62 *	-1.25 *	0.65 NS	-1.87 *	6.24
	MDX 4-4210	-1.38 *	-2.07 *	-1.56 *	-0.34 NS	-1.75 *	7.10
Raw Sienna	A-2186	-0.60 *	-1.18 *	-0.73 *	0.54 *	-0.56 *	3.61
	MDX 4-4210	-0.86 *	-1.22 *	-0.69 *	-1.04 *	-1.61 *	5.42
Mars Violet	A-2186	-0.51 *	-0.71 *	-1.17 *	0.64 *	-1.93 *	4.96
	MDX 4-4210	-0.69 *	-2.54 *	-1.08 *	-0.71 *	-1.52 *	7.26
Subtotal	A-2186	2.41 *	4.78 *	4.20	2.84	4.70	18.93
	MDX4-4210	3.99	7.26	4.80	2.09	5.08	23.22
Total		6.40	12.04	9.00	4.93	9.78	42.15

* : Significant between control and eperimental group($p<0.05$)

NS: not significant between control and experimental group

V. DISCUSSION

The currently available maxillofacial prostheses materials can be divided into three groups: methacrylate resin, polyurethane elastomers, and silicone elastomers. Silicone materials are now a popular materials for maxillofacial prostheses, and they have to have several properties for success in prostheses. One of the requirements of the ideal maxillofacial prosthetic materials is color stability[4,5]. But the limited service of facial prostheses is a result of the rapid degradation of the elastomer and its color instability[6,8]. Deterioration is mainly caused by environmental exposure to ultraviolet light, air pollution, and changes in humidity and temperature[8,9].

A number of investigators have studied on the such causes of discoloration in maxillofacial materials. Craig et al.[11] tested the color stability of nonpigmented polyvinyl chloride(PVC), polyurethane, and four silicone elastomers including MDX 4-4210 and MDX4-4515 after aging in a weatherometer. In his study PVC tended to lighten in color after 100 hours, and all silicone materials were color-stable, with MDX 4-4210 exhibiting the best overall properties. But the polyurethane material was severely degraded after 300 hours.

Koran et al.[12] found out very small changes in testing of MDX 4-4210 using 11 different maxillofacial pigments. Koran et al.[13] studied to determine resistance to external staining with tea, lipstick, and disclosing solution. RTV silicones, MDX 4-4210, Silastic 382;one high temperature-vulcanized (HTV)silicone, 4-4515; and a PVC material were tested. In their study, Tea produced the least color change; lipstick and disclosing solution produced the greatest change. MDX 4-4210 was the most resistant to tea and disclosing solution, but showed the greatest change from lipstick. PVC was the least resistant to staining while all silicones displayed good stain resistance. Lemon et al.[8] studied on the efficacy of a UV light absorber on the color stability of a facial elastomer. Color was evaluated before and after artificial weathering and direct outdoor exposure. In their study, color change with artificial aging causing a great change than outdoor aging, and the UV light absorber did not protect the samples from color changes.

Haug et al.[14] studied on the effect of environmental factors on maxillofacial elastomers. They concluded that all of the treatments caused a visually detectable change in color(ΔE^*) in all of the materials including A-2186. And all of the treatments caused to change in chroma toward green. And they reported the chroma of Silastic 4-4210 material changed toward blue with all treatment. In our study, the a* values of the most specimens were increased, so that it changed to red,

Pigno et al.[6] stressed the black discoloration of the inside surface of nasal prostheses, and they concluded that genus *Penicillium* was associated with discoloration of prostheses. Lemon et al.[8] stated that the major changes in appearance of maxillofacial prostheses result from staining that is caused by environmental factors such as stains, fungal accumulation, handling, body oil accumulation, or cosmetics applied by patient.

In this study only MDX 4-4210 silicone elastomer pigmented with Mars Violet and Red Yellow in experimental group 2 showed changes of ΔE^* more than 2.0(Table 9). The rests of MDX4-4210 specimens and all A-2186 silicone elastomer specimens showed less than 2.0 in change of ΔE^*(Table 9). Seghi et al.[15] demonstrated that a ΔE^* value of 2 units represent the minimum amount of color change that could be detected visually with a high degree of accuracy.

Beatty et al.[9] demonstrated that color changes occurring soon after a maxillofacial prosthesis is fabricated may be caused by inherent chemical change occurring within the elastomer or by color losses occurring with certain pigments that are not UV-resistants. They implied Mars Violet and Cosmetic Yellow Ochre are UV-resistant pigments, on the other hand the Cosmetic red and Cadmium yellow pigmemts were UV-sensitive.

In this study, all specimens revealed decreased L* value, so they became dark. Lemon et al.[8] explained the cause of darkening of L in the outdoor-aged samples in their study is attributed to the impregnation of dirt into the porous surface of the elastomer. In our study, we found out the change of lightness in all specimens even in specimens which were not exposed to air. It suggested that the change of lightness was not only depend upon Ultraviolet, but it could be resulted from composition of material itself. Andres and et al.[16] concluded in their survey that the most popular material for the fabrication of extraoral prostheses was MDX4-4210 silicone material and Polyzois et al.[17] concluded that A-2186 silicone elastomer has certain advantages in clinical application over Mollomed and Silbione 71566 materials they tested. In this study, we also selected MDX4-4210 and A-2186 silicone materials for this study.

Because MDX4-4210 and A-2186 silicone materials are transparent, all specimens used in this study were fabricated with siliocone materials combinded with pigment. This study suggested that environmental factors such as sunlight, aging in darkness, thermocycling, soap soaking could be causes of discoloration in maxillofacial silicone materials. And this study did not found out the effects of pigments on the discoloration of silicone elastomers.

In this study, In order to investigate the degree or amount of color change in silicone material, the total amounts of changes were calculated. The total amount of change of L* and a* value were greater in A-2186 silicone, but that of ΔE^* was greater in MDX4-4210 silicone. And the total amount of change of L* value was greater in experimental group 4, that of a* was greater in group 1, and those of b* and ΔE* values were greater in group 2.

V. SUMMARY AND CONCLUSION

The following conclusions were drawn from this study.

1. The L* value in all experimental group was lesser than in control group.
2. The a* value was increased in most experimental group, but those of MDX4-4210 materials pigmented with Raw sinna and with Mars violet in group 3,4,5 were decreased.
3. The b* value in group 1,2,3 was decreased, but that in group 4,5 was increased. There was no statistical difference between control and most of group 3.4.5.
4. The ΔE* value was decreased in all experimental group except A-2186 material in group 4, and the changes of ΔE* value of MDX4-4210 materials pigmented with Red yellow and with Mars violet were great(over than 2.0).
5. The total amount of change of L* and a* value were greater in A-2186 silicone, but that of ΔE* was greater in MDX4-4210 silicone.
6. The total amount of change of L* value was greater in experimental group 4, that of a* was greater in group 1, and those of b* and ΔE* values were greater in group 2.

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국문초록

치과용 임플란트를 이용한 악안면 보철치료에 관한 임상적 연구. 1부-악안면보철용 실리콘의 색안정성

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본 연구는 악안면보철용 실리콘의 색안정성을 연구하기 위하여 실리콘 재료로 MDX 4-4210 Silicone(Dow Corning, Midland, Mich.)과 A-2186(Factor II, Lakeside, Az)을 사용하고 Mars Violet, Golden Yellow, Red yellow, Raw Sienna등 4종의 색소(Factor II, Lakeside, Az)를 이용하여 시편을 제작한 후 1군은 섭씨5-55도에서 700회 thermocycling하였고, 2군은 10%의 비눗물(Ivory, Procter & Gamble Inc,. Toronto, Ontario)에 담아 섭씨5-55도에서 700회 thermocycling하였다. 3군은 10%의 비눗물에 담아 75일간 실온에서 보관하였으며 4군은 실온의 암실에 75일간 보관하였다. 5군은 초여름인 6월 중순부터 75일간 햇볕이 잘드는 곳에 위치하였다. 이를 측색색차계(Model TC-6FX, Tokyo Denshoku Co., Japan)를 이용하여 측정하고 색변화를 연구한 결과 다음과 같은 결론을 얻었다.

1. L*값의 경우 모든 실험군에서 대조군에 비해 유의하게 감소하였다.
2. a*값의 경우 대부분의 실험군에서 증가하였으나 Raw sienna, Mars violet색소를 사용한 실험 3.4.5군의 MDX4-4210의 경우 감소하는 경향을 보였다.
3. b*값은 실험1.2.3군의 경우 대부분 감소하였고 실험4.5.군의 경우에서 증가하였으나 3.4.5군의 경우에서 대부분 유의한 차이가 없었다.
4. ⊿E*의 값은 실험군에서 대부분 감소하였으나 4군의 A-2186에서 증가하는 경향을 보였고 실험 2군의 Red yellow, Mars violet을 사용한 MDX4-4210에서 비교적 큰 변화를 보였다.
5. L*값과 a값의 변화량의 합은 A-2186의 경우에서 크게 나타났으나 ⊿E*값의 변화량은 MDX4-4210에서 크게 나타났다.
6. L*값의 변화량의 합은 실험4군에서 크게 나타났으며 a*값은 1군에서, b*값과 ⊿E*값의 변화량의 합은 2군에서 크게 나타났다.