CLINICAL RESEARCH

Clinical Evaluation of an Experimental Body Shade Guide Based on In-Vivo Tooth Color Measurements

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Purpose: **The purpose of this study was to develop and evaluate an experimental body porcelain tooth shade-guide system based on in-vivo color measurements. This system was tested against two widely used commercial body shade porcelains.**

Materials and Methods: **A body porcelain shade guide consisting of 16 tabs was fabricated from available opaques, body, and incisal porcelains and modified with metallic oxide tints. The target Hue, Value and Chroma of these tabs were based on middle-site in-vivo tooth color measurements reported by Goodkind and Schwabacher in 1987.[1] Two control groups of body porcelains were fabricated from Ceramco and Bioform porcelains. A new Dental Shade Comparator was used in a clinical test of these tabs in visually matching middle sites of 300 maxillary anterior teeth of 103 subjects.**

Results: **The demographic trends in Hue, Value and Chroma were in agreement with those found in the previous study. Four of the 16 experimental body shade tabs were frequently chosen compared with 13 of 16 Ceramco and 3 of 25 Bioform body shades. Intraexaminer and interexaminer reliability tests showed good agreement using the new Dental Shade Comparator.**

Conclusions: **The 20 shade tabs that were most frequently selected as a 1st or 2nd choice ranged from 8.25YR to 1.80Y in Hue, 6.45/ to 8.00/ in Value and /2.05 to /4.15 in Chroma. The new Dental Shade Comparator is a useful tool in the task of shade matching. The current Ceramco II body shades contain many useful porcelains that should be augmented with higher value and with redder, darker shades.**

INDEX WORDS: tooth color, porcelain, shade guide

SHADE DUPLICATION of natural teeth, a critical part of achieving an esthetic result in prosthodontics, has traditionally been troublesome for dentists and dental laboratory technicians. Predictability in shade selection requires an understanding and application of color theory. The problem is confounded by the lack of a shade guide that truly represents the color of natural teeth. The purpose of this study was to develop and evaluate an experimental body-porcelain tooth shade-guide system based on in vivo color measurements. This system was tested against two widely used commercial body shade porcelains.

Review of Literature

Attempts at describing color have brought about the emergence of various color order systems, ie, Munsell, CIE, and CIEL*a*b*. Instruments have been developed that are capable of incorporating certain color order systems and converting the data obtained into tooth color measurements.

Tooth color studies have been reported in the literature since the early 20th century. Clapp in 1914,[2] Clark in 1931,[3] Hayashi in 1967,[4] Sproull in 1973,[5] and Goodkind et al in 1985[6] reported color measurements of natural teeth. Goodkind and

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Schwabacher in 1987[1] measured 2830 anterior teeth in vivo with the use of the Chromascan (Sterndent Corp, Stamford, CT). Their data on the cervical, middle and incisal parts of anterior teeth were converted to Hue, Value and Chroma. They found anterior teeth became redder and lower in value with age. Women were found to have yellower, higher Value and less saturated teeth than men. Maxillary central incisors were found to have the highest Value of all anterior teeth. Canines measured lower in Value than incisors.

After studying approximately 6,000 teeth using a shade set of 703 tabs, Clark put together a shade guide set of 60 porcelain tabs, which he called the Tooth Color Indicator.[7] Hayashi used paper shade guide samples in his set of 125 shades.[4] Miller[8] in 1987 compared the colors of available dental porcelain shades and the color ranges of natural teeth reported in earlier studies. He and others found that these populations of color measurements did not completely match.[4,5,7-11]

In 1990, Schwabacher and Goodkind[11] reported the Munsell coordinates of three commercially available shade guides and compared them with natural tooth colors found in their earlier study.[1] Their results also showed some mismatch of the color spaces of the shade guides and natural teeth.[4,7,9-11] They reported deficiencies in the shade guides tested in the yellow-red range and in the higher value shades.[11]

Thus, shade guide systems currently available have inadequacies that need to be addressed. They do not represent the full spectrum of natural tooth color. It is difficult to arrange shade guide systems according to a logical color order, which would make it possible to make interpolations between shade tabs.[12,13] Shade tabs included in these systems are characterized with stains and do not accurately represent the color of porcelain they designate. Some shade guide systems include tabs that are composed of materials different from the ones used in restorations.

A logically ordered shade guide based on the natural tooth color space should be developed. This would eliminate the shortcomings of existing guides so that color matching in dentistry could be achieved more predictably.

Method

The color measurements of the middle third of the labial surface of 2830 anterior teeth reported in the in-vivo study done by Goodkind and Schwabacher[1] were used as the basis for this study. Maxillary and mandibular central incisors, lateral incisors, and canines were measured in the above study. Middle third measurements showed Hues ranging from 4.50 yellow-red (YR) to 2.30 yellow (Y), a Value range of 5.70/ to 8.50/ and a Chroma range of /1.10 to /5.00. Target shades for the experimental shade guide were chosen according to tooth population density from Hue versus Chroma plots at 0.5/ Munsell Value intervals ranging from 8.5/ to 6.0/.[11]

Glossy paper samples corresponding to the desired Munsell Hue, Value, and Chroma of the target shades were manufactured by the Kollmorgen Company (Baltimore, MD). Porcelain body shade samples were fabricated using a shade tab form similar to that used by Miller in 1987. A specially designed micrometer gauge was used to allow standardization of porcelain thickness (Fig 1). Two control groups consisting of 16 Ceramco and 25 Bioform shade tabs were fabricated. Sixteen experimental body porcelain shade tabs consisting of available opaques, body, and incisal porcelains were modified with metallic oxide tints to approximate target paper shades (Fig 2). The control tabs were made using Ceramco II porcelain (Ceramco, Inc, Windsor, NJ) and Biobond porcelain (Dentsply International, York, PA). Unavailable Biobond shades found on the Bioform shade guide were replaced with Spectrum porcelain (Dentsply International), which is marketed as matching the Bioform extended-range shade guide. Sixteen of the 25 Bioform tabs have been labeled with the same Vita-Lumin shade designations that Ceramco uses.

Tables 1 and 2 show the Munsell Hue, Value, and Chroma measurements of the control porcelain body

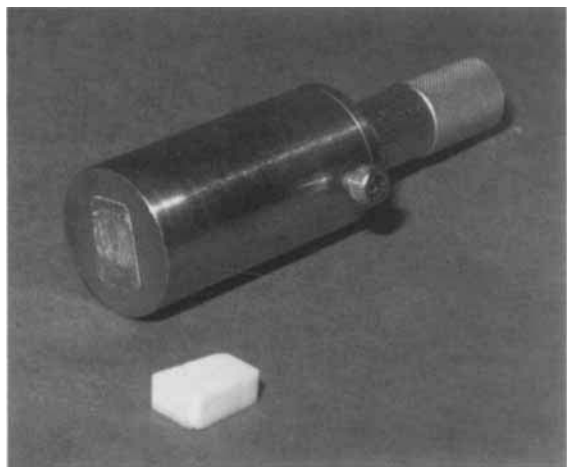

Figure 1. Calibrated shade tab former.

Figure 2. Fifty-seven porcelain body shade tabs.

shade tabs. Table 3 shows a comparison of the Munsell Hue, Value, and Chroma of the paper target shades and the experimental body porcelain shades used in the study. These body shade tab measurements were obtained with a recording spectrophotometer (General Electric Co, Westlynn, MA; Hemmendinger H, personal communication, October 1990; Color Measurement Laboratory, Princeton, NJ). The recorded tristimulus values were then converted to Munsell Hue, Value, and Chroma using the Davidson conversion program (Davidson Colleagues, Tatamy, PA).

Shade Matching Procedures

The clinical trials were performed in the Graduate Prosthodontics clinic at the University of Minnesota. Lighting was provided by cool white, full-spectrum fluorescent light bulbs (new Ultralume 50 bulbs, Phillips Lighting Company, Somerset, NJ) with a color rendering index of 85. This light source was chosen because it was a close match to the CIE Illuminant C used in determining the tristimulus values X, Y, and Z from the shade tab spectral data.[6]

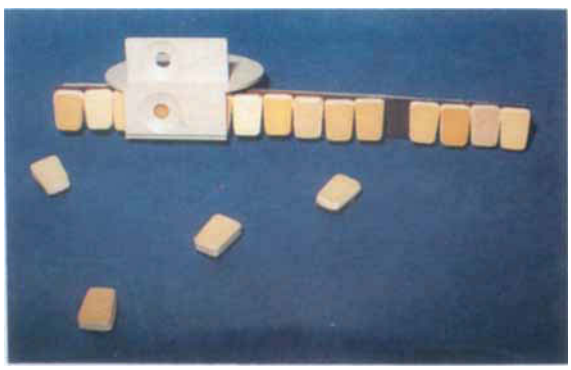

Figure 3. Mounted porcelain body shade tabs drawn through the new dental shade comparator.

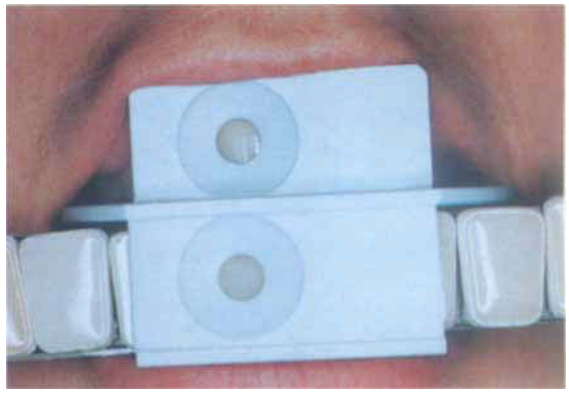

Figure 4. In-vivo shade matching with the new dental shade comparator.

Because natural tooth color changes with age,[1] it was necessary to include several age groups in the study. Table 4 shows the age distribution of the subjects whose natural tooth colors were matched. The number of subjects in each age group varied to reflect the age distribution of patients commonly requiring ceramic restorations.

Two examiners performed the shade matching procedures. Both were tested for anomalous color vision with the Farnsworth 100 Hue Test[14] at the University of Minnesota Ophthalmology Clinic. The examiners' ability to discern small differences in value was further tested by requiring them to arrange in descending order 10 unmarked shade tabs from a standard Bioform shade guide with known values. Both examiners accomplished this task with 90% accuracy.

A maxillary central incisor, lateral incisor, and

Table 1. Control: 16 Ceramco Glazed Body Porcelain Shade Tabs

Sample	*Hue*	*Value/Chroma*
A1	1.81 Y	7.58/2.54
A2	0.28 Y	7.46/2.81
A3	0.03 Y	7.09/3.11
A3.5	0.21 Y	6.99/3.60
A4	9.67 YR	6.65/3.77
B1	1.63 Y	7.4/2.14
B2	1.33 Y	7.2/2.91
B3	0.82 Y	7.14/3.75
B4	0.24 Y	7.06/4.14
C1	1.10 Y	7.32/2.55
C2	1.67 Y	7.06/2.98
C3	0.59 Y	6.65/3.13
C4	9.88 YR	6.53/3.46
D2	0.67 Y	7.22/2.58
D3	9.71 YR	7.01/3.41
D4	1.32 Y	7.16/3.36

Table 2. Control: 25 Biobond/Spectrum Glazed Body Porcelain Tabs

Sample	*Hue*	*Value/Chroma*
B59 (B1)	2.11 Y	7.82/2.29
B51 (A1)	1.28 Y	7.92/2.47
B91 (C1)	0.71 Y	7.40/2.19
B62	9.77 YR	7.30/2.82
B66	9.83 YR	7.33/3.80
B92 (D2)	0.47 Y	7.38/2.49
B53 (A2)	9.82 YR	7.45/3.05
B54 (A3)	0.51 Y	7.47/3.58
B65	9.11 YR	7.33/3.95
B93 (D3)	9.98 YR	7.11/3.29
B55 (B3)	0.48 Y	7.29/4.03
B69 (D4)	0.88 Y	6.74/2.85
B94 (C2)	2.03 Y	6.78/2.98
B95 (C3)	0.99 Y	6.61/2.98
B67	1.23 Y	7.17/3.11
B56 (B4)	0.07 Y	7.05/3.57
B77	0.24 Y	6.79/3.54
B81	0.05 Y	6.78/3.50
B96 (C4)	0.89 Y	6.37/2.93
B52 (B2)	0.79 Y	7.49/3.09
B51s (A1)*	1.37 Y	7.60/2.95
B63s*	9.99 YR	7.35/3.60
B83s (A3.5)*	0.08 Y	6.56/4.24
B84s (A4)*	9.20 YR	6.45/3.94
B85s*	0.86 Y	6.46/4.17

*Spectrum body porcelain (Dentsply International).

canine were used for the shade matching procedures. Each matched tooth was devoid of extrinsic staining and was without caries or restorations affecting the area of examination. The teeth were cleaned of plaque and food debris with a toothbrush and dentifrice before shade matching. The subjects were seated upright in the dental chair with the teeth positioned to eliminate glare.[12]

The shade of natural teeth varies considerably with the background color.[15,16] Lipstick and bright makeup were removed. A neutral gray drape (Munsell N/7 to N/9, as recommended by the Inter-Society Color Council American Society for Testing and Materials) was placed over the subjects' clothing.

Actual shade matching procedures were done with the aid of a new Dental Shade Comparator (Figs 3 and 4). It consists of an occlusal platform and a neutral gray face plate with two beveled ports designed to display the middle third of the tooth being matched and the center of the shade tabs. The comparator allowed for close placement of the shade tab and the tooth being matched. This device also minimized distraction from the red cast of the lips, the gingiva, and the darkness of the oral cavity.[13]

All 57 experimental and control samples were randomly selected and groups affixed to 6-inch plexiglass strips with magnetic fasteners. They were drawn, one at a time, past the viewing port of the comparator (Fig 3). An assistant positioned the device to expose the middle third of the tooth being matched through the tooth port. The strips with the shade tabs were then slid through the comparator, exposing one tab at a time for the inspection of the examiner (Fig 4). The teeth were slightly moistened with wet gauze throughout the entire shade matching procedure to avoid dessication and a chalky appearance.[16,17]

The human eye quickly loses its ability to perceive

Table 3. Experimental Group: Paper Target Shades Compared With Their Porcelain Approximations

	Hue			*Value/*			*/Chroma*		
No.	*Paper*	*Porcelain*	*Difference*	*Paper*	*Porcelain*	*Difference*	*Paper*	*Porcelain*	*Difference*
1	2.22 Y	2.94 Y	+0.72	8.62	8.36	−0.26	1.92	2.05	+0.13
2	1.29 Y	2.82 Y	+1.53	7.67	8.15	−0.48	3.24	3.60	+0.36
3	0.86 Y	0.24 Y	−0.62	8.18	7.71	−0.47	2.36	2.44	+0.08
4	0.55 Y	0.47 Y	−0.08	8.12	7.98	−0.14	1.91	2.23	+0.32
5	0.94 Y	2.22 Y	+1.28	7.66	7.48	−0.18	3.66	3.56	−0.10
6	0.43 Y	9.86 YR	−0.57	7.68	7.29	−0.39	3.25	3.69	+0.44
7	9.79 YR	0.15 Y	+0.36	7.68	7.46	−0.22	2.80	2.87	+0.07
8	9.28 YR	9.25 YR	−0.03	7.67	7.02	−0.65	2.37	2.56	+0.19
9	8.96 YR	8.24 YR	−0.72	7.65	7.26	−0.39	1.90	2.47	+0.57
10	0.23 Y	0.33 Y	+0.10	7.18	6.99	−0.19	3.54	3.68	−0.14
11	9.10 YR	9.72 YR	+0.37	7.19	7.04	−0.15	2.95	3.43	+0.48
12	8.33 YR	8.10 YR	−0.23	7.17	6.74	−0.43	2.19	2.18	−0.01
13	7.47 YR	8.05 YR	+0.58	7.18	6.75	−0.43	1.51	1.38	−0.13
14	9.17 YR	9.28 YR	+0.11	6.76	6.55	−0.21	3.62	3.57	−0.05
15	7.39 YR	8.72 YR	+1.33	6.74	6.43	−0.31	2.30	2.03	−0.27
16	8.11 YR	8.61 YR	+0.50	6.24	6.09	−0.15	3.12	3.01	−0.11

Table 4. Age Distribution of 103 Subjects

Group	*N*	*Age Range (y)*
I	20	21-30
II	20	31-40
III	20	41-50
IV	40	51 and over

subtle differences in hue, a phenomenon called hue accommodation. The examiners were allowed to view each tab for 5 seconds and to focus on a blue screen before resuming shade matching.[12,18] After excluding obvious mismatches, tabs closest to the tooth color were then affixed to one strip. Each examiner then selected the two best matches if two were close. Both choices were used in the statistical analysis of the results.

All statistical analysis was performed with the use of the statistical package SPSSX (Statistical Package for the Social Sciences, Chicago, Illinois: SPSS-X, v. 2, SPSS Inc, 1988). Chi-square analysis was used to determine the existence of shade tab preferences in the different age groups and between male and female subjects. Multivariate analysis of variance (MANOVA) based on a repeated measures design was used to test if differences in Munsell Hue, Value and Chroma existed with respect to the factors of sex, age group, and tooth type. Descriptive statistics used to outline the relationship of the factors of age, sex, and tooth type to Munsell Hue, Value, and Chroma were derived from box plots. CLR-Analysis of Variance was used to evaluate examiner reliability.

Results

The sixteen porcelain shade tabs made to correspond to the Munsell paper samples (Table 3) were neither visual nor spectrophotometric exact matches but are the closest that could be fabricated. The positive values in Hue difference signify a yellower porcelain tab shade than its paper shade sample. In contrast, negative values would indicate a Hue that is redder than desired. Positive and negative values in Munsell Value difference indicate higher and lower Values, respectively, than that of the paper sample shades. Chroma distances with negative values indicate that the experimental tabs have less color intensity than their corresponding paper samples and vice versa.

Table 5 lists the 20 tabs most frequently chosen as first and second choices from all 57 shade tabs. It shows Hue, Value and Chroma measurements of each.

Three yellow-red experimental samples (nos. 9, 16, and 20) were selected as the best matches 17, 8, and 7 times, respectively. Experimental sample no. 8, selected on 19 occasions, had the highest Value of these 20 tabs, and experimental sample no. 20, selected on 7 patients, had the lowest Value.

Munsell Hue, Value, and Chroma measurement differences were related to the subjects' age, sex, and tooth type. Figure 5 shows that Hue shifted toward

Table 5. Twenty Most Frequently Chosen Tabs From All 57 Porcelain Shade Tabs

Tab	*Description*	*Frequency*	*Hue*	*Value/Chroma*
1	Ceramco C3	57	0.59 Y	6.65/3.13
2	Ceramco A1	52	1.81 Y	7.58/2.54
3	Ceramco B1	49	1.63 Y	7.40/2.14
4	Ceramco B2	48	1.33 Y	7.20/2.91
5	Ceramco C2	46	1.67 Y	7.06/2.98
6	Ceramco C1	36	1.10 Y	7.32/2.55
7	Ceramco D2	31	0.67 Y	7.22/2.58
8	experimental	19	0.47 Y	7.98/2.23
9	experimental	17	9.25 YR	7.02/2.56
10	Ceramco D4	14	1.32 Y	7.16/3.36
11	Ceramco A3.5	12	0.21 Y	6.99/3.60
12	Ceramco B3	12	0.82 Y	7.14/3.75
13	Biobond B69	11	0.88 Y	6.74/2.85
14	Ceramco A2	09	0.28 Y	7.46/2.81
15	Bioform B51s	08	1.37 Y	7.60/2.95
16	experimental	08	8.24 YR	7.26/2.47
17	Ceramco A3	07	0.03 Y	7.09/3.11
18	Ceramco B4	07	0.24 Y	7.06/4.14
19	Biobond B91	07	0.71 Y	7.40/2.19
20	experimental	07	8.72 YR	6.43/2.03

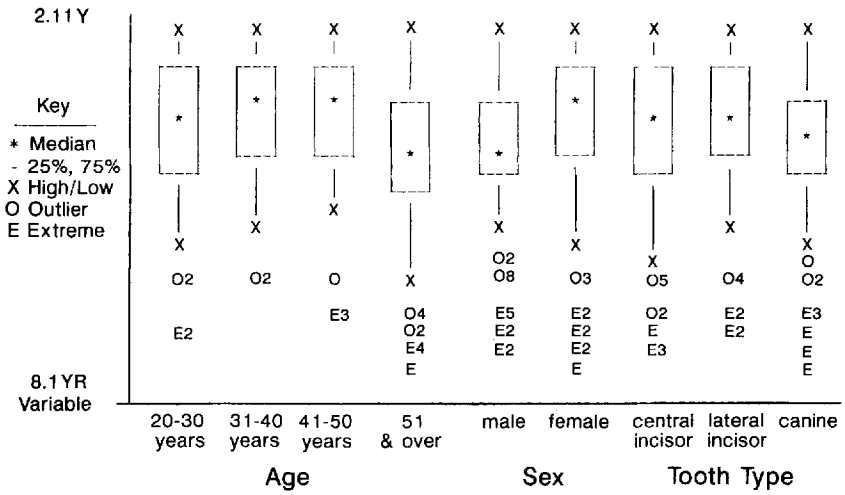

Figure 5. Hue changes in four age groups and in male and female subjects.

the yellow-red range with increasing age and that women were found to have yellower teeth than men. No significant differences were found among the central incisor, lateral incisor, or canine tooth types. A trend towards decreasing Value was found with age over 40. There was more scatter of Values in the 51-and-older age group than in the younger groups. Women had higher Values than men. Values progressively decreased from central incisor to canine (Fig 6). Chroma of subjects over 40 years old was slightly higher than that of the younger subjects. Women tended to have lower Chroma than men. Chroma increased from central incisor to canine (Fig 7).

Examiner reliability was determined by comparing the shade selections made on 10 subjects on two different occasions by both examiners. Intraexaminer reliability showed 66.6% agreement and interexaminer reliability was 63.3%.

Table 6 shows the frequencies at which Ceramco and the corresponding Bioform body shades were chosen. The Ceramco body porcelains and 16 of the Bioform body porcelains have been labeled by their respective manufacturers to correspond with the Vita-Lumin shade guides. It was found that Bioform shade tabs did not perform as well as their Ceramco counterparts. For example, Ceramco body A1 was selected 52 times and Biobond B51 (A1) was not chosen at all. In one instance, Bioform shade B96 (C4) was selected more often than its Ceramco counterpart (C4).

DISCUSSION

Paper Targets Versus Experimental Porcelain Colors

The color target papers were difficult to duplicate in experimental porcelain samples. The highest Values

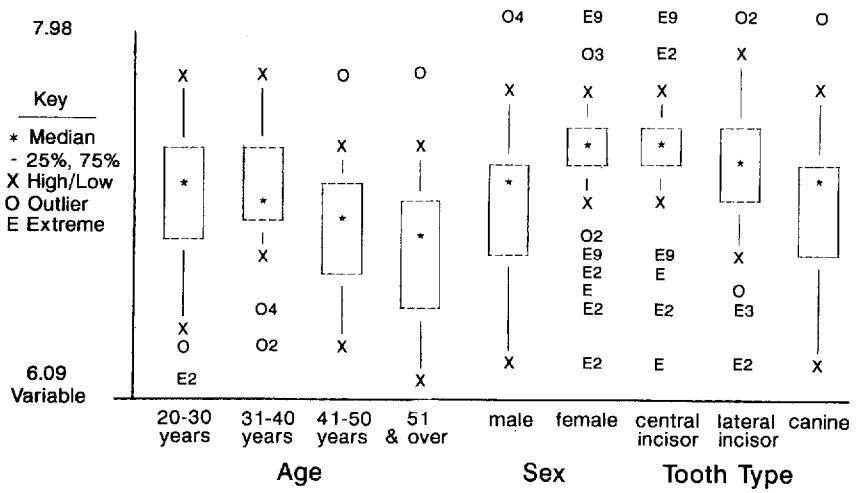

Figure 6. Value changes in four age groups and in male and female subjects.

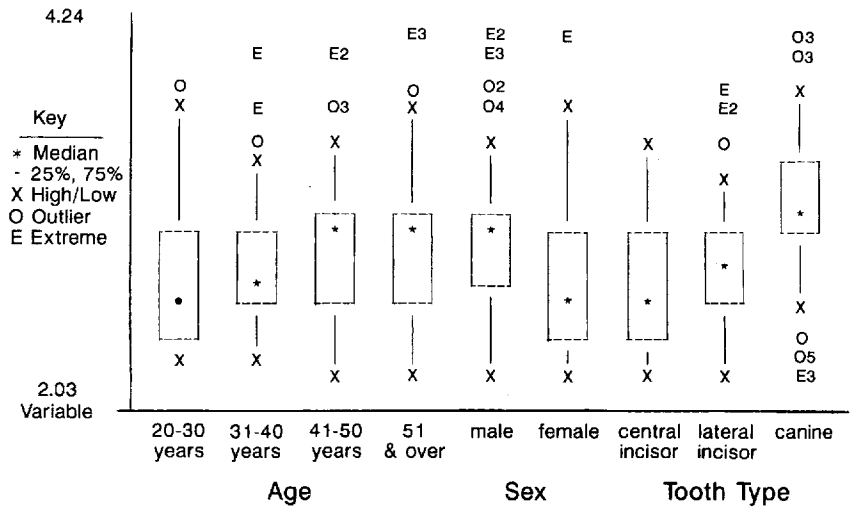

Figure 7. Chroma changes in four age groups and in male and female subjects.

desired were unavailable in sufficiently translucent porcelain. The redder Hues were obtained at too low a Value. Nevertheless, an experimental tab of the highest Value available was the eighth most frequently chosen. Shades 9, 16, and 20 were the only yellow-red shades of the samples chosen and shade tab 20 had the lowest Value. These four popular experimental tabs were not necessarily the ones closest to their target shades. The frequency at which the tabs were chosen was not always directly related to the differences between the paper targets and the porcelain tabs. Even if the experimental porcelains did not precisely correspond to the paper colors, they might still represent parts of the natural tooth color space that is neglected by the commercial shade guides.

From the results obtained, it can be deduced that certain new shades are necessary if a sufficiently ranged body shade guide set is to be assembled. This study corroborated findings of previous investigations stating that currently available porcelains are deficient in shades from the yellow-red spectrum and both high and low extremes in value.[1,5,8,10,18-20] But the majority of body shades currently used fits the population of this study.

Comparison of Results With Previous Studies

The Hue, Value, and Chroma ranges of the 20 tabs, along with previously reported ranges, can be seen in Table 7.

This table shows that the range of Hue, Value and Chroma of the shade tabs that matched the subjects'

Table 6. Frequency With Which Ceramco and the Corresponding Bioform Shade Tabs Were Chosen

Ceramco No.	*Hue*	*Value/Chroma*	*Frequency*	*Bioform No.*	*Hue*	*Value/Chroma*	*Frequency*
A1	1.81 Y	7.58/2.54	52	B51 (A1)	1.28 Y	7.92/2.47	0
A2	0.28 Y	7.46/2.81	9	B53 (A2)	9.82 YR	7.45/3.05	0
A3	0.03 Y	7.09/3.11	7	B54 (A3)	0.51 Y	7.47/3.58	0
A3.5	0.21 Y	6.99/3.60	12	B83s (A3.5)	0.08 Y	6.56/4.24	3
A4	9.67 YR	6.65/3.77	2	B84s (A4)	9.20 YR	6.45/3.94	2
B1	1.63 Y	7.40/2.14	49	B59 (B1)	2.11 Y	7.82/2.29	5
B2	1.33 Y	7.20/2.91	48	B52 (B2)	0.79 Y	7.49/3.09	1
B3	0.82 Y	7.14/3.75	12	B55 (B3)	0.48 Y	7.29/4.03	1
B4	0.24 Y	7.06/4.14	7	B56 (B4)	0.07 Y	7.05/3.57	1
C1	1.10 Y	7.32/2.55	36	B91 (C1)	0.71 Y	7.40/2.19	7
C2	1.67 Y	7.06/2.98	46	B94 (C2)	2.03 Y	6.78/2.98	5
C3	0.59 Y	6.65/3.13	57	B95 (C3)	0.99 Y	6.61/2.98	5
C4	9.88 YR	6.53/3.46	3	B96 (C4)	0.89 Y	6.37/2.93	6
D2	0.67 Y	7.22/2.58	31	B92 (D2)	0.47 Y	7.38/2.49	1
D3	9.71 YR	7.01/3.41	3	B93 (D3)	9.98 YR	7.11/3.29	0
D4	1.32 Y	7.16/3.36	14	B69 (D4)	0.88 Y	6.74/2.85	11

Table 7. Hue, Value, and Chroma Ranges of Natural Teeth From Previous Reports and Those From the Present Study

Study	*Hue*	*Value*	*Chroma*
Hayashi (1967)[3]	8.75 YR–3.75 Y	6/–8/	/1–/5
Sproull (1973)[4]	7.5 YR–2.7 Y	5.8/–8.5/	/1.5–/5.6
Lemire and Burk (1975)[19]	8.9 YR–3.3 Y	5.8/–8.0/	/0.8–/3.4
Goodkind et al (1985)[5]	8.2 YR–2.9 Y	6.1/–8.4/	/2.0–/4.3
Goodkind and Schwabacher (1987)[6]	4.49 YR–2.26 Y	5.66/–8.48/	/1.09–/4.96
Present study	8.25 YR–1.80 Y	6.45/–8.00/	/2.05–/4.15

teeth in the present study falls within most of the ranges reported by previous investigators. This is illustrated by superimposing the 20 most frequently chosen shade tabs on the hue-chroma pie plot diagrams (Fig 8) of the in-vivo tooth color measurements.[1]

Demographics

The results showed correlations between subject age, sex, and tooth type and the Hue, Value, and Chroma of their teeth. These findings corroborate those of previous investigations performed on tooth color.[1-3,5,18,19-21] The shift toward the yellow-red hue seen in patients of older age groups and the decrease in Value observed may be explained in part by the continuous deposition of reparative and secondary dentin. This agrees with the in-vivo study.[1] Thus similar trends were shown by both visual and indirect instrumental methods.

The Dental Shade Comparator

The Dental Shade Comparator provided to be a useful tool in simplifying the task of shade selection. The examiner reliability test results can be considered satisfactory because they showed greater agreement within (67%) and between (63%) examiners than the 22% agreement that Culpepper reported in 1970.[22] This study also stated that a predilection for choosing lighter or darker shades existed in several of the examiners regardless of lighting and shade guide used. This phenomenon was found to be nonexistent between the examiners in the present study. Complete agreement in shade matching is not to be expected in such a subjective measurement.[18]

Control Shade (Bioform and Ceramco) Comparison

The results showed disproportionate counts between the number of times each Ceramco body tab and Bioform body tab of similar color designation was chosen. In order to analyze this, Hue-Chroma and Value/Chroma diagrams of the 20 frequently chosen tabs were superimposed on corresponding diagrams of the natural tooth population[11] (Fig 8).

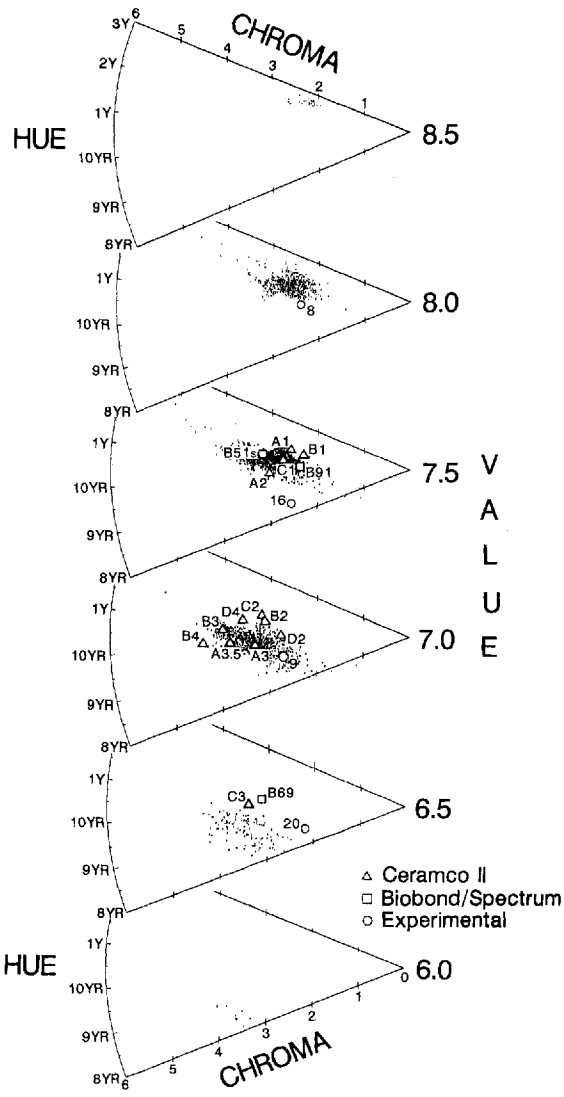

Figure 8. Top 20 shade tab choices superimposed on the in-vivo natural tooth color space.[11]

Ceramco body shades A1, A2, A3, A3.5, B3, C1, C4, D2, and D4 lie within the tooth population of the 1987 study.[1] Bioform tabs B51s (A1), B52 (B2), B92 (D2), and B93 (D3) were also within the population. When comparing the frequency with which tabs of each group were chosen as a first and a second choice, the Ceramco body tabs scored higher. This may be attributed to the differences in measurements of Hue, Value, and Chroma, and to differences in composition and translucency of the porcelains making their colors appear different to visual discrimination.[23] Another example of this may be seen in Bioform shade B51 (Biobond) and B51s (Spectrum). B51s was chosen 8 times and B51 was excluded on all occasions. The difference in the frequency may be attributed to the more translucent character of B51s.

Ceramco Shade Tabs Versus In-Vivo Tooth Population

Certain Ceramco tabs (B1, B2, C2, and C3) that measured yellower and darker than the population of the 1987 survey[1,11] were frequently selected as first and second choices. There may be enough of a difference between the population of this study and that of the earlier survey to account for this occurrence. In color matching, the background makes a difference. In the research survey, Play-Doh modeling clay was placed behind patients' translucent teeth to provide a uniform background. No Play-Doh was used in this clinical study, and this may have contributed to the selections made. In addition, a possible systematic error in comparing the visual method of this study with indirect instrumental methods[1,6] cannot be excluded. If the Value level of the tooth color measurements were lowered by a half step, these tabs would fit into the color space. This could account for a general shift to yellower Hue and slightly darker Value of half step when the porcelain shade tabs rather than the teeth were measured. This does not change the shape of the region in color space occupied by the two populations.

The redder experimental tabs, 9, 16, and 20, were in fact more frequently chosen than the reddish Ceramco tabs, A4, B4, C4, and D3. This shows that this systematic shift is not of sufficient magnitude to discredit the reported natural tooth color space. Teeth are more red than the porcelain shades now available, just as the choices of experimental tab 8 justified the conclusion about the existence of teeth lighter than the porcelain shades now in use. The present set of 16 experimental tabs may not be superior to the 16 Ceramco body shades. A different set might be, one that would include redder and lighter shade tabs. This study justifies the old practice of adding new shades to existing sets, although it also suggests not retaining all the old ones (see Table 5). For the reasons discussed in the previous paper,[11] ordering tabs by Value, as was done, for example, by Bioform, also provides a beginning order in other variables. Another logically ordered body shade guide has been derived from these results, but it has not yet been clinically tested.

Conclusions

Four of the 16 experimental body shade tabs were frequently selected as first or second choices, compared with 13 of 16 Ceramco and 3 of 25 Bioform body shades. The 20 shade tabs that were most frequently selected as a first or second choice ranged from 8.25 YR to 1.80 Y in Hue, 6.45/ to 8.00/ in Value, and /2.05 to /4.15 in Chroma. There is a correlation between the variables of age, sex, and tooth type with Hue, Value, and Chroma. The new dental shade comparator is a useful tool in the task of shade matching. The current Ceramco II body shades contain many useful porcelains that should be augmented with higher value and with redder, darker shades.

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