Reflection Spectrophotometry of Facial Skin

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The color of human skin of 241 whites, blacks, and orientals was measured by reflection spectrophotometry. Among the groups studied, major differences in luminous reflectance and excitation purity, but not in dominant wavelength, were observed. Parameters determined for Source A were higher than for Source C.

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Introduction.

A maxillofacial prosthesis must accurately match the skin color of the patient for it to blend in esthetically with the rest of the patient's face. This color match is very difficult considering such factors as changes in color with different light sources and the natural variation in skin color and character, even within a small area on the skin. Unfortunately, all of the methods currently used to choose pigments for maxillofacial prostheses are dependent upon the human eye for discrimination. Not only is it difficult to compare colors by visual methods, it is also difficult to determine which pigments should be used and in what amount to achieve an adequate color match. Edwards and Duntley[1] in 1939 examined the spectral reflectance curves of several patients with particular emphasis on the skin color of various regions of the body and the contribution of specific skin and blood pigments to skin color. Cantor[2] also has reported on the use of a reflectance spectrophotometer to measure the color of human skin and maxillofacial pigments. He demonstrated that maxillofacial materials and pigments could be blended to match the color of human skin. A spectrophotometer has been used to evaluate the color stability of maxillofacial pigments and materials under conditions of accelerated aging,[3] as well as the stain resistance of maxillofacial materials.[4]

The purpose of this study was to measure the color of human skin quantitatively with a reflectance spectrophotometer as a precursor to computerized selection of pigments for individual patients requiring a maxillofacial prosthesis.

Materials and methods.

A total of 241 subjects, including 195 whites, 22 blacks, and 24 orientals, participated in this study. Since the white group was large, it was further divided into 123 males and 72 females. The participants were primarily dental students, faculty, and staff members of the dental school. The tests were conducted during April, May, and June, 1978.

Skin color was measured with a double-beam ultraviolet-visible spectrophotometer* and integrating sphere† in the specular mode. The subjects gently placed their left cheek in the area of the molar prominence over the sample port (2.5 cm in diameter) of the integrating sphere of the spectrophotometer. The incident light beam covered a rectangular area of skin 4 x 7 mm. Women were asked not to wear make-up on the day they participated in the study. One reflectance curve was obtained for each subject in the visible spectrum from 400-700 nm.

Luminous reflectance (Y), dominant wavelength (DW), and excitation purity (EP) were calculated for each subject by use of a computer program based on the 1931 C.I.E.‡ Chromaticity Diagram and Sources A (tungsten, color temperature of 2856°K) and C (sunlight, color temperature of 6774°K).[5] The spectrophotometer was calibrated to 100% reflectance with a barium

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*Acta CIII, Beckman Instruments, Irvine, CA 92664

†ASPH-U integrating sphere, Beckman Instruments, Irvine, CA 92664

‡International Commission on Illumination

sulfate standard§ placed over the reference port of the integrating sphere.

The spectrophotometric parameters (Y, DW, and EP) were studied by analysis of variance[6] and means were compared by Scheffe intervals[7] at a 95% level of confidence.

Results.

The parameters of skin color for the population groups using light Source A are listed in Table 1. For luminous reflectance (Y) or value, the lightest skin color was observed for white females at 34.3 and darkest for blacks at 21.9. There was no statistical difference between the values of Y for all whites, white males, and orientals. The value of Y for white males was lower than of Y for white females. Values of Y for orientals were different than Y for white females and blacks.

For dominant wavelength (DW) or hue, there was no difference between all whites at 590.7 nm and the values for white males and white females. There was also no difference between blacks at 588.0 nm and orientals at 588.4 nm. The dominant wavelength for blacks and for orientals differed from that of whites by 2.3 to 2.7 nm.

For excitation purity (EP) or chroma, the mean values for whites, white females, and white males were not different from each other; however, each of these means was different from those of blacks and orientals. The excitation purity for blacks was also different than for orientals. As a group, the whites had the least saturation of skin color at 0.287, while the blacks had the largest excitation purity at 0.360.

The effect of two light sources on the skin color of white males is shown in Table 2. Source A represents a tungsten light source and Source C represents sunlight. For all patients, values of luminous reflectance, dominant wavelength, and excitation purity determined for Source A were higher than for Source C. The largest change was in dominant wavelength.

The range of skin color for the various groups can be seen in Figs. 1 through 3. Fig. 1 shows the superimposed reflectance curves for 195 white males and females, as well as the mean reflectance curve. The energy reflected is more prominent in the red end of the visual spectrum and low in the blue region. Two depressions in the mean reflectance curve were noted at about 540 and 580 nm. These depressions were more pronounced for white females than white males.

The superimposed reflectance curves for orientals and blacks are shown in Figs. 2 and 3, respectively. The mean reflectance curve for orientals is lower in percent reflectance than for whites, and depressions in the mean curve at 540 and 580 nm were not as pronounced as for whites (see Fig. 4). The mean curve for blacks is lower in percent reflectance than for all other groups (Fig. 4), and depressions in the curve at 540 and 580 nm were not seen. There was considerable variability in skin color in the black group. This group had the largest standard deviations of all population groups for luminous reflectance and excitation purity.

§Part No. 375285, Beckman Instruments, Irvine, CA 92664

TABLE 1
VALUES OF LUMINOUS REFLECTANCE (Y), DOMINANT WAVELENGTH (DW), AND EXCITATION PURITY (EP) FOR SKIN COLOR OF PATIENTS STUDIED

	Y	DW, nm	EP
WHITES	30.9 (5.0)*[a]	590.7 (3.0)[b]	0.287 (0.036)[a]
White Females	34.3 (4.0)	590.3 (2.9)[b]	0.284 (0.033)[a]
White Males	28.8 (4.5)[a]	590.9 (3.1)[b]	0.289 (0.038)[a]
BLACKS	21.9 (7.6)	588.0 (1.9)[a]	0.360 (0.051)
ORIENTALS	28.4 (4.0)[a]	588.4 (2.1)[a]	0.320 (0.028)

*Mean value with standard deviation in parentheses. Values with the same superscript (a, b) are not statistically different at the 95% level of confidence.

TABLE 2
EFFECT OF LIGHT SOURCE ON SPECTROPHOTOMETRIC PARAMETERS OF SKIN COLOR OF WHITE MALES

	Y	DW, nm	EP
Source A Tungsten	31.6 (4.7)*	601.2 (3.3)	0.320 (0.043)
Source C Sunlight	28.8 (4.5)	590.9 (3.1)	0.289 (0.028)

*Mean value with standard deviation in parentheses.

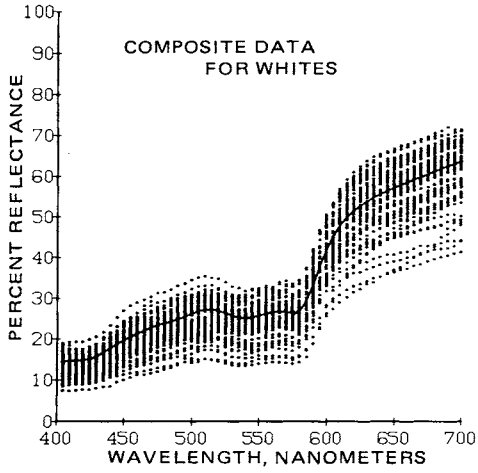

Fig. 1 – Superimposed reflectance curves and mean curve for 195 white patients. Dots (many of which overlap) represent data for all patients at each wavelength.

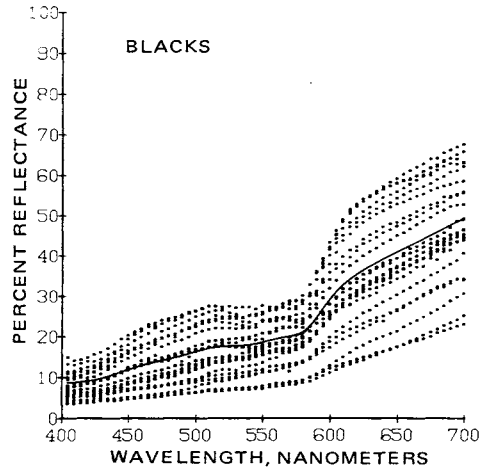

Fig. 3 – Superimposed reflectance curves and mean curve for 22 black patients. Dots (many of which overlap) represent data for all patients at each wavelength.

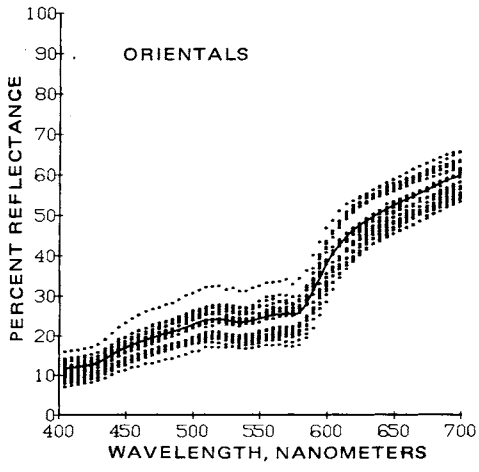

Fig. 2 – Superimposed reflectance curves and mean curve for 24 oriental patients. Dots (many of which overlap) represent data for all patients at each wavelength.

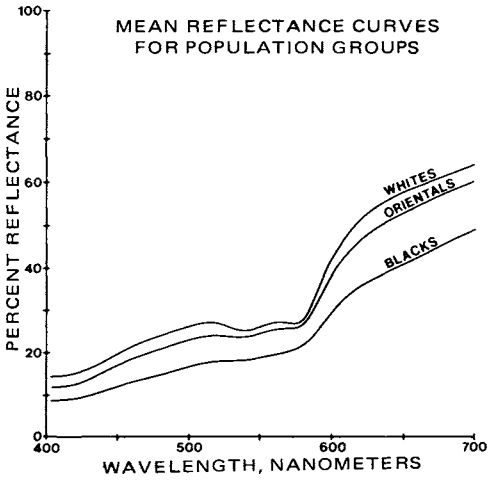

Fig. 4 – Mean reflectance curves for white, black, and oriental patients.

Discussion.

A reflectance spectrophotometer was used to measure skin color for various groups within a specific population. It should not be interpreted as representative of any other population since differences due to climate, geography, and ethnic background would undoubtedly yield slightly different results. In the future it would be interesting to compare the skin color of population groups at different times of the year to examine the effect of tanning on skin color.

The effect of light sources on observed skin color was demonstrated and indicates the importance of matching reflectance curves of skin and maxillofacial pigments rather than matching luminous reflectance, dominant wavelength, and excitation purity. If the actual reflectance curve of the patient's skin were used to match the reflectance curve of the prosthesis, the color match would be independent of the incident light, and metameric effects would be minimized.

The two depressions in the reflectance curves at about 540 and 580 nm were reported by Edwards and Duntley[1] to be representative of the twin absorption bands of oxyhemoglobin, since oxyhemoglobin is present in the arterial blood flow in the skin. In areas of the body where the blood flow is predominantly venous, this twin depression of the reflectance curve is not seen. These depressions in the mean reflectance curves of the various groups (Fig. 4) were most pronounced for whites, less pronounced for orientals, and almost nonexistent for blacks. Since the luminous reflectance for these groups was 30.9, 28.8, and 21.9, respectively, the darker skin colors tend to mask the twin absorption peaks of the oxyhemoglobin. This masking is probably caused by melanin pigment in the skin.

A computer program is currently being developed which will utilize the reflectance curve obtained from a patient to quantitatively select maxillofacial pigments to achieve an isomeric color match of a maxillofacial prosthesis with the patient's facial skin.

Conclusions.

The color of human skin of 241 whites, blacks, and orientals was measured by reflection spectrophotometry. Among these groups, major differences in luminous reflectance and excitation purity, but not in dominant wavelength, were observed. The twin absorption bands of oxyhemoglobin at 540 and 580 nm were more prominent in whites (particularly females) than in orientals or blacks. Parameters determined for Source A were higher than those for Source C.

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