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Dental Shade Guide Variability for Hues B, C, and D Using Cross-Polarized Photography

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This study evaluated the color variability of hues B, C, and D between the VITA Classical shade guide (Vita Zahnfabrik) and four other VITA-coded ceramic shade guides using a digital camera (Canon EOS 60D) and computer software (Adobe Photoshop CC). A cross-polarizing filter was used to standardize external light sources influencing color match. A total of 275 pictures were taken, 5 per shade tab, for 11 shades (B1, B2, B3, B4, C1, C2, C3, C4, D2, D3, and D4), from the following shade guides: VITA Classical (control); IPS e.max Ceram (Ivoclar Vivadent); IPS d.SIGN (Ivoclar Vivadent); Initial ZI (GC); and Creation CC (Creation Willi Geller). Pictures were evaluated using Adobe Photoshop CC for standardization of hue, chroma, and value between shade tabs. The VITA-coded shade guides evaluated here showed an overall unmatched shade in all their tabs when compared to the control, suggesting that shade selection should be made with the corresponding manufacturer guide of the ceramic intended for the final restoration. Int J Periodontics Restorative Dent 2018;38(suppl):s113–s118. doi: 10.11607/prd.3270

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Following a recommended protocol for conventional and instrumental shade matching in achieving esthetic and predictable results,[1] some understanding of color is needed for accurate interpretation and communication.[2] Color is described in terms of its three dimensions: hue (how color families are distinguished from one another), value (amount of white in an object, distinguishing light and dark colors), and chroma (intensity/saturation of the hue).[3]

Light can affect color perception of an object,[4–9] and natural daylight is the recommended condition for color matching. However, variations in external conditions can affect visual color determination.[4] Because every object has a specific spectral reflectance, accurate color matching of dental shades is challenging.[10]

Color selection can be performed visually, with instruments, or through a combination of the two. Visual selection alone is subjective and strongly dependent on the interaction between light and dental structure,[1,4,6,11–13] with the final decision depending on the operator.[4] Instrumental determination might eliminate human error by standardizing the shade determination procedure.[1,6,11–14] Three categories of devices are used for instrumental tooth color measurements: spectrophotometers, colorimeters, and digital cameras.[1,11,15–17] Although

Fig 1 *Photograph taken with a cross-polarizing filter. Note the absence of specular reflections, which allows a more straightforward and precise observation of natural teeth internal structures.*

these devices are intended to standardize the parameters of shade selection, measurement of tooth color is complex.[7,12,13,18] Human enamel, for instance, possesses small, irregular-surfaced, semitranslucent structures that challenge color readings, since a considerable fraction of the light that hits the surface is dissipated.[12,19] Equipment-related parameters, such as the head size of the device, have been reported to influence shade selection.[13]

Another drawback related to these instruments is their high cost, which limits widespread routine use.[20] Advances in image acquisition, flashes, and data storage with digital cameras have encouraged their general use.[15,20] Digital cameras also facilitate image sharing between clinicians and technicians and show good potential in dental color matching.[1,8,15,20]

Cross-polarizing filters have been used to reduce specular reflections from the camera flash[8,21] and overcome the tendency to overestimate the prevalence of white opacities[8,22] (Fig 1). In a previous study by the same authors, the use of a camera combined with a cross-polarizing filter allowed evaluation and comparison of color matching between different shade tabs.[8]

Another problem related to color acquisition is that porcelains do not always match the shade guides to which they are compared, and shade variations exist between different lots from the same manufacturer.[2,5,6,12] While a previous study comparing the A hue by means of digital photography reported a unmatched shade between VITA-coded shade guides and the VITA Classical itself,[8] no information is available for the B, C, and D hues.

Considering the need to achieve excellent color matching in esthetics procedures with precise communication between dentists and dental technicians, this study evaluated the matching efficacy of selected shade parameters of VITA-coded ceramic shade guides with the VITA Classical shade guide using a digital camera combined with a cross-polarizing filter. The hypothesis tested was that there would be differences among shade guides for hue, chroma, and value.

Materials and Methods

A total of 275 photographs were taken of 5 different shade guides and 11 different shade tabs. The shade tabs evaluated were B, C, and D (B1, B2, B3, B4, C1, C2, C3, C4, D2, D3, and D4), since the A hue variability was reported in a previous study.[8] The shade guides analyzed in this study were VITA Classical (control) (Vita Zahnfabrik), IPS e.max Ceram (Ivoclar Vivadent), IPS d.SIGN (Ivoclar Vivadent), Initial ZI (GC), and Creation CC (Creation Willi Geller).

Photographs were taken using a Canon EOS 60D digital camera (Canon), equipped with a 100-mm Canon Macro Lens (Canon) and a ring flash (MT-14 Ring Flash, Canon), at a standardized parameter of ambient light and camera settings. Camera parameters were set for exposure (1/125, f16); ISO (100); flash (ETTL); distance; focusing (1:1); and background. All photographs were taken at intervals of 1 minute, aiming to allow consistent flash intensity. Adobe Photoshop CC software (Adobe Systems) was used to analyze the images. Digital cameras can be set in two different color spaces, sRGB and Adobe RGB. Adobe RGB color space was selected for this study, as it encompasses roughly 50% of the L*a*b* color space (where L represents lightness and a and b the color opponents green-red and blue-yellow, respectively), although this broader spectrum is largely toward the cyan-green hues. To eliminate specular reflections, which may alter the image and produce defective analyses, a cross-polarizing filter (Polar_Eyes, Emulation) was used.

After the pictures were taken, RAW images were processed with Adobe Photoshop CC software for shade assessment (Table 1). The software provided results based on the HSB model (hue, saturation, and brightness). This is the color model used for data analysis, since it is the same as the Munsell Color Order System (hue, chroma, and value) generally accepted in dentistry.[23] HSB is the color model in which the classic shade guides were developed. According to this model, any color can be represented by three numbers. The first number is the hue, and its value ranges from 0 to 360 degrees. Each degree represents a distinct color. First is the red color (0 or 360 degrees), followed by the rest of the color spectrum (eg, yellow at 120 degrees, green at 180 degrees, blue at 240 degrees) up to violet. The second number is the saturation. It represents the amount of color or, more precisely, its percentage. Its value ranges from 0 to 100, where 0 represents no color and 100 represents the fully saturated color. The third number is brightness. Color brightness can be enhanced by the addition of white, or it can be reduced by the inclusion of black. In brightness values, 0 represents white and 100 represents black. The closer this value is to 0, the brighter the color is; the closer it is to 100, the darker it is.

Table 1 Step-by-Step Process for Evaluation of the Photographs

1. Open shade tab photograph in Photoshop.
2. Using the rectangular marquee tool, select a 10 × 10-pixel square in the middle of the shade tab photograph
3. Crop the selected 10 × 10 square using the crop tool (Image—Crop).
4. Zoom in on the cropped 10 × 10 square using the Zoom in tool (View—Zoom in).
5. Apply Gaussian Blur Filter (Filter—Blur—Glaussian Blur).
6. Using the Eyedropper tool, click on the 10 × 10 square. A new window will pop up.
7. Register the obtained values.

The HSB data for all the tabs and shades was recorded and statistically analyzed using univariate analysis of variance with $P = .05$ and Tukey post hoc test. Hue, chroma, and value were analyzed separately for all the shade tabs.

Results

The parameters of hue, chroma, and value evaluated in this study are reported in Tables 2, 3, and 4, respectively. None of the parameters showed complete match with the VITA-coded shade tabs for any shade guide.

Considering hue (Table 2), the VITA shade guide presented the lowest values for all shade tabs, while the d.Sign shade guide presented the highest. Statistically significant differences ($P < .05$) were observed for B1, B2, B3, B4, C1, C4, D2, and D4 shade tabs for all shade guides compared to the VITA Classical shade guide. Equivalence ($P > .05$) was found between Creation and e.max for the C2 shade, between e.max for the C3 shade, and between e.max for the D3 shade, compared to the VITA shade guide. The shade guide that presented the highest equivalence for hue, compared to VITA, was e.max (3 matches out of 11).

Comparing chroma in the VITA classical shade guide (Table 3), a statistically significant difference ($P < .05$) was found for B2, C1, C3, D2, and D3 shade tabs for all the shade guides. In evaluating D2, none of the tabs were equivalent to VITA Classical, while for D4 only d.Sign did not match with VITA. Equivalence ($P > .05$) was found between Initial for B1, between e.max and d.Sign for B3, between d.Sign for B4, between Creation and d.Sign for C2, with d.Sign for D4 shade, and for Initial, e.max, and Creation for D4 compared to VITA Classical. The shade guide that

Table 2 Mean (SD) Values for Hue

Tab	B1	B2	B3	B4	C1	C2	C3	C4	D2	D3	D4
Creation	69.80 (0.44)^{b}	60.00 (0.00)^{b}	53.00 (0.00)^{b}	50.80 (1.09)^{b}	61.60 (0.89)^{b}	53.40 (0.54)^{b,c}	53.00 (0.00)^{a}	47.00 (0.00)^{b}	58.00 (0.00)^{c}	55.60 (1.34)^{b}	55.60 (0.54)^{a}
d.Sign	75.00 (0.00)^{a}	62.80 (1.78)^{a}	54.40 (1.34)^{a}	53.80 (0.83)^{a}	66.00 (2.23)^{a}	57.00 (0.00)^{a}	54.00 (0.00)^{a}	49.80 (0.83)^{a}	66.20 (1.78)^{a}	58.00 (0.00)^{a}	56.60 (0.89)^{a}
e.max	70.00 (0.00)^{b}	60.80 (1.09)^{b}	52.80 (0.44^{b}	53.00 (1.41)^{a}	61.20 (1.78^{b}	54.20 (1.64)^{b,c}	50.80 (1.09)^{b}	46.40 (0.54)^{b}	60.00 (0.00)^{b,c}	53.00 (1.87)^{c,d}	55.60 (0.54)^{a}
Initial	65.00 (2.82)^{c}	57.00 (0.00)^{c}	52.20 (0.44)^{b}	50.60 (1.34)^{b}	60.40 (0.89)^{b}	55.40 (1.34)^{a,b}	53.60 (0.54)^{a}	49.40 (0.54)^{a}	62.00 (2.73)^{b}	54.00 (0.00)^{b,c}	55.20 (1.09)^{a}
VITA	60.00 (0.00)^{d}	54.00 (0.00)^{d}	48.20 (0.44)^{c}	47.40 (0.54)^{c}	52.00 (0.00)^{c}	52.20 (1.09)^{c}	49.80 (1.09)^{b}	44.80 (1.09)^{c}	53.40 (0.89)^{d}	51.00 (0.00)^{d}	50.60 (1.34)^{b}

Different superscript letters indicate different means within each column ($P \leq .05$).

Table 3 Mean (SD) Values for Chroma

Tab	B1	B2	B3	B4	C1	C2	C3	C4	D2	D3	D4
Creation	16.20 (0.44)^{b,c}	21.20 (0.44)^{d}	34.80 (0.44)^{b}	39.80 (0.44)^{a}	20.20 (0.83)^{c}	29.00 (0.00)^{b}	30.60 (0.54)^{c}	39.80 (0.44)^{b}	21.20 (0.44)^{b}	25.80 (0.44)^{c}	32.40 (0.54)^{a,b}
d.Sign	13.20 .447^{d}	22.00 0.000^{c}	36.00 .707^{a}	37.40 .894^{b}	17.00 0.000^{e}	29.00 0.000^{b}	31.00 0.000^{c}	38.80 .447^{b,c}	16.80 1.095^{d}	22.20 .447^{d}	28.60 (0.54)^{c}
e.max	15.60 (0.54)^{c}	23.60 (0.54)^{b}	36.60 (0.54)^{a}	39.20 (0.44)^{a}	21.80 (0.44)^{b}	31.40 (0.54)^{a}	37.00 (0.00)^{a}	42.80 (0.83)^{a}	18.40 (0.54)^{c}	33.20 (0.83)^{a}	32.60 (0.54)^{a}
Initial	17.20 (1.09)^{a,b}	24.00 (0.00)^{b}	33.40 (0.54)^{c}	39.40 (0.54)^{a}	18.60 (0.89)^{d}	28.00 (0.00)^{c}	28.40 (0.54)^{d}	35.80 (1.48)^{d}	15.20 (0.44)^{e}	24.60 (0.89)^{c}	31.20 (1.09)^{b}
VITA	17.80 (0.44)^{a}	25.80 (0.44)^{a}	36.00 (0.00)^{a}	37.80 (0.44)^{b}	24.80 (0.44)^{a}	29.60 (0.54)^{b}	32.80 (0.44)^{b}	38.00 (0.70)^{c}	22.80 (0.44)^{a}	28.40 (0.54)^{b}	32.40 (0.54)^{a,b}

Different superscript letters indicate different means within each column ($P \leq .05$).

presented the highest equivalence for chroma compared to VITA was d.Sign (4 matches out of 11).

When the value parameter (Table 4) was compared to VITA Classical for all shade guides, a statistically significant difference was found only for B4. The D4 shade tab presented the greatest equivalence to VITA, being different only for the Creation shade guide. Equivalence was found with Creation for B1, B2, B3, C1, C2, and D2; with Initial for C1 and D4; with d.Sign for C3, C4, D2, D3, and D4; and with e.max for D3 and D4. The shade guide that presented the highest equivalence for value compared to VITA was Creation (6 matches out of 11). Of the three parameters evaluated, value presented the greatest equivalence between shade tabs compared to VITA Classical.

Discussion

The study of color is paramount in esthetic dentistry. Matching color in restorations leads to a pleasing natural appearance and satisfaction for patient and clinician.[1] However, it is challenging due to the complexity of dental optical properties.[4,7] Three factors can influence perception of color: light source, object, and observer.[2] The hypothesis evaluated in this study was accepted, since none of the shade guides showed complete equivalence in terms of hue, chroma or value compared to the VITA Classical shade guide. This is in agreement with a previous study of the A hue that used the same methodology presented here.[8]

Table 4 Mean (SD) Values for Value

Tab	B1	B2	B3	B4	C1	C2	C3	C4	D2	D3	D4
Creation	62.40 (0.89)[b]	62.80 (0.83)[b]	60.80 (0.83)[b]	62.60 (0.54)[b]	59.40 (0.54)[a]	57.20 (0.83)[b]	55.40 (0.54)[b]	53.20 (0.44)[a]	57.00 (0.70)[b]	52.80 (1.09)[c]	58.20 (0.83)[a]
d.Sign	58.80 (1.09)[c]	56.80 (0.83)[c]	56.00 (0.70)[c]	57.00 (1.00)[d]	51.80 (0.44)[c]	54.00 (0.00)[d]	53.40 (0.54)[c,d]	50.60 (0.89)[b]	58.00 (1.00)[b]	56.40 (0.54)[b]	54.80 (0.44)[c]
e.max	58.00 (0.00)[c]	57.80 (0.83)[c]	57.40 (0.89)[c]	56.00 (0.70)[d]	56.80 (1.30)[b]	55.20 (0.44)[c]	54.60 (0.54)[b,c]	48.60 (0.89)[c]	55.00 (0.00)[c]	57.00 (0.70)[b]	57.40 (0.54)[a,b]
Initial	64.60 (0.54)[a]	67.20 (0.44)[a]	62.60 (0.54)[a]	64.20 (0.44)[a]	59.80 (0.44)[a]	61.20 (0.44)[a]	57.40 (1.51)[a]	53.80 (0.44)[a]	64.20 (0.44)[a]	62.80 (0.44)[a]	56.00 (1.41)[b,c]
VITA	61.00 (1.22)[b]	62.20 (0.44)[b]	60.40 (0.54)[b]	59.60 (0.54)[c]	59.20 (0.44)[a]	56.40 (0.54)[b]	52.20 (1.09)[d]	50.40 (0.54)[b]	56.60 (0.89)[b]	56.00 (0.70)[b]	56.40 (0.54)[b,c]

Different superscript letters indicate different means within each column ($P \leq .05$).

Equivalence was observed more frequently in some shades than in others. Some shade guides showed a better correlation to VITA Classical than others, which is in accordance with other studies.[2,4–6,8,12,24] It has been reported that darker and more chromatic tabs of VITA Classical were more often mismatched,[4] and that some brands produced better match with VITA Classical than others.[24] In the present study, considering the hue parameter, e.max showed the best equivalence to the VITA Classical shade guide, d.Sign was better for chroma, and Creation presented more matches for value.

In this study, color parameters were recorded in the L*a*b* color space, which is related to human color perception in three dimensions. L* is the lightness variable; and a* and b* are chromaticity coordinates.[23,25,26] In the CIELAB metric, the greater the value, the larger the color difference and thus the more perceptible the difference to the human eye.[27]

Of the three parameters evaluated in this study, value presented the most equivalence between shade tabs compared to VITA Classical. Value is also the most significant parameter, since slight differences in hue or chroma are less perceptible by the human eye.[5,6] Clinically acceptable color matching shows an L (value) < 2.0 and a total E of < 4.0.[16]

The high esthetic demands of patients combined with the variability and subjectivity of the human eye has led to the development of color measurement devices that allow an objective choice of shade values,[18] reducing or overcoming imperfections and inconsistencies of traditional visual shade matching.[1,6,7,11–13,15–18,20] However, devices such as spectrophotometers and colorimeters may not always be convenient to use and can lead to misreading in situations such as curved surfaces and translucent materials, both of which are present in dental structures.[7,12,13,18]

Digital cameras have been shown to improve tooth color matching performance and allow for better color communication using a reference photograph with reference shade tabs.[15] A digital camera is a simple and easy-to-use system for three-color image acquisition, and each camera has a specific sensitivity and can be calibrated to device-independent L*a*b* color space.[28,29] However, it cannot simulate various illuminations. Inconsistent flash performance and specular reflection in images could cause color mismatches.[20] The light source that illuminates an object affects color perception, since individual sources contain varying quantities of each of the visible wavelengths of light.[2]

The use of a cross-polarizing filter helped to eliminate specular reflections from the shade guides, allowing a more uniform color evaluation by the software, which is in agreement with a previous study.[8] Experts generally agree that instrumental shade selection must be accompanied by a deeper analysis including shade mapping, photography with shade tabs, and a cross-polarizing filter.[22]

It is recommended that instrumental color matching should always be complemented by experienced human visual shade confirmation.[12] Communication between dentists and technicians is extremely important in color matching. According to the present results, shade selection should always be made using the shade guide of the ceramic brand to be used.

Conclusions

For all the parameters evaluated, none of the shade guides completely matched with the VITA Classical shade guide, showing variable color matching results in all tabs.

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