Color of Dental Restorative Resins

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The color of 7 composite resins, an unfilled restorative resin, and 3 glaze coatings was determined by reflection spectrophotometry and visually with Munsell color tabs. Statistically significant correlations existed between comparable parameters of the spectrophotometric and Munsell data. There were observable color variations among the 11 resins studied, but only 3 materials were within the range for natural tooth color.

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As a result of the color variation found in natural teeth[1,2] and the translucency of enamel and dentin, it has been characteristically difficult to obtain an exact shade match between direct restorative materials and tooth structure.[3] The Bis-GMA resin matrix in composite restorative materials has been combined with an optically matched dispersion of ceramic particles to approximate more closely the various clinical shades of natural teeth. The majority of commercial products are marketed in a "universal" shade which is sufficiently translucent to reflect the internal shades of underlying tooth structure. When underlying dentin is either thin or nonexistent, the restorative material must provide total color for the restoration. The purpose of this study was to evaluate the basic variation in shade among resin restorative materials and glaze coatings after initial set.

Materials and Methods

Seven commercial composite resins, 3 glaze coatings, and an unfilled restorative resin were evaluated for color characteristics after initial set. Codes, shades, batch numbers, and manufacturers for the materials selected for study are listed in Table 1.

Five sample disks (36 mm in diameter and 1.3 mm in thickness) were made for each product by polymerizing the resin in a metal die. The samples were placed in an oven at 37 C within 90 seconds after initiating the mix and were stored for 24 hours before making the baseline evaluation. Specimens of the two materials activated by ultraviolet light (NF and NS) were polymerized in the same die by exposing the open side through a thin glass plate to an ultraviolet light source* for 2 minutes at a distance of 5 cm. The arithmetic average roughness of a sample as measured from profile tracings† was 2.5 μm.

Value, chroma, and hue[4] were determined for each resin by visual comparison with color tabs (glossy finish)‡ under fluorescent light§ against a white background. The light intensity at the viewing surface was measured with a photometer¶ to be 200 μWatts/cm². 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 from tabs with an increasing saturation of color; and finally, hue was selected from tabs with the predetermined value and chroma. An example observation would be 2.5Y 8/4 to indicate a hue of 2.5 in the yellow (Y) family, a value of 8/ and a chroma of /4. The designation YR was used to indicate a hue in the yellow-red family.

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

Curves of percent reflectance versus wave-

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* Blak-Ray, model B-100A, Ultra-Violet Products, Inc., San Gabriel, Ca 91775.

† Surfanalyzer 150, Gould Inc., Instrument Systems Division, Cleveland, Oh 44114.

‡ Munsell Book of Color, Munsell Color, Baltimore, Md 21218.

§ F40CW Cool White Mainlighter, General Electric Co, Cleveland, Oh 44112.

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

TABLE 1

CODE, PRODUCT NAME AND SHADE, BATCH NUMBERS, AND MANUFACTURERS OF COMPOSITE AND UNFILLED RESINS AND GLAZES

Code	Product Name (Shade)	Batch Numbers	Manufacturer
Composite Resins:			
A	Adaptic (Universal)	base—SF101 catalyst—SF101	Johnson & Johnson Dental Products Division East Windsor, NJ 08520
AR	Adaptic Radiopaque (Universal)	base—1126D03 catalyst—1126D03	Johnson & Johnson
C	Concise (Universal)	base—6159L13 catalyst—6159L13	3M Company St. Paul, Mn 55101
NF	Nuva Fil (Light)	base—7414,7426 initiator—7661	L. D. Caulk Co. Div. of Dentsply International, Inc. Milford, De 19963
P	Prestige (Universal)	base—HPR0114 catalyst—HPR0115	Lee Pharmaceuticals South El Monte, Ca 91733
S	Simulate (Universal)	base—1066 catalyst—1160	Kerr Manufacturing Co. Div. of Sybron Corp. Romulus, Mi 58174
V	Vyytol (Light)	base—042976 catalyst—042976	L. D. Caulk Co.
Unfilled Resin:			
SV	Sevriton (S5—Light Yellow)	powder—PA14PE liquid—PH6PK	Amalgamated Dental Trade Dist., Ltd. London, England
Glazes:			
F	Finite	base—041076 catalyst—G0025	Lee Pharmaceuticals
G	Adaptic Glaze	base—0815D04 catalyst—0815D04	Johnson & Johnson
NS	Nuva Seal	base—75104 initiator—7661	L. D. Caulk Co.

length (λ) were obtained for five samples 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 two conditions for combined specular and diffuse reflectance: (a) backed by a black standard‡ and (b) backed by a white standard.§ A second white standard was used in the reference port for calibration of zero and 100 percent 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 ($\Delta\lambda = 5$ nm) as described elsewhere.[6] Values of CIE chromaticity coordinates (x,y) were calculated from the tristimulus values[6] and were used to obtain dominant wavelength and excitation purity from CIE chromaticity data (1931)[6] with the use of a computer program.|| 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,[7] Y_a/Y_b, where the subscripts refer to the aforementioned experimental conditions.

* ACTA C III UV-Visible Spectrophotometer, Beckman Instruments, Inc., Irvine, Ca 92664.

† ASPH-U Integrating Sphere, Beckman Instruments, Inc., Irvine, Ca 92664.

§ Part No. 375287, Beckman Instruments, Inc., Irvine, Ca 92664.

§ Part No. 104384, Beckman Instruments, Inc., Irvine, Ca 92664.

¶ International Commission on Illumination.

|| The computer program is available on request from the authors.

Comparisons among colors determined visually were made by use of an estimate of the critical color difference (I_c) necessary to show a significant difference between two colors. The distribution of I was estimated by an exponential function:[8]

$$f(I) = \frac{1}{\beta} e^{-I/\beta}$$

where β is an expected value equal to $\bar{I}$, which is the average color difference between two observations of a sample among the products tested. The parameter I_c 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.

The spectrophotometric parameters, luminous reflectance, dominant wavelength, and excitation purity were studied by a two-way analysis of variance[9] to determine the effects of products and background conditions (a and b) for the composite resins and for the glazes. Data for the contrast ratio were studied by a one-way analysis of variance.[10] Tukey's intervals at the 95% level of confidence were calculated[11] for comparisons among means.

Results

Mean values and standard deviations of luminous reflectance, dominant wavelength, excitation purity, and contrast ratio are listed in Table 2 for the composite resins and the unfilled resin and in Table 3 for the glazes. Data for both black and white backgrounds are presented. The consensus values of Munsell color

TABLE 2

MUNSELL COLOR AND SPECTROPHOTOMETRIC DATA OBTAINED WITH BLACK AND WHITE BACKGROUNDS FOR COMPOSITE AND UNFILLED RESINS

		Property*				
Code	Background	Luminous Reflectance (Y)	Dominant Wavelength, nm	Excitation Purity	Contrast Ratio†	Munsell Color (Hue Value/Chroma)
Composite Resins						
A						
	black	40.1(1.0)	577.15(0.09)	0.138(0.004)		
	white	59.4(1.3)	578.90(0.07)	0.270(0.004)	0.675(0.012)	2.5Y 7.5/3
AR						
	black	42.3(1.4)	577.75(0.21)	0.132(0.003)		
	white	61.0(1.0)	579.57(0.18)	0.265(0.006)	0.694(0.012)	2.5Y 7.5/3
C						
	black	43.5(0.6)	576.34(0.09)	0.169(0.003)		
	white	66.1(1.4)	578.53(0.05)	0.307(0.007)	0.658(0.013)	2.5Y 8.0/4
NF						
	black	46.3(0.6)	573.25(0.25)	0.068(0.001)		
	white	78.9(1.5)	576.11(0.11)	0.160(0.001)	0.587(0.010)	5.0Y 8.5/2
P						
	black	38.3(1.3)	576.53(0.05)	0.181(0.003)		
	white	51.6(1.2)	578.50(0.09)	0.289(0.005)	0.742(0.012)	2.5Y 7.0/3
S						
	black	44.8(0.7)	576.56(0.12)	0.167(0.003)		
	white	66.3(1.6)	578.63(0.14)	0.300(0.007)	0.676(0.012)	2.5Y 8.0/4
V						
	black	49.8(0.6)	573.12(0.18)	0.089(0.003)		
	white	72.2(0.4)	575.91(0.04)	0.207(0.003)	0.690(0.009)	5.0Y 8.0/2
Unfilled Resins						
SV						
	black	51.5(3.9)	573.3 (0.4)	0.136(0.009)		
	white	64.7(1.5)	576.28(0.04)	0.232(0.020)	0.796(0.055)	7.5Y 8.0/2

* Mean of 5 replications with standard deviations in parentheses.
† Y black/Y white.

TABLE 3

MUNSELL COLOR AND SPECTROPHOTOMETRIC DATA OBTAINED WITH BLACK AND WHITE BACKGROUNDS FOR GLAZES

Code	Back-ground	Luminous Reflectance (Y)	Dominant Wavelength, nm	Excitation Purity	Contrast Ratio†	Munsell Color (Hue Value/ Chroma)
		Property*				
Glazes						
F						
	black	21.5(0.9)	572.42(0.21)	0.146(0.008)		
	white	67.9(1.1)	575.78(0.19)	0.294(0.013)	0.317(0.010)	2.5Y 7.5/5
G						
	black	9.3(0.4)	571.0 (1.4)	0.044(0.006)		
	white	80.4(0.7)	573.48(0.26)	0.154(0.010)	0.116(0.006)	5.0Y 9.0/3
NS						
	black	9.0(0.4)	486 (5)	0.008(0.004)		
	white	87.7(1.0)	571.07(0.14)	0.035(0.006)	0.102(0.004)	10Y 9.5/1

* Mean of 5 replications with standard deviations in parentheses.
† Y black/Y white.

determined against a white background also are listed in Tables 2 and 3.

The data for luminous reflectance, dominant wavelength, and excitation purity of the composite resins were studied by a two-way analysis of variance to determine differences among materials and between backgrounds. Both factors and their interaction were significant at the 95% level of confidence for the 3 spectrophotometric parameters. Data for the unfilled resin were excluded from the analysis because the variances associated with the parameters were unusually high. Analysis of variance for the glazes was made and similar results were found. Tukey's intervals at the 95% level for comparisons of means among products and between backgrounds are listed in Table 4 for the composite resins and the glazes. Data for the contrast ratio were studied by a one-way analysis of variance to determine differences among the composite resins and among the glazes. Tukey's intervals for comparisons of mean values of contrast ratio are also listed in Table 4. To compare values of Munsell color, the critical color difference (I_c) was calculated at the 95% level ($P = 0.05$) and was 3.1 for all the restorative resins tested.

The luminous reflectance of the composite resins measured on a white background ranged from 51.6 for P to 78.9 for NF. The unfilled resin (SV) had a value of 64.7. The glazes had values from 67.9 for F to 87.7 for NS. Values of luminous reflectance (Y) measured on a white background were always higher than values measured on a black background. The ratio of the lower value of Y to the higher value of Y is the contrast ratio. The contrast ratio of the composites ranged from 0.587 for

TABLE 4

TUKEY'S INTERVALS FOR COMPARISONS AMONG MEAN VALUES OF SPECTROPHOTOMETRIC DATA

Comparisons	Luminous Reflectance (Y)	Dominant Wavelength, nm	Excitation Purity	Contrast Ratio
	Tukey's Intervals			
Among composite resins	1.5	0.19	0.006	0.023
Between black and white background for composite resins	0.5	0.06	0.002	—
Among glazes	0.9	2.2	0.009	0.012
Between black and white background for glazes	0.6	1.5	0.006	—

NF to 0.742 for P. The unfilled resin (SV) had a ratio of 0.796. The unfilled glazes (NS and G) had values of 0.102 and 0.116, whereas the filled glaze (F) had a contrast ratio of 0.317.

The dominant wavelength of the composite resins measured on a white background ranged from 575.91 nm for V to 579.57 nm for AR. The unfilled resin (SV) had a value of 576.28 nm. The dominant wavelength of the glazes ranged from 571.07 nm for NS to 575.78 nm for F. Values of dominant wavelength measured on a white background were always higher than values measured on a black background, but the differences were small (1.7 to 2.9 nm) except for NS (85 nm).

The excitation purity of the composite resins measured on a white background ranged from 0.160 for NF to 0.307 for C. The unfilled resin (SV) had a value of 0.232. The excitation purity of the glazes ranged from 0.035 for NS to 0.294 for F. Values of excitation purity measured on a white background were always higher than values on a black background.

The hue of Munsell color of the composite resins measured on a white background ranged from 2.5Y to 5.0Y, the value from 7.0/ to 8.5/, and the chroma from /2 to /4. The color of the unfilled resin was 7.5Y 8.0/2. The hue of the glazes ranged from 2.5Y to 10Y, the value from 7.5/ to 9.5/, and the chroma from /1 to/5. The correlation coefficient (r) between hue and dominant wavelength for the eleven resins studied was computed[10] to be 0.826; r between value and luminous reflectance was 0.948; and r between chroma and excitation purity was 0.791. The critical value for r above which the hypothesis of independence of the aforementioned pairs of parameters could be rejected was 0.602 at the 95 percent level of confidence.

Discussion

The 5 composite resins (A, AR, C, P, and S) in which a "universal" shade was evaluated were more red in hue and had a slightly higher dominant wavelength than the 2 composite resins in which the "light" shade was evaluated (NF and V). The unfilled restorative resin (SV) appeared visually more yellow-green in hue, but the dominant wavelength was similar to that for the "light" shade composites. The composite (NF) activated by ultraviolet light was the lightest in value and had the highest luminous reflectance, followed by C, S, V, and SV in the middle range, and then P which was the darkest in value and had the lowest luminous reflectance. Both NF and V were among the lighter shades of the materials studied. In comparing chroma, C and S were the deepest and had the highest excitation purity; A, AR, and P were intermediate; and NF, V and SV were the least chromatic. Both the "light" shades (NF and V) and the unfilled resin (SV) were more gray (less chromatic) than the "universal" shades.

Color varied considerably among the 3 glaze coatings. The glaze (NS) activated by ultraviolet light was more green in hue, lighter in value, and less chromatic than either of the self-curing materials (F and G). The filled glaze (F) had color characteristics similar to the "universal" shade composite resins, but had somewhat greater chroma. The glaze coatings

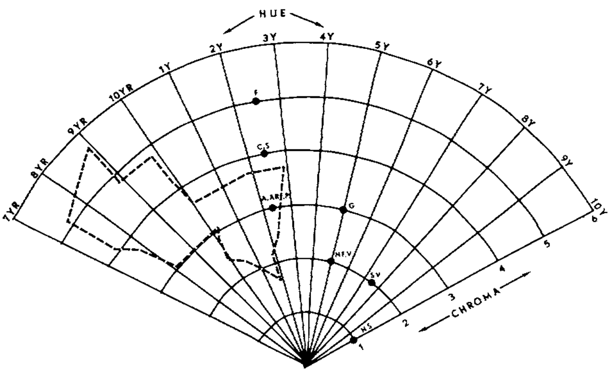

FIG 1.—A comparison of the color distribution for hue and chroma between restorative resins and natural teeth.[1]

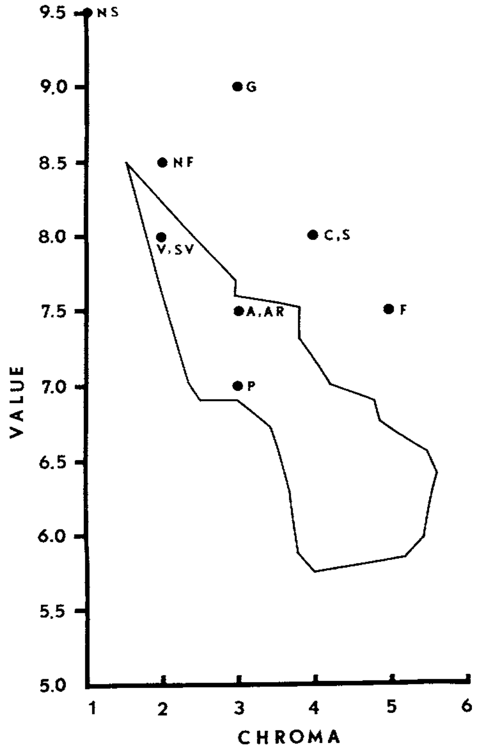

FIG 2.—A comparison of the color distribution for value and chroma between restorative resins and natural teeth.[1]

all were more translucent than the restorative resins. Although the filled glaze (F) was more translucent than the restorative resins, it was 3 times as opaque as the 2 unfilled glazes.

In comparing the color distribution of the restorative resins in this study with Munsell data obtained previously by Sproull[1] for natural teeth, only A, AR, and P appear to fall within the range for hue and chroma of human teeth (Fig 1). C. S, and F possess too much chroma, and the remaining materials are outside the range for a natural hue. When value and chroma of the resins are compared to those obtained for natural teeth[1] (Fig 2), V and SV also fall within the acceptable range with A, AR, and P. The remaining materials are too light for the amount of chroma displayed.

Conclusions

The color of 7 commercial composite restorative resins, an unfilled restorative resin and 3 glaze coatings was determined by reflection spectrophotometry and visually with Munsell color tabs. The interexaminer agreement for visual color evaluation of the 11 resins resulted in a critical color difference (I_c) of 3.1. Statistically significant correlations between comparable parameters of the spectrophotometric and Munsell data were observed. Values of luminous reflectance, dominant wavelength, and excitation purity were higher for the resins tested when measured against a white as opposed to a black background. The contrast ratio of samples 1.3 mm thick ranged from 0.587 to 0.742 for the composite resins and from 0.102 to 0.317 for the coatings. Only 3 of the "universal" shades of the composite resins tested were observed in the value, hue, and chroma reported for natural teeth.

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