MATERIALS SCIENCE

Color of Selected Shades of Composites by Reflection Spectrophotometry

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The colors of seven shades of a conventional composite and five shades of a microfilled composite were measured by reflection spectrophotometry at three thicknesses and for two backgrounds. Intrinsic color was determined from reflectivity data computed from optical properties. As thickness increased, the color approached the intrinsic color. Differences in color among shades were statistically significant.

J Dent Res 61(10):1176-1179, October 1982

Introduction.

Composite restorative materials for esthetic restoration of anterior teeth are formulated typically as a "universal" shade which is usually esthetically acceptable in small restorations. The colors of a number of commercial composites have been studied instrumentally and visually.[1,2] Background color and thickness of the composite have been shown to influence the color of the composite.[3,4]

In a large restoration or in the restoration of teeth of an unusual shade or translucency, some modification of color of the "universal" shade of a composite may be required to obtain an acceptable color match. Recently, shaded conventional and microfilled composites have become available.

The purpose of this study was to evaluate the color and opacity of shaded composites by reflection spectrophotometry at three thicknesses and for two backgrounds. These data were related to intrinsic color as determined from reflectivity data computed from optical properties.[5]

Materials and methods.

One conventional brand* (C) and one microfilled brand† (S) of composite were used. Seven shades of C and five shades of S were evaluated for color characteristics after initial set. Codes, shades, and batch numbers of the products are listed in Table 1.

Nine sample disks (36 mm in diameter and 1.2 mm in thickness) were prepared following manufacturer's recommendations for each product by polymerization of the composite in a metal die. Two min after the mix was initiated, the samples were placed in an environment of 37 ± 1°C and 95 ± 5% relative humidity for 15 min. The specimens were then stored for 24 h in distilled water at 37 ± 1°C before finishing. Surface finishes for both sides of the samples were made with a metallurgical grinder and 600 grit abrasive paper# under water. The samples were stored in an environment of 23 ± 2.0°C and 50 ± 10% relative humidity for four d before testing.

Three out of nine disks were selected from each product as 1.2 mm samples. Three samples at each of two additional thicknesses were obtained by placing any two of nine sample disks together to form 2.4 mm samples, and by placing any three of nine sample disks together to form 3.6 mm samples. The actual thicknesses for all 1.2, 2.4, and 3.6 mm samples were measured to the nearest 0.01 mm.

A double-beam ultraviolet-visible spectrophotometer+ with an integrating sphere‡ was used to obtain reflectance data at wavelengths (λ) of every 5 nm between 405 and 700 nm for combined specular and diffuse reflectance. A transmission blank§ was used for calibration of zero reflectance. A white porcelain standard∞ for which values of absolute reflectance were known at every 5 nm was evaluated in a sample port (25 mm in diameter) with a barium sulfate standard¶ in a reference port to obtain calibration coefficients at every 5 nm.

Specimens of each thickness (1.2, 2.4, and 3.6 mm) for each product were evaluated in the sample port with the barium sulfate standard in the reference port under two conditions: (a) backed by a black standard,** and (b) backed by a white standard.†† Reflectance values of the black standard and white standard were obtained as well. The data were then multiplied by the corresponding calibration coefficients to obtain absolute reflectance values.

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 and, with the use of a computer program,[1] were used to obtain dominant wavelength and excitation purity from CIE chromaticity data (1931). Luminous reflectance was equal to the tristimulus value, Y. An estimate of the opacity of each product at each thickness was obtained by calculation of the contrast ratio,[7] achieved by dividing the luminous reflectance with a black background by the luminous reflectance with a white background, Y black/Y white.

The light reflectivity (RI) of materials was calculated algebraically from the data of spectral reflectance of the 1.2 mm samples of the material as a function of wavelength at every 5 nm, by applying the Kubelka-Munk theory[8] as described elsewhere.[5] From the data of light reflectivity (RI),[5] the tristimulus values (X, Y, Z) relative

Received for publication August 10, 1981
Accepted for publication September 10, 1981

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Based on a thesis submitted in partial fulfillment of the requirements for the Master's degree in the Horace H. Rackham School of Graduate Studies at The University of Michigan, 1981

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*Concise, 3M Company, St. Paul, MN 55101

†Silar, 3M Company, St. Paul, MN 55101

#Gp-304, SiC Strips, Grit 600, Mager Scientific, Inc., Dexter, MI 48130

+ACTA C III UV-visible Spectrophotometer, Beckman Instruments, Inc., Irvine, CA 92664

‡ASPH-U Integrating Sphere, Beckman Instruments, Inc., Irvine, CA 92664

§Part No. 587738, Beckman Instruments, Inc., Irvine, CA 92664

∞Standard No. D33C-2051, Hunter Associates Laboratory, Inc., Fairfax, VA 22030

¶Part No. 104384, Beckman Instruments, Inc., Irvine, CA 92664

**Part No. 375287, Beckman Instruments, Inc., Irvine, CA 92664

††Part No. 375285, Beckman Instruments, Inc., Irvine, CA 92664

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TABLE 1
CODES, PRODUCTS, AND BATCH NUMBERS OF COMPOSITE RESINS TESTED

Code	Product*	Batch Number
CU	Concise Universal	Base – OY27 † Catalyst – OX19
CY	Concise Yellow	Base – OP1
CDY	Concise Dark Yellow	Base – OP1
CL	Concise Light	Base – 9L1
CG	Concise Gray	Base – ON2
CO	Concise Opaque	Base – 9335K1
CT	Concise Translucent	Base – 9039Y1
SU	Silar Universal	Base – OP3 ‡ Catalyst – OM2
SY	Silar Yellow	Base – OE4
SDY	Silar Dark Yellow	Base – OG4
SL	Silar Light	Base – OG3
SG	Silar Gray	Base – OL2

*Manufactured by 3M Company, St. Paul, MN 55101
†Catalyst OX19 was used for all shades of C.
‡Catalyst OM2 was used for all shades of S.

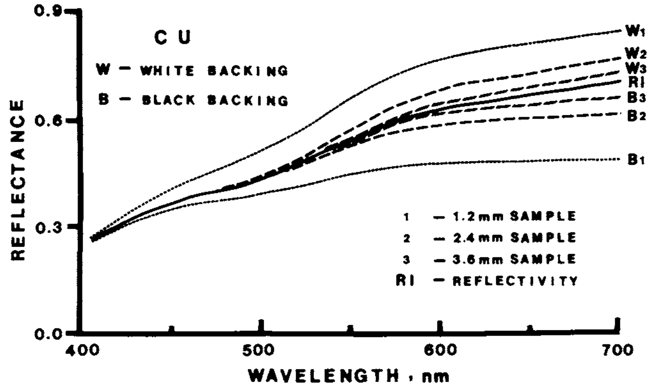

Fig. 1 – Absolute spectral reflectance curves for CU measured on a white and black backing at thicknesses of 1.2, 2.4, and 3.6 mm. The reflectivity curve (RI)[5] is shown for comparison.

to the 1931 CIE color-matching function for CIE Standard Illuminant C were computed at every 5 nm wavelength for each product. The luminous reflectance, dominant wavelength, and excitation purity for the light reflectivity (RI) data of each product were determined as described before.

The effects of shade and thickness on the luminous reflectance, dominant wavelength, and excitation purity (measured on a white background) and on the contrast ratio were studied by analysis of variance.[9] For light reflectivity (RI), the luminous reflectance, dominant wavelength, and excitation purity of the composites were studied by a one-way analysis of variance[10] to determine the effect of shade. Tukey intervals[11] at the 95% level of confidence were calculated for comparisons among means.

Results.

Absolute spectral reflectance curves for CU measured on white and black backgrounds and at thicknesses of 1.2, 2.4, and 3.6 mm are shown in Fig. 1. The curve of light reflectivity (RI)[5] is shown for comparison. As the thickness of the composite increased, the reflectance curves approached the light reflectivity (RI) curve of the material for all the shades of C and S studied.

Mean values and standard deviations of luminous reflectance (LR), dominant wavelength (DW), and excitation purity (EP) were calculated from the absolute reflectance spectra and are listed in Table 2 for CU as a function of background and thickness. The data for RI represent the color calculated from light reflectivity (RI) data of CU as reported elsewhere.[5] For a black background, the luminous reflectance and excitation purity increased with increasing thickness for all shades of C and S. For a white background, these parameters decreased with increasing thickness. Luminous reflectance and excitation purity for both backgrounds approached values at RI, as indicated in Table 2 for CU. The effects of thickness and background on the dominant wavelength of C and S were statistically significant, but there was no uniform relationship.

Spectrophotometric properties of all shades of C and S are listed in Table 3 for 1.2 mm samples with black and white backgrounds and for light reflectivity data. There were statistically significant differences among the means as determined by analysis of variance. Tukey intervals for comparisons among means of shades of C or S are listed in Table 3.

As shown in Table 3, the luminous reflectance and excitation purity of 1.2 mm samples of all shades of C and S were lower for the black than for the white background. For C and S measured on either background, the luminous reflectance of light shades (CL and SL) and universal shades (CU and SU) was higher than that of other shades (except CO on black). The luminous reflectance of gray shades (CG and SG) and dark yellow shades (CDY and SDY) was lower than that of other shades. For both C and S, the excitation purity of dark yellow shades (CDY and SDY) and yellow shades (CY and SY) was higher than that of other shades. Composites with light shades (CL and SL)

TABLE 2
SPECTROPHOTOMETRIC PROPERTIES OF CU AS A FUNCTION OF BACKGROUND AND THICKNESS

Property	Background	Thickness, mm 1.2	2.4	3.6	RI*
LR	Black	44.7 (0.6)†	52.5 (0.7)	54.5 (0.9)	55.0 (0.7)
	White	66.7 (0.6)	58.3 (0.5)	55.9 (0.8)	
DW, nm	Black	576.73 (0.04)	578.28 (0.04)	579.07 (0.51)	579.78 (0.03)
	White	578.87 (0.04)	580.26 (0.03)	580.06 (0.07)	
EP	Black	0.149 (0.001)	0.210 (0.002)	0.231 (0.003)	0.240 (0.002)
	White	0.279 (0.005)	0.266 (0.001)	0.249 (0.003)	

*The properties were calculated from light reflectivity (RI) data.[5]
†Mean value of three replications with standard deviations in parentheses.

TABLE 3
SPECTROPHOTOMETRIC PROPERTIES OF C AND S FOR 1.2 mm SAMPLES WITH BLACK AND WHITE BACKGROUNDS AND FOR LIGHT REFLECTIVITY DATA

	Property					
	LR			EP		
Material Code	Black	RI*	White	Black	RI*	White
CU	44.7 (0.6)†	55.0 (0.7)	66.7 (0.6)	0.149 (0.001)	0.240 (0.002)	0.279 (0.005)
CY	41.1 (1.4)	49.3 (1.3)	60.3 (0.9)	0.240 (0.006)	0.328 (0.009)	0.386 (0.008)
CDY	36.6 (0.0)	41.8 (0.2)	50.6 (0.5)	0.273 (0.007)	0.339 (0.006)	0.405 (0.007)
CL	49.1 (0.8)	57.0 (0.4)	66.0 (0.2)	0.138 (0.003)	0.212 (0.000)	0.259 (0.000)
CG	37.3 (0.7)	43.5 (1.0)	54.0 (1.2)	0.200 (0.008)	0.271 (0.005)	0.330 (0.006)
CO	51.6 (0.2)	54.8 (0.0)	58.8 (0.2)	0.195 (0.003)	0.237 (0.008)	0.269 (0.002)
CT	42.0 (0.6)	52.1 (0.7)	64.7 (0.6)	0.168 (0.005)	0.258 (0.005)	0.298 (0.002)
Tukey Interval for C‡	2.0	2.1	2.0	0.015	0.017	0.015
SU	43.4 (0.2)	56.8 (0.1)	70.7 (0.4)	0.107 (0.003)	0.240 (0.001)	0.298 (0.001)
SY	38.1 (0.2)	50.0 (0.5)	64.4 (0.6)	0.229 (0.002)	0.367 (0.004)	0.445 (0.002)
SDY	32.5 (0.4)	38.2 (0.2)	48.7 (0.6)	0.260 (0.003)	0.348 (0.005)	0.447 (0.004)
SL	50.4 (0.2)	61.6 (0.2)	72.2 (0.2)	0.105 (0.003)	0.210 (0.003)	0.254 (0.004)
SG	31.9 (0.1)	37.4 (0.2)	48.8 (0.7)	0.166 (0.003)	0.250 (0.001)	0.353 (0.002)
Tukey Interval for S‡	1.1	0.7	1.1	0.022	0.010	0.022

*The properties were calculated from light reflectivity (RI) data.[5]
†Mean value of three replications with standard deviations in parentheses.
‡ Tukey intervals for comparisons among means of shades of C or S were computed from analysis of variance at the 95% level of confidence.

had lower excitation purity than did other shades. The translucent (CT) shade of C had slightly lower values of luminous reflectance than CU but had higher values of excitation purity. The opaque shade (CO) of C was similar to CU for properties calculated from light reflectivity data; but, at a thickness of 1.2 mm, CO deviated less from values at RI than did CU.

As shown in Table 3, the luminous reflectance of shades of S determined from reflectivity data (RI) was slightly greater than or equal to that of corresponding shades of C, except for SDY and SG, which had lower values of LR. The excitation purity of shades of S at RI was the same as or greater than values of C, except for SG, which had a lower value of EP than CG.

The effect of thickness on the contrast ratio is shown in Fig. 2 for C and Fig. 3 for S. There were statistically significant differences among the mean values of contrast ratio. Tukey intervals for comparison of means among shades were 0.023 for C and 0.014 for S. The contrast ratio increased with increasing thickness and approached a value of one. Among the shades of C at 1.2 mm, CT was least opaque; CU, CY, and CG had similar values of contrast ratio, followed by CDY and CL; CO was most opaque. At 3.6 mm, only CT and CU had contrast ratios significantly different from 1.00. Among the shades of S at 1.2 mm, SU and SY were least opaque, followed by SG and SDY; SL was most opaque. At higher thicknesses, SY and SU remained least opaque, whereas SG, SDY, and SL were more opaque. At each thickness, the shades of S were less opaque than were corresponding shades of C, although at 3.6 mm the differences were not significant.

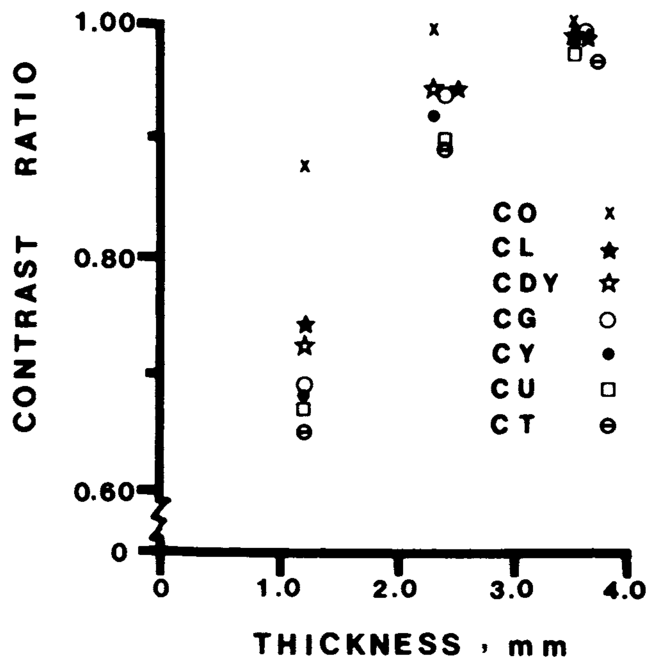

Fig. 2 – Contrast ratio of C as a function of thickness.

are less opaque than those of C, the color of thin (1.2 mm) samples of S is more affected by the background than is that of C.

Clinically, the shades of C and S represent a broad range of values of luminous reflectance and excitation purity. For 1.2 mm samples and a white background, the luminous reflectance of C ranged from 50.6 (CDY) to 66.7 (CU), and that of S ranged from 48.7 (SDY) to 72.7 (SL). Under these conditions, the excitation purity of C ranged from 0.405 (CDY) to 0.259 (CL), and that of S ranged from 0.447 (SDY) to 0.254 (SL). Colors which could be obtained by mixing two or more shades were not evaluated in this study.

Discussion.

The colors determined from reflectivity data[5] of like shades of the conventional (C) and microfilled (S) composites were generally similar, although there were some statistically significant differences. Because the shades of S

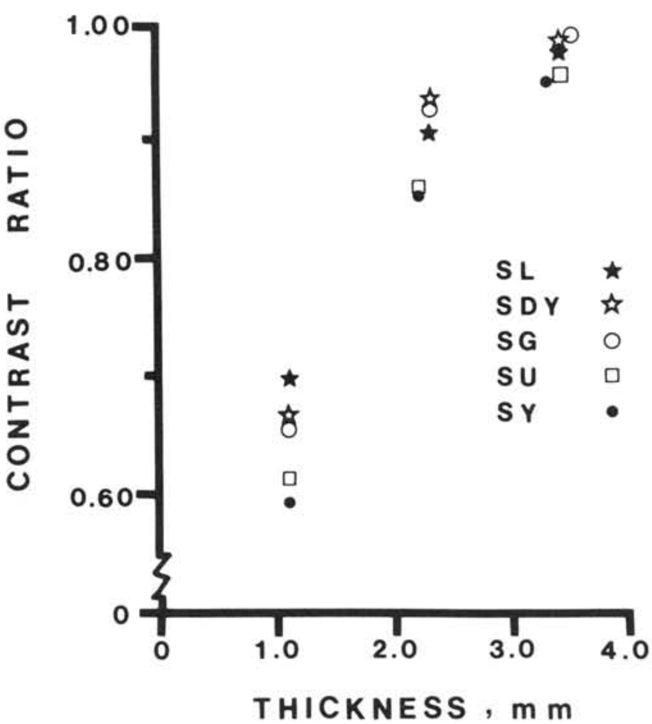

Fig. 3 – Contrast ratio of S as a function of thickness.

Conclusions.

The colors of seven shades of a conventional (C) composite and five shades of a microfilled (S) composite were measured by reflection spectrophotometry at three thicknesses and for two backgrounds. Intrinsic color was determined from reflectivity data computed from optical properties. The color of the composites approached the intrinsic color, and the contrast ratio approached one as thickness increased between 1.2 and 3.6 mm. The background affected the color of S more than of C. Samples on a black background had lower values of luminous reflectance and excitation purity than did samples on a white background. Significant color differences were observed among the shades of C and S.

Acknowledgments.

The cooperation of the 3M Company for providing commercial materials is acknowledged.

Dr. Yeh acknowledges the financial support of the Government of the Republic of China and National Defense Medical Center, Taipei, Republic of China, for his graduate studies at the University of Michigan.

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