Color Analysis of Dental Modifying Porcelains

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Sintered samples of modifying porcelains of various colors and manufacturers were analyzed using reflectance spectrophotometry. Color designations are reported according to practices of the Commission Internationale de l'Eclairage (International Commission for Illumination), and color names were assigned based on a method developed through a joint effort of the Inter-Society Color Council and the United States National Bureau of Standards (ISCC-NBS). Within samples labeled by the same color, differences among manufacturers were found in the color designations and names. These differences were noted in part by plots of the chromaticity coordinates of the samples. The ISCC-NBS method of designating colors is proposed as a uniform and descriptive color-naming method for modifier porcelain. Consistent color naming is a step in improving communication over the use of modifying porcelains.

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Introduction.

Dental porcelains are supplied pigmented to match existing shade guides. Shade guides provide a method of uniform color description for the individual shades of the guide. Pre-mixed porcelains may be altered by the addition of modifier porcelains which contain a high concentration of one pigment color. These modifier porcelains are also useful in simulating the appearance of translucency with porcelain-fused-to-metal restorations and in duplicating color features of adjacent natural teeth. The objectives of this study are to: (1) determine the color designations of commercially available dental modifying porcelains by diffuse reflectance spectrophotometry; (2) compare the color designations of those porcelains identified by the same color; and (3) propose a color-naming system for these materials.

Materials and methods.

Samples were made by vibrating one g of modifier porcelain powder, with enough distilled water for handling, into a 3/8"-diameter cylindrical mold, with the surface to be analyzed formed against glass. One sample of each available color from each manufacturer* was dried and fired once according to manufacturer's directions. In order to determine the confidence interval of the subsequent spectrophotometric determinations, an additional specimen was made for one brand of the colors blue, brown, gray, orange, pink, and yellow. The resultant six groups of two replicates were used instead of replicating all measurements because of the low variability in the measurements.

Diffuse reflectance measurements were made for each sample, using a dual-beam spectrophotometer with an integrating sphere and condensing lenses.† The reference material was magnesium oxide, and an absolute reflectance calibration standard‡ was employed. Every reflectance measurement was corrected[1] to absolute reflectance. Reflectance spectra were measured from 410 to 700 nm at 10-nm intervals. The bandwidth was set at 2 nm. The reflectance spectrum of each specimen was recorded with a black backing and compared to that obtained with a white backing. If the two reflectance measurements at any wavelength differed by greater than 0.005 in absolute reflectance, that specimen was not used, and a thicker specimen was made.

Commission Internationale de l'Eclairage (CIE—International Commission for Illumination) color designations of chromaticity coordinates (x and y), luminous reflectance (Y) in percent, dominant wavelength (DW), and excitation purity (EP) were calculated[2] for CIE Illuminant D65 and CIE 1934 Standard Observer. Also, determinations of the Inter-Society Color Council and National Bureau of Standards color names[3] were made at level 3 (ISCC-NBS-3). This latter system divides the color solid into 267 parts and labels each division with an easily-understood color name.

Results.

The variances of the chromaticity coordinates of the duplicate samples were not significantly different ($P > 0.05$) and, when pooled, resulted in a confidence interval ($P = 0.05$) of 0.003 for either coordinate for a sample of one Similarly, the confidence interval of the dominant wavelength was calculated to be 1.4 nm, while that for excitation purity was 0.007, with 2.7% for luminous reflectance.

For each sample, the ISCC-NBS-3 color name and CIE color designations (DW, EP, and Y) are given in Table 1. Where more than one brand of any one color was studied, the ranges of the CIE color designations are given in Table 2, and the chromaticity coordinates were plotted as shown in Figs. 1-8. The chromaticity coordinates of the illuminant are shown in these Figs. for reference where possible.

Discussion.

The ISCC-NBS-3 color name is a highly descriptive name which would enhance a user's ability to determine either the effect of a modifier porcelain mixed with a standard shade, or the effect of a thin layer of modifier placed over another shade. This name would be helpful in determining any secondary coloring effects which would result from using a particular modifier.

For some samples, the ISCC-NBS-3 color names disagree

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*The brands and manufacturers are as follows: B – Biobond^{R} 1750 VF Porcelain Opaque Modifier, Dentsply Int'l., Inc., York, PA 17405; CE – Ceramco^{R} VT Vacuum Porcelain, Ceramco, Inc., New York, NY 11101; CR – Crystar^{TM} Metal-Bond VF Porcelain, Shofu Dental Corp., Menlo Park, CA 94025; D – Denpac^{TM} Gingival Modifier Porcelain, Denpac Corp., Hackensack, NJ 07601; E – Excelco^{R} Vacuum Porcelain Universal Gingival Modifier, Excelco, Int'l., Inc., Santurce, PR 00908; M – Micro-Bond^{R} Hi-Life^{R} Porcelain, Howmedica, Inc., Dental Div., Chicago, IL 60632; N – Neydium^{TM} Opaque Modifier Porcelain, J.M. Ney Co., Bloomfield, CT 06002; V – Vita VMK^{R}, Unitek Corp., Monrovia, CA 91016; W – Will-Ceram^{TM} Porcelain Body Modifier, Williams Gold Refining Co., Buffalo, NY 14214.

†Beckman Instruments, Inc., Fullerton, CA 92634; spectrophotometer model ACTA CIII: sphere attachment model ASPH-U; condensing lenses model ASPH-BR.

‡Hunter Assoc. Laboratory, Inc., Fairfax, VA 22030; reflectance standard #S1003.

TABLE 1
COLOR ANALYSIS OF DENTAL MODIFYING PORCELAINS

Code	Labeled Color	ISCC-NBS-3 Color Name	CIE Color Designation		
			DW (nm)	EP	Y (%)
B	yellow	moderate yellow	579	0.505	48.9
CE	yellow	moderate yellow	575	0.476	38.8
CR	yellow	moderate yellow	575	0.509	40.9
D	yellow	moderate yellow	575	0.479	36.4
E	yellow	moderate yellow	577	0.553	36.4
M	yellow	moderate greenish yellow	571	0.471	56.2
N	yellow	light yellowish brown	583	0.423	46.5
W	yellow	moderate yellow	575	0.458	40.4
W	honey yellow	moderate yellowish brown	582	0.475	23.3
M	peach	moderate yellowish pink	587	0.220	41.4
V	green	grayish olive green	559	0.202	14.6
W	green	grayish green	552	0.117	15.3
B	brown	light brown	585	0.335	18.9
CE	brown	grayish reddish brown	594	0.160	10.9
CR	brown	moderate yellowish brown	582	0.363	12.4
D	brown	grayish red	600	0.144	11.0
E	brown	grayish reddish brown	592	0.180	11.6
M	brown	grayish brown	588	0.204	12.4
N	brown	light brown	583	0.337	24.6
V	brown	moderate yellowish brown	583	0.353	12.5
W	light brown	light brown	583	0.466	17.9
W	dark brown	moderate brown	584	0.322	11.4
B	orange	light brown	584	0.446	33.2
CE	orange	light brown	584	0.457	26.3
CR	orange	moderate yellowish brown	583	0.508	18.5
E	orange	light yellowish brown	582	0.531	32.3
M	orange	light brown	583	0.578	25.0
N	orange	moderate orange	579	0.477	48.9
V	orange	strong yellowish brown	582	0.574	19.9
B	pink	dark purplish red	495C	0.133	34.1
CE	pink	dark pink	494C	0.129	28.6
CR	pink	grayish red	607	0.173	24.0
D	pink	light grayish purplish red	493C	0.118	28.2
E	pink	dark pink	494C	0.141	29.8
M	pink	moderate yellowish pink	587	0.210	41.7
N	pink	moderate yellowish pink	589	0.206	48.8
V	pink	light reddish brown	593	0.191	25.0
		C denotes complementary wavelength.			
CR	light pink	grayish red	600	0.213	21.3
CR	dark pink	grayish red	609	0.210	18.5
W	rose	grayish red	659	0.091	17.7
CE	blue	light purplish blue	476	0.289	20.0
CR	blue	grayish purplish blue	471	0.297	7.6
E	blue	pale blue	478	0.209	27.7
M	blue	moderate blue	472	0.342	18.2
V	blue	grayish blue	482	0.140	13.1
W	blue	grayish blue	481	0.186	12.7
B	blue gray	bluish gray	483	0.058	19.0
CE	gray	medium gray	477	0.021	17.9
CR	gray	brownish gray	579	0.069	8.3
E	gray	bluish gray	482	0.047	25.5
M	gray	light olive gray	575	0.088	24.3
N	gray	bluish gray	485	0.059	23.9
V	gray	brownish gray	579	0.074	11.6
W	gray	dark gray	491	0.021	13.1
B	white	yellowish gray	577	0.070	68.1
CR	white	white	568	0.017	76.3
E	white	light gray	568	0.018	42.2
M	white	light gray	570	0.028	52.8
N	white	yellowish white	574	0.085	83.3
V	white	white	566	0.024	79.9

TABLE 2
RANGES OF COLOR DESIGNATIONS FOR MODIFYING PORCELAINS LABELED BY THE SAME COLOR

Labeled Color	n*	Ranges of Color Designations		
		DW (nm)	EP	Y (%)
yellow	8	11	0.130	19.8
green	2	7	0.085	0.7
brown	8	18	0.219	13.7
orange	7	5	0.132	30.4
pink	8	>20	0.092	24.8
blue	6	11	0.202	20.1
gray	7	102	0.067	17.2
white	6	11	0.068	41.1

*n indicates the number of brands analyzed for each labeled color.

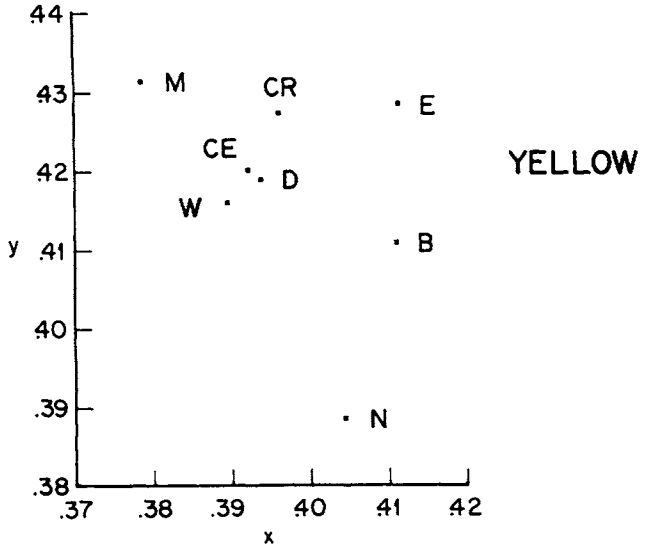

Fig. 1 – Portion of CIE 1931 (x,y)-chromaticity diagram showing chromaticity points of samples labeled yellow.

with the labeled colors, especially for those modifiers labeled orange, pink, or white. The assignment of color labels for modifier porcelains should be made in conjunction with a standard color-naming system. A single hue name is useful when a quick approximate designation of color is sufficient. However, a complete understandable color name of up to four words is available as described in this study.

The scatter of color names derived in this study for samples of identical color labeling describes the variation of each color between manufacturers. This variation is more technically described by the large ranges of the CIE color parameters relative to the respective confidence intervals. The variation is largest for the luminous reflectance of those samples labeled white, orange, pink, and blue; for the excitation purity of those labeled brown, blue, orange and yellow; and for the dominant wavelength of those labeled gray and pink. The large range in dominant wavelength of the gray samples describes the large variation of the hues of these samples, even though the gray samples exhibited very low saturation.

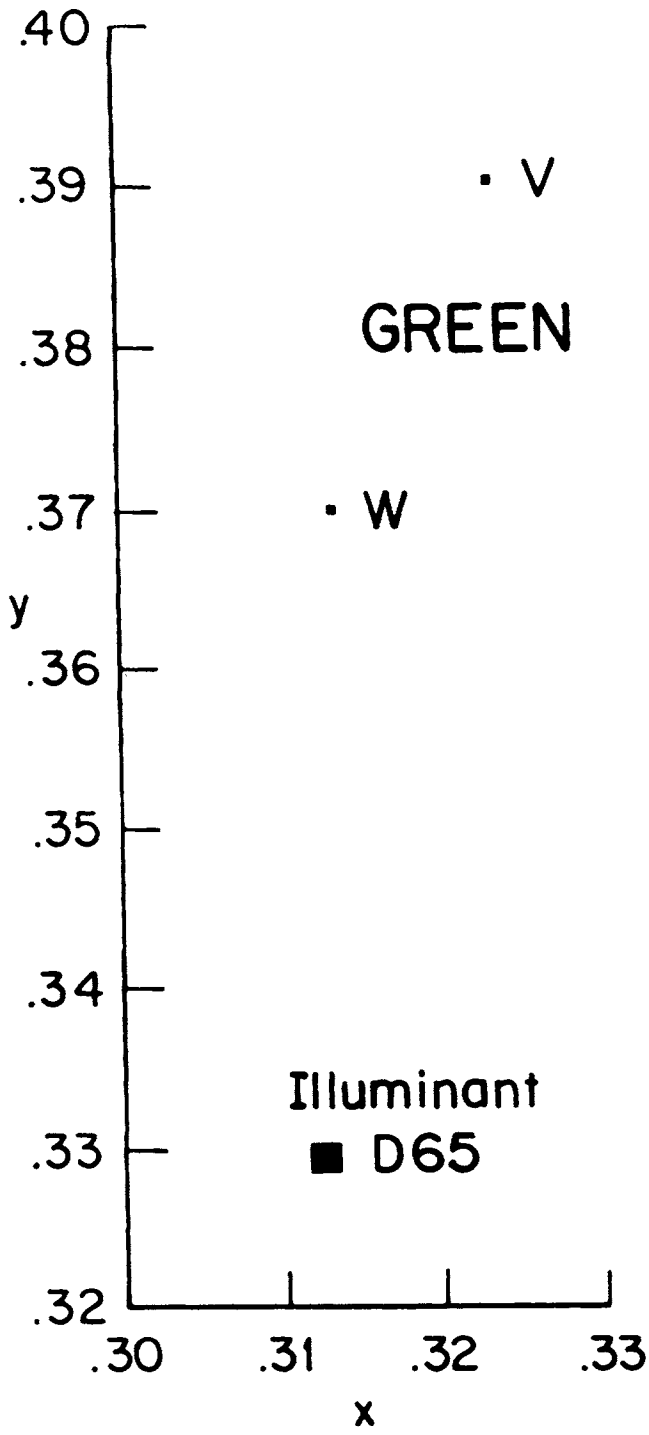

Fig. 2 – Portion of CIE 1931 (x,y)-chromaticity diagram showing chromaticity points of samples labeled green.

Conclusions.

1. The labeled colors of available dental modifying porcelains do not always agree with their color names as assigned by a method developed at the U.S. National Bureau of Standards.

2. The color names and designations of samples of these porcelains labeled by the same color vary significantly between manufacturers.

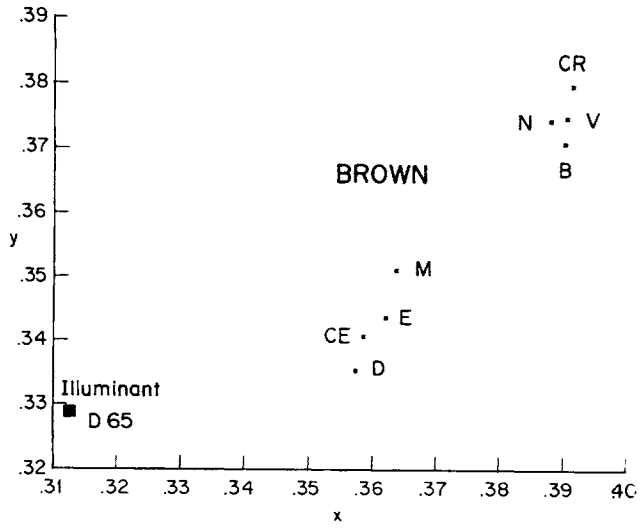

Fig. 3 – Portion of CIE 1931 (x,y)-chromaticity diagram showing chromaticity points of samples labeled brown.

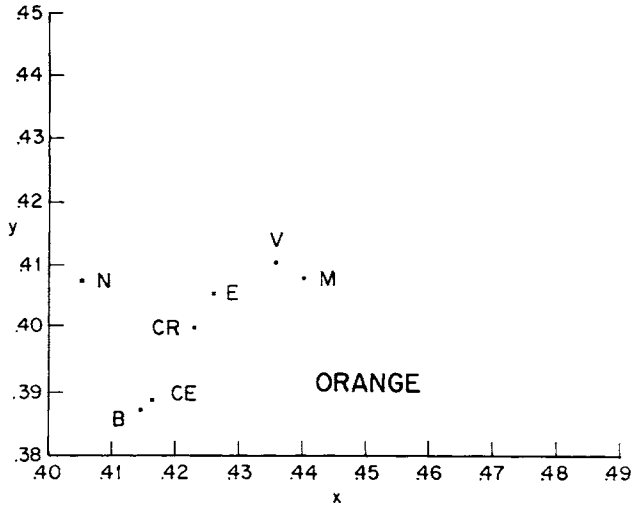

Fig. 4 – Portion of CIE 1931 (x,y)-chromaticity diagram showing chromaticity points of samples labeled orange.

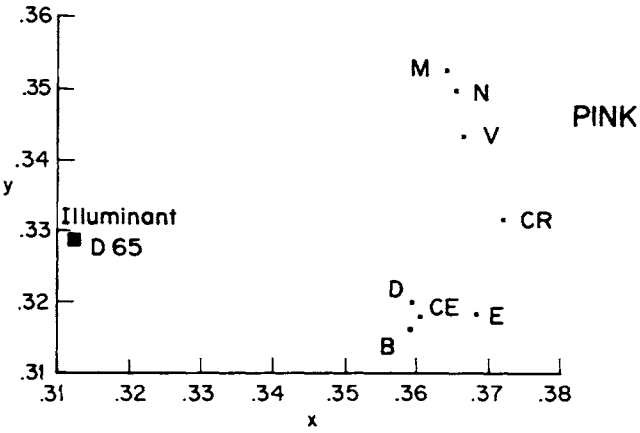

Fig. 5 – Portion of CIE 1931 (x,y)-chromaticity diagram showing chromaticity points of samples labeled pink.

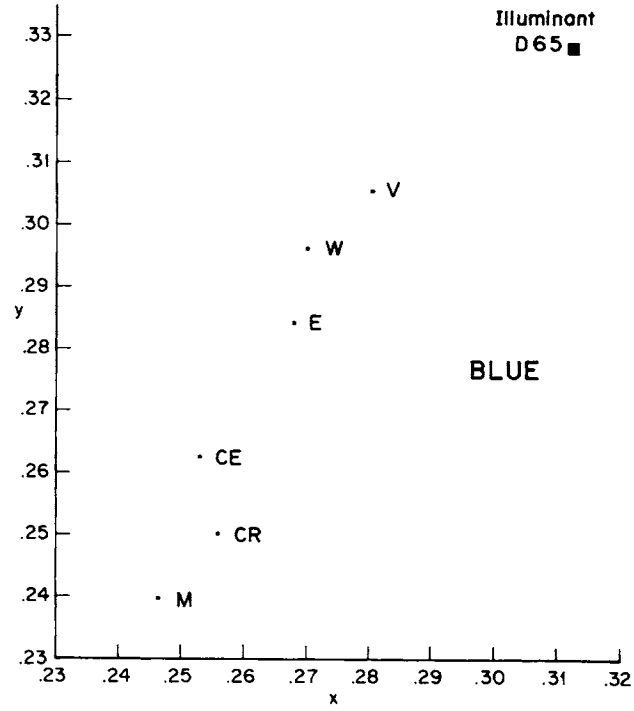

Fig. 6 – Portion of CIE 1931 (x,y)-chromaticity diagram showing chromaticity points of samples labeled blue.

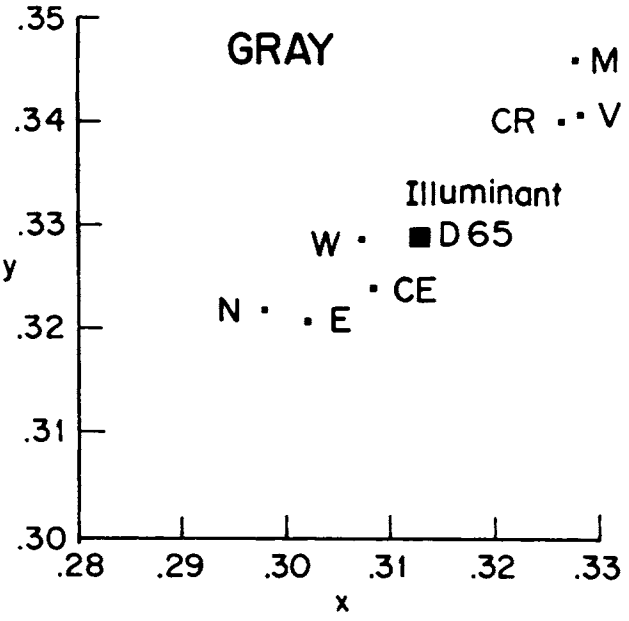

Fig. 7 – Portion of CIE 1931 (x,y)-chromaticity diagram showing chromaticity points of samples labeled gray.

3. The color-naming method proposed by the Inter-Society Color Council and developed by the National Bureau of Standards provides uniform and descriptive color names for dental modifying porcelains. These color names would enhance a user's ability to determine the coloring effect of these materials. Consistent color naming is a step in improving communication over the use of modifying porcelains.

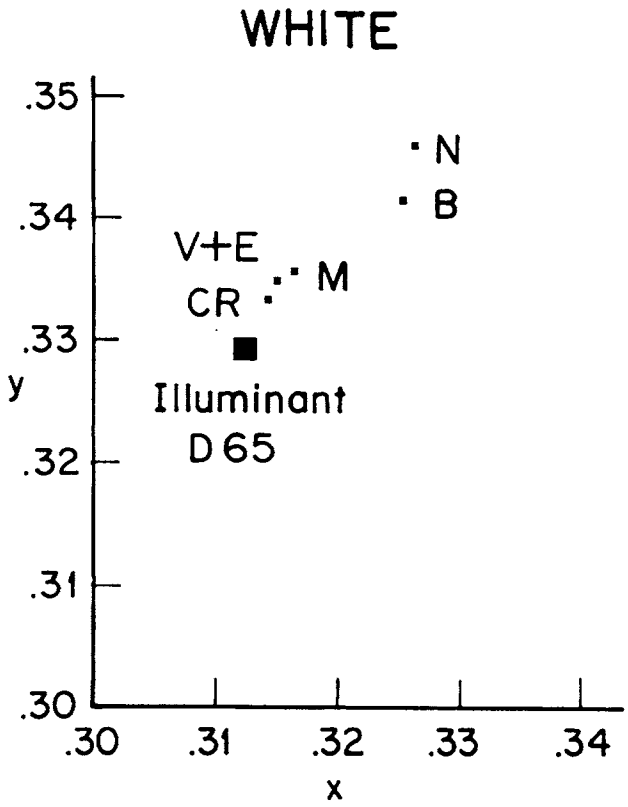

Fig. 8 – Portion of CIE 1931 (x,y)-chromaticity diagram showing chromaticity points of samples labeled white.

Acknowledgment.

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REFERENCES

1. KORTÜM, G. and LOHR, J.E. (translator): **Reflectance Spectroscopy**, New York, NY: Springer-Verlag, 1969, pp. 137-150.
2. JUDD, D.B. and WYSZECKI, G.: **Color in Business, Science, and Industry**, 3rd ed., New York, NY: Wiley, 1975, pp. 102-172.
3. KELLEY, K.L. and JUDD, D.B.: **Color – Universal Language and Dictionary of Names** (NBS Spec. Publ. 440), Washington, D.C.: U.S. Government Printing Office, 1976, p. 10.