Color of Denture Resins

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The color of 24 commercially available denture resins was determined visually with Munsell color tabs and by reflection spectrophotometry. Correlation between Munsell and spectrophotometric data was found. The resins characterized for Black patients had a higher degree of specular reflectance and were more opaque than resins for Caucasians.

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The development of more esthetic denture resins will be facilitated by quantitative data on the color of existing resins and of healthy gingival tissues. Recently, data on the Munsell value, chroma and hue of attached gingival tissues of 100 Black and 100 Caucasian patients were reported.[1] The color of uniformly pigmented, attached gingiva of both Blacks and Caucasians was described most often by a Munsell value between 5/ and 7/, a chroma of /4, and a range of hues from 2.5R to 7.5R when determined under fluorescent light. The color of attached gingiva pigmented by melanin in 61 Black patients was lower in value (3/ to 4/) and chroma (/1 to /2), but had a similar range of hues compared to uniformly-pigmented gingiva. Data on the color of commercially available denture resins characterized for Blacks and Caucasians are not available, however.

The purpose of this investigation was to determine the color of commercially available denture resins by use of Munsell color tabs and by reflection spectrophotometry.

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*Bendick Polish, The Bendick Co., Lapeer, Mi.

† Munsell Book of Color, Munsell Color, Baltimore, Md.

‡ F40CW Cool White Mainlighter, General Electric Co., Cleveland, Oh.

§ J16 Digital Photometer, Tektronix, Inc., Beaverton, Or.

¶ Ney-Lite, The J. M. Ney Company, Bloomfield, Ct.

* ACTA C III UV-Visible Spectrophotometer, Beckman Instruments, Inc., Irvine, Ca.

† ASPH-U Integrating Sphere, Beckman Instruments, Inc., Irvine, Ca.

Materials and Methods

Codes, batch numbers, and manufacturers of commercially available denture resins characterized for Black patients and for Caucasian patients are listed in Tables 1 and 2, respectively. A block (50 × 50 × 5.7 mm) of each resin was processed according to manufacturer's instructions and was finished with fine pumice and then with a final polishing agent.*

Value, chroma, and hue were determined for each resin by visual comparison with color tabs (glossy finish)† under fluorescent light‡ against a neutral gray background. The light intensity at the viewing surface was measured with a photometer§ to be 200 μ Watts/cm^2. Fluorescent light comparable to that used in a clinical study[1] was used so that comparisons could be made between resin and gingival colors. In addition, 13 of the resins were evaluated under simulated daylight.¶ Value was determined first by selection of a tab that most nearly corresponded with the lightness or darkness of the resin. Chroma then was determined by use of tabs that were close to the value measured for the resin but were of increasing saturation of color. The hue of the resin then was determined from tabs with a value and chroma already matched. An example observation would be 2.5R 6/8 to indicate a hue of 2.5 in the red (R) family, a value of 6/ and a chroma of /8. The designation RP was used to indicate a hue in the red purple family.

Each resin was evaluated independently by two observers. If disagreement in color match existed between the observers, then a consensus color match was agreed upon and recorded. Color difference (I) between the two observations of a resin and the consensus color was determined with the use of an equation derived by Nickerson,[2] $I = (C/5)\ (2\ \Delta H) + 6\ \Delta V + 3\Delta C$, where C is the average chroma, ΔH is the difference in hue, ΔV is the difference in value, and ΔC is the difference in chroma; ΔH, ΔV, and ΔC were always positive.

Curves of percent reflectance versus wavelength (λ) were obtained for one sample of each resin between 405 and 700 nm with a double-beam, ultraviolet-visible spectrophotometer* and integrating sphere.† Each resin was

evaluated in the sample port (1 inch in diameter) under four conditions: (a) backed by a black standard‡—combined specular and diffuse reflectance, (b) backed by a black standard—diffuse reflectance only, (c) backed by a white standard§—combined specular and diffuse reflectance, and (d) backed by a white standard—diffuse reflectance only. A second white standard was used in the reference port for calibration of zero and 100% reflectance and to obtain data. Tristimulus values (X,Y,Z) relative to the 1931 CIE¶ color-matching functions for CIE standard illuminant C were determined by numerical integration ($\Delta\lambda = 5$ mm) as described elsewhere.[3] Values of CIE chromaticity coordinates (x,y) were calculated from the tristimulus values[5] and were used to

‡ Part No. 375287, Beckman Instruments, Inc., Irvine, Ca.
§ Part No. 104384, Beckman Instruments, Inc., Irvine, Ca.
¶ International Commission on Illumination.

TABLE 1

CODE, BATCH NUMBER, AND MANUFACTURER OF DENTURE RESINS CHARACTERIZED FOR BLACK PATIENTS

Code	Material	Batch Number	Manufacturer
B1	Characterized Lucitone (Bluish Pink)	Liq—L74143, Pwd—P74149	L. D. Caulk., Div. of Dentsply International, Inc. P. O. Box 359 Milford, De 19963
B2	Hy Pro (Fibered Dark)	Liq—L74143, Pwd—P73239	L. D. Caulk Co.
B3	COE-LOR Natural (Mild)	Liq—10058, Pwd—070173	Coe Laboratories, Inc. 3737 West 127th Street Chicago, Il 60658
B4	COE-LOR Natural (Moderate)	Liq—10058, Pwd—080173	Coe Laboratories, Inc.
B5	COE-LOR Natural (Heavy)	Lip—10058, Pwd—090173	Coe Laboratories, Inc.
B6	Improved Densene 33 (Meharry)	Liq—300131, Pwd—180531	Cosmos Dental Products, Inc. 320 Washington Street Mt. Vernon, NY 10553
B7	Hircoe (Dark Fibered)	Liq—12011, Pwd—12011	Coe Laboratories, Inc.
B8	Pro-fit (Fibered Purple)	Liq—104013, Pwd—104024	Howmedica, Inc. Dental Division 5101 South Keeler Avenue Chicago, Il 60632
B9	Permatone (Meharry Veined)	Liq—10421267, Pwd—10421196	Kerr Manufacturing Co. Div. of Sybron Corp. P.O. Box 455 Romulus, Mi 48174
B10	Permatone (Meharry)	Liq—10421267, Pwd—10421204	Kerr Manufacturing Co.
B11	Duraflow (Burnet)	Liq—0174A, Pwd—1272B	Myerson Tooth Corp. 66–90 Hamilton Street Cambridge, Ma 02139
B12	Microlon (Shade 53)	Liq—02524, Pwd—not given	Hygienic Dental Manufacturing Co. 1245 Home Avenue Akron, Oh 44310
B13	Microlon (Heavy Veined B)	Liq—not given, Pwd—not given	Hygienic Dental Manufacturing Co.

obtain dominant wavelength and excitation purity by a graphic technique with the use of a CIE chromaticity diagram (1931). Luminous reflectance was equal to the tristimulus value, Y. An estimate of the opacity of each resin was obtained by calculation of the contrast ratio,[4] Y_b/Y_d, where the subscripts refer to the aforementioned experimental conditions. An estimate of the degree of specular reflection was obtained by calculation of the ratio, Y_c/Y_d.

The spectrophotometric parameters, luminous reflectance, dominant wavelength and excitation purity, were studied by a two-way analysis of variance[5] to determine the effects of resins and conditions (a to d) for each set of resins (B and C). The error term of the analysis for each parameter was estimated from the variance of nine replications of resin C3 under condition d. Scheffe intervals at the 95% level were calculated.[6] Chromaticity coordinates and luminous reflectance corresponding to the Munsell color data were obtained from conversion tables based on CIE standard illuminant C.[3] Comparisons of the differences between the Munsell data and the spectrophotometric data were made by a one-way analysis of variance[7] of the parameters, x, y, and Y, for conditions a to d. The error term was the variance among the 24 resins.

* Data obtained for conditions a, b, and c are available on request from the author.

Results

The Munsell color obtained under fluorescent light, spectrophotometric data for diffuse reflectance of samples backed by a white standard (condition d)* and the ratios, Y_b/Y_c and Y_c/Y_d, are listed in Tables 3 and 4 for resins characterized for Blacks and Caucasians, respectively.

Luminous reflectance and excitation purity were affected significantly at the 95% level by

TABLE 2

CODE, BATCH NUMBER, AND MANUFACTURER OF DENTURE RESINS CHARACTERIZED FOR CAUCASIAN PATIENTS

Code	Material	Batch Number	Manufacturer
C1	Characterized Lucitone (Light)	Liq—L74164, Pwd—P74198	L. D. Caulk Co., Div. of Dentsply International, Inc. P. O. Box 359 Milford, De 19963
C2	Characterized Lucitone (Lt. Reddish Pink)	Liq—L74143, Pwd—P74225	L. D. Caulk Co.
C3	Characterized Lucitone (Reddish Pink)	Liq—L74143, Pwd—P74149	L. D. Caulk Co.
C4	Hy Pro (Plain)	Liq—L749, Pwd—P4955	L. D. Caulk Co.
C5	Hy Pro (Filtered)	Liq—L20156, Pwd—P14456	L. D. Caulk Co.
C6	Hy Pro (Fibered Light)	Liq—L73179, Pwd—P73106	L. D. Caulk Co.
C7	Densene Muco-Tone	Liq—210532, Pwd—080050631	Cosmos Dental Products, Inc. 320 Washington Street Mt. Vernon, NY 10553
C8	Pro-fit (Translucent Light)	Liq—104013, Pwd—104029	Howmedica, Inc. Dental Division 5101 South Keeler Avenue Chicago, Il 60632
C9	Pro-fit (Fibered Pink)	Liq—104013, Pwd—084040	Howmedica, Inc.
C10	Pro-fit (Fibered Medium)	Liq—104013, Pwd—104050	Howmedica, Inc.
C11	Perma-Cryl (Light)	Liq—110174, Pwd—090374	Coe Laboratories, Inc. 3737 West 127th Street Chicago, Il 60658

TABLE 3

MUNSELL COLOR AND SPECTROPHOTOMETRIC DATA OF DENTURE RESINS CHARACTERIZED FOR BLACK PATIENTS

Code	Munsell Color (Hue, value/chroma)	Spectrophotometric Data* Chromaticity Coordinates x	y	Luminous Reflectance (Y)	Dominant Wavelength, nm	Purity	(Yb/Yd)	(Yc/Yd)
B1	10RP 5.5/6	0.4067	0.3100	21.52	631	0.243	0.934	1.16
B2	7.5R 4.5/4	0.3902	0.3272	15.60	602	0.245	0.947	1.19
B3	2.5R 5/4	0.3883	0.3190	21.05	612	0.217	0.904	1.08
B4	5R 4/4	0.3979	0.3272	12.07	603	0.265	0.979	1.32
B5	2.5R 3.5/2	0.3727	0.3185	8.21	611	0.175	1.00	1.44
B6	5RP 5.5/4	0.3699	0.3067	22.21	—493†	0.150	0.978	1.16
B7	10RP 5.5/6	0.4191	0.3132	24.40	621	0.284	0.941	1.16
B8	7.5RP 4.5/4	0.3774	0.3109	14.95	636	0.167	0.987	1.22
B9	10RP 4.5/4	0.3845	0.3091	17.02	644	0.181	0.982	1.12
B10	2.5R 4.5/4	0.3931	0.3135	18.68	622	0.216	0.983	1.13
B11	5R 5.5/4	0.3765	0.3329	25.88	596	0.223	0.992	1.14
B12	2.5R 5/8	0.4356	0.3145	21.32	618	0.332	0.950	1.16
B13	2.5R 5/7	0.4284	0.3107	19.00	625	0.302	0.907	1.17

* Relative to 1931 CIE color matching functions for CIE standard illuminant C when determined from diffuse reflectance of samples backed by a white standard (condition d).

† The negative sign indicates a complementary wavelength and a dominant wave length in the purple hue.

resins, conditions (a to d) and their interaction. Scheffe intervals for comparisons of means of these parameters among resins coded B (Table 3) were 0.44 and 0.014 and among resins coded C (Table 4) were 0.41 and 0.013, respectively. Dominant wavelength was affected significantly only by resins. The Scheffe intervals for comparison among resins coded B and C were 6.2 and 5.7 nm, respectively. Luminous reflectance (Y) was observed to be most sensitive to the differences among conditions a to d based on the analysis of variance.

Mean values of the differences between the Munsell data obtained under fluorescent light and the spectrophotometric data for the parameters, x, y, and Y, are listed in Table 5.

TABLE 4

MUNSELL COLOR AND SPECTROPHOTOMETRIC DATA OF DENTURE RESINS CHARACTERIZED FOR CAUCASIAN PATIENTS

Code	Munsell Color (Hue, value/chroma)	Spectrophotometric Data* Chromaticity Coordinates x	y	Luminous Reflectance (Y)	Dominant Wavelength, nm	Purity	(Yb/Yd)	(Yc/Yd)
C1	2.5R 5.5/6	0.4201	0.3202	23.80	611	0.306	0.920	1.16
C2	2.5R 5.5/8	0.4365	0.3177	23.70	614	0.343	0.948	1.14
C3	2.5R 5.5/6	0.4240	0.3121	22.80	623	0.294	0.902	1.14
C4	5R 6/8	0.4351	0.3288	27.62	605	0.369	0.946	1.13
C5	5R 5.5/8	0.4443	0.3229	24.41	610	0.378	0.925	1.15
C6	2.5R 5.5/6	0.4195	0.3182	24.98	614	0.299	0.872	1.13
C7	2.5R 6/7	0.4269	0.3195	25.64	612	0.322	0.938	1.12
C8	5R 5.5/6	0.4313	0.3260	23.80	607	0.351	0.935	1.16
C9	5R 5.5/6	0.4168	0.3251	24.64	607	0.310	0.958	1.11
C10	5R 5/6	0.4302	0.3283	22.49	605	0.354	0.933	1.13
C11	5R 5.5/6	0.4167	0.3337	28.63	601	0.333	0.772	1.12

* Relative to 1931 CIE color matching functions for CIE standard illuminant C when determined from diffuse reflectance of samples backed by a white standard (condition d).

TABLE 5

RESULTS OF ANALYSIS OF VARIANCE OF DIFFERENCES BETWEEN SPECTROPHOTOMETRIC AND MUNSELL DATA

Conditions	Average Differences Between Spectrophotometric and Munsell Data		
	Chromaticity Coordinates		*Luminous Reflectance*
	x*	y†	y‡
a. Sample backed by black standard-combined specular and diffuse reflectance	—0.0046	0.0033	1.75
b. Sample backed by black standard-diffuse reflectance only	0.0077	0.0038	—1.54
c. Sample backed by white standard-combined specular and diffuse reflectance	0.0076	0.0033	3.13
d. Sample backed by white standard-diffuse reflectance only	0.0216	0.0040	—0.11

* Scheffe interval was 0.0085 at 95% level.
† Scheffe interval was 0.0033 at 95% level.
‡ Scheffe interval was 1.60 at 95% level.

Scheffe intervals at the 95% level for comparisons of means among conditions a to d and with zero are listed also. For x, there was no significant difference between conditions b and c, but only condition d was different from zero. For y, there were no significant differences among conditions a through d, but conditions b and d were significantly different from zero. For Y, there was no significant difference between conditions a and c nor between b and d, but conditions a and c were both significantly different from zero. Condition d was selected as the spectrophotometric technique that correlated best with the visual Munsell technique, because the agreement between Munsell and spectrophotometric data for the luminous reflectance (Y) was best for condition d.

The contrast ratio, Y_b/Y_d, is a measure of opacity and was determined by comparison of the luminous reflectance of a specimen backed by a black and then by a white standard. The curve of percent reflectance versus wavelength obtained from the spectrophotometer should not vary as a function of the backing of the specimen if the specimen is completely opaque. The average ratio, Y_b/Y_d, was 0.96 with a standard deviation of 0.03 for the resins characterized for Black patients and was 0.91 with a standard deviation of 0.05 for the resins characterized for Caucasian patients. These means were different statistically at the 95% level of confidence as determined by analysis of variance.

The ratio, Y_c/Y_d, is a measure of the degree of specular reflectance of each resin and was determined by comparison of the luminous reflectance of a specimen backed by a white standard in mode c where both specular and diffusely reflected light were allowed to be detected and in mode d where only diffusely reflected light was allowed to be detected by the spectrophotometer. The average ratio, Y_c/Y_d, was 1.19 with a standard deviation of 0.09 for the resins characterized for Black patients and was 1.14 with a standard deviation of 0.02 for the resins characterized for Caucasian patients. These means were different statistically at the 95% level of confidence as determined by analysis of variance.

The Munsell hue, value, and chroma obtained under fluorescent light for the denture resins characterized for Black and for Caucasian patients are compared in Figure 1. The resins characterized for Blacks ranged in hue from 5RP to 7.5R, in value from 3.5 to 5.5, and in chroma from 2 to 8. The resins characterized for Caucasians ranged in hue from 2.5R to 5R, in value from 5 to 6, and in chroma from 6 to 8. There were no visible differences in color ($I = 0$) for the 13 resins observed under fluorescent light versus simulated daylight.

Agreement between observers in determination of Munsell color occurred for 14 of the 24 resins. The average color difference ($\bar{I}$) between two observations of a resin and its consensus color was 1.8 among the 24 resins. The

distribution of I was estimated by an exponential function:[8]

$$f(I) = \frac{1}{ß} e^{-I/ß} ;$$

where ß is an expected value equal to $\bar{I}$. An estimate of the critical color difference ($\bar{I}_c$) necessary to show a significant difference between two colors was computed by the equation:

$$I_c = -\bar{I} \ln P,$$

where P is the probability that an observed I is greater than I_c. For P equal to 0.01, I_c was 8.3.

Discussion

The Munsell value, chroma and hue of a specimen correlates well with an observer's perception of its value, chroma and hue if three conditions are met: (1) the observer has normal color vision; (2) the observer is adapted to daylight; and (3) the observer views the specimen illuminated by CIE standard illuminant C or D_{6500} on a middle gray to white background.[9] In this study, the illumination source was fluorescent light which may have contributed to a systematic error. The specular energy of fluorescent light is low, between 650 to 700 nm when compared with that of natural or simulated daylight; however, the effect of this low red component was not observed in the visual comparison of the resins with fluorescent and simulated daylight. Additional error may have resulted from the heterogeneous nature of the veined and pigmented resins. Of the 24 resins tested, 19 had fibers or pigmentation that were visibly distinct from the dominant pigmentation of the resin; both the Munsell and spectrophotometric techniques discern only a dominant color. For example, the dominant color of the resins of C1, C3, and C6 was given the Munsell notation 2.5R 5.5/6. In appearance, however, C3 was distinct from C1 and C6 because the characterization of C3 with fibers was more intense. The dominant wavelength of C3 was 623 nm compared with 611 and 614 nm for C1 and C6. The dominant color of the resins of C8, C9, and C11 was observed to be 5R 5.5/6; however, C8 and C9 were characterized with fibers whereas C11 was not. The dominant wavelength of the characterized resins C8 and C9 was 607 nm compared with 601 nm for C11. The high value of luminous reflectance of C11 compared with the values for C8 and C9 observed with the spectrophotometer under condition d is explained by the low opacity (0.77) of C11 compared with the values for C8 (0.935) and C9 (0.958). The dominant color of the resins of B1 and B7 was observed to be 10RP 5.5/6. In appearance, B1 was distinct from B7 because B1 was characterized with red and blue fibers whereas B7 was characterized to a lesser extent with red fibers only.

Clinically, the color of a denture base is affected by the thickness and specular reflection of the denture and by the opacity of the resin. The color of a denture made of a less opaque resin would be affected more by the color of the supporting soft tissues. In this study, the aver-

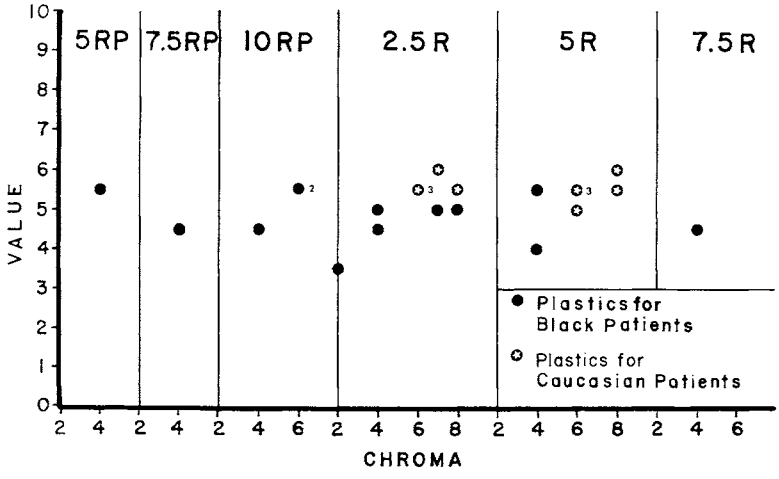

FIG 1.—Munsell color of denture resins characterized for Black and for Caucasian patients.

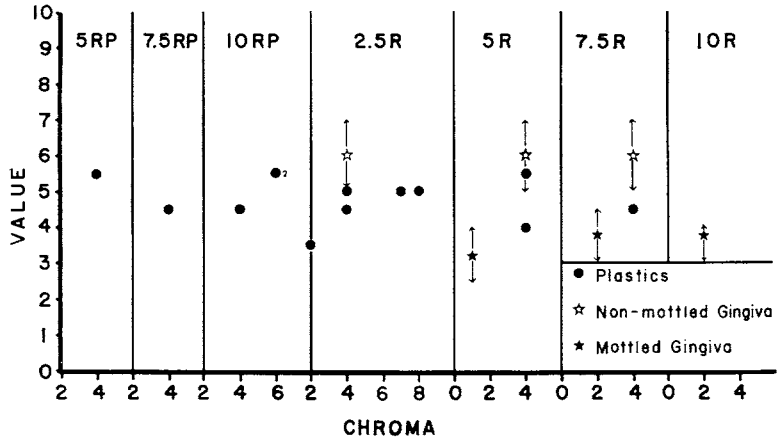

FIG 2.—Munsell color of denture resins characterized for Black patients compared to ranges of Munsell color observed for mottled and nonmottled, attached gingiva of Black patients.

age thickness of the resins was 5.7 mm with a standard deviation of 0.4 mm, a thickness about three times that of a typical denture base. The greater thickness was chosen in this study in an attempt to measure the dominant color of the resin with less contribution from the supporting background. An evaluation of color as a function of thickness of a denture resin was not within the scope of this study. The specular reflection is affected by the degree of polishing as well as by the nature of the resin itself. In this study, both the opacity and the degree of specular reflectance were greater on the average for the resins characterized for Black patients than for the resins characterized for Caucasian patients.

TABLE 6

COLOR DIFFERENCES (I) BETWEEN RESINS AND AVERAGE GINGIVAL COLORS[1] FOR BLACKS AND CAUCASIANS

Resins Characterized for Blacks				Resins Characterized for Caucasians		
Code	Color Difference (I) for Mottled, Attached Gingiva of Blacks	Color Difference (I) for Nonmottled, Attached Gingiva of Blacks	Color Difference (I) for Attached Gingiva of Caucasians	Code	Color Difference (I) for Attached Gingiva of Caucasians	Color Difference (I) for Nonmottled, Attached Gingiva of Blacks
B1	34.6[a]	14.6[b]	19.4[c]	C1	14.4[c]	9.6[b]
B2	10.2[d]	9.6[e]	9.6[e]	C2	20.4[c]	15.6[b]
B3	12.1[a]	6.6[b]	11.4[c]	C3	14.4[c]	9.6[b]
B4	12.6[a]	10.8[f]	13.2[g]	C4	13.2[g]	13.2[f]
B5	5.1[a]	21.6[b]	26.4[c]	C5	16.2[g]	13.8[f]
B6	31.6[a]	15.6[b]	20.4[c]	C6	14.4[c]	9.6[b]
B7	34.6[a]	14.6[b]	19.4[c]	C7	14.4[c]	9.6[b]
B8	23.1[a]	17.6[b]	22.4[c]	C8	10.2[g]	7.8[f]
B9	20.6[a]	13.6[b]	18.4[c]	C9	10.2[g]	7.8[f]
B10	18.1[a]	9.6[b]	14.4[c]	C10	13.2[g]	10.8[f]
B11	19.2[d]	1.8[f]	4.2[g]	C11	10.2[g]	7.8[f]
B12	35.1[a]	18.6[b]	23.4[c]			
B13	31.6[a]	15.6[b]	20.4[c]			

[a] Average Munsell color of gingiva—5R 3.4/1.
[b] Average Munsell color of gingiva—2.5R 6.1/4.
[c] Average Munsell color of gingiva—2.5R 6.9/4.
[d] Average Munsell color of gingiva—7.5R 3.8/2.
[e] Average Munsell color of gingiva—7.5R 6.1/4.
[f] Average Munsell color of gingiva—5R 5.8/4.
[g] Average Munsell color of gingiva—5R 6.2/4.

The Munsell colors of denture resins characterized for Black patients are compared in Figure 2 to ranges of Munsell color observed for mottled and nonmottled, attached gingiva of Black patients reported in a previous study.[1] The ranges illustrated represent data on the nonmottled gingiva of 80 of 100 patients and data on the mottled gingiva of 42 of 61 patients. Color differences (I) between the resins and average gingival colors for Blacks and Caucasians are listed in Table 6. These color differences can be compared to I_c of 8.3 to determine if they are within experimental error. The average colors of mottled areas of attached gingiva of Blacks are duplicated best by resin B5 ($I = 5.1$). The colors of nonmottled areas are duplicated best by resins B11 ($I = 1.8$) and B3 ($I = 6.6$). The colors of attached gingiva of Caucasians are duplicated best by resin B11 ($I = 4.2$).

The Munsell colors of denture resins characterized for Caucasian patients are compared in Figure 3 to ranges of Munsell color observed for the nonmottled attached gingiva of 80 of 100 Black patients and 83 of 100 Caucasian patients reported in a previous study.[1] From inspection of Table 6, the colors of attached gingiva of Caucasians are not duplicated well by the resins coded C (I equal to 10.2 or greater). The colors of nonmottled, attached gingiva of Blacks are duplicated best by resins C8, C9, and C11 ($I = 7.8$).

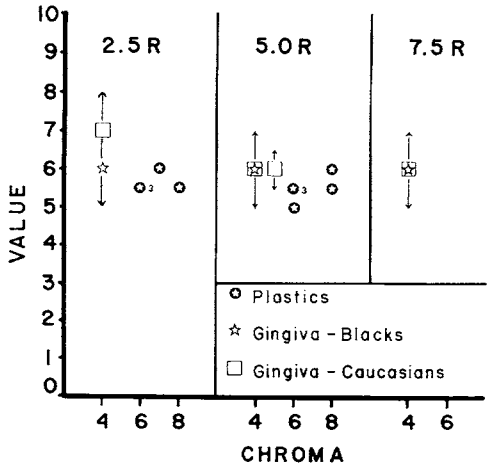

FIG 3.—Munsell color of denture resins characterized for Caucasian patients compared to ranges of Munsell color observed for nonmottled, attached gingiva of Black and Caucasian patients.

Conclusions

The color of 24 commercially available denture resins was determined visually with Munsell color tabs and by reflection spectrophotometry. Correlation between Munsell and spectrophotometric data was best when diffuse reflectance of samples backed by a white standard was measured by the spectrophotometer. The resins characterized for Black patients were more opaque and had a higher degree of specular reflectance than the resins characterized for Caucasians. Comparison of the Munsell color of denture resins with the Munsell color of attached geniva of Black and Caucasian patients indicated that 6 of the 24 resins matched the color of attached gingival tissues within experimental error.

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