Variations of L*a*b* Values among Vitapan® Classical Shade Guides

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Purpose: **To measure the variations in $L^*a^*b^*$ values of a group of 25 guides and to assess whether shade guides are indeed interchangeable.**

Materials and Methods: **The $L^*a^*b^*$ values of individual shade tabs were measured with a LabScan(tm) XE scanning spectrocolorimeter (SSC) with a special attachment for reproducibly positioning shade tabs. Each shade guide (Vitapan Classical, Vident) contained 16 shade tabs. Absolute calibration of the SSC was performed with color tiles traceable to NIST. One shade guide was used to determine the reproducibility of the experimental method by measuring and then removing each shade tab of the standard 10 times. This assessed the variations in observed values induced by the measurement method and the geometry of the specimens. The entire sample consisted of 25 shade guides. The tabs of each of the 25 shade guides were read five times in the SSC, without moving the specimen. Measurements and calculations of E, L^*, a^*, and b^* were performed using Universal Software V4.10 (Hunter Associates Laboratory). The mean, standard deviation, and range were determined of the E, L^*, a^*, and b^* values for each one of the 16 shades in the shade guides. Differences in color are expressed as ΔE in color science. The standard deviation of E (E_{sd}) and the range of E ($E_{r)}$ for each of the shades were used as a ΔE value to assess color differences.**

Results: **For the reproducibility measurements, the shades had values for E_r varying from 0.08 to 0.69, and E_{sd} between 0.02 and 0.22. This established the detection limit for our method for each of the shades. For the group of 25 shade guides, E_r varied from 0.75 to 3.05, and E_{sd} from 0.22 to 0.54. The difference in value of E_r obtained from the reproducibility test and the E_r of the group of 25 guides is significant at $p < 0.05$. The same was found for E_{sd}. The largest reproducible E_r observed was 3.05 for shade C1.**

Conclusions: **The differences observed between shade guides are larger than the variations induced by the experimental method. The difference in E values for the shades C1 and C2 is 2.19; hence the observed E_r of 3.05 between shade tabs of the same shade (C1) is larger than the changes in color between shades. This large a variation in what are claimed as identical shade tabs is deemed of clinical importance, and therefore, the shade guides should not be considered interchangeable.**

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COMMUNICATION BETWEEN dentist and ceramist is a very important step in the shade matching process.[1] Shade guides are commonly used by dentists to communicate a shade to the dental laboratory; however, when the only information submitted to a ceramist is the shade tab designation, problems arise.[2] Five areas of weakness have been discussed by Sorensen and Torres regarding current shade matching procedures and communication between the dentist and ceramist:[3] (1) the observer, (2) variable viewing conditions, (3) inadequate technology, (4) poor communication, and (5) commercially available shade guides.

The inadequacies of various commercial shade tabs have been reported.[4] The shade guides being used by dentist and ceramist can have the same determinant number of tabs, and the numbers designated to the tabs may be the same, but the tabs can vary greatly from one shade guide to another of the same manufacturer.[2] A very popular shade guide used by dentists,[5] and still considered by many as the "gold standard" for color is the

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Vitapan® Classical Shade Guide, formerly Vita Lumin (Vita Zahnfabrik, H. Rauter GmbH & Co. KG, Bad Säckingen, Germany).[6] In a study of 20 Vita Lumin shade guides (shade tabs A3, B2, and C1), Ryther et al, reported a statistically significant total color difference between shade guides.[7] The introduction of the CIE L*a*b* color system by the Commission Internationale de l'Éclairage (International Commission on Illumination) in 1976 has allowed for a more objective measurement of color stimulus with the use of electronic color measurement devices.[8] L*a*b* refers to: L*, the luminosity dimension ranging from 0 (pure black) to 100 (reference to white, which varies with the color and brightness of the illuminant); a*, the red-green contrast with a+ being red, and a– referring to green; and b*, the blue-yellow contrast, with b+ as a light yellow and b– as blue.[9] By acquiring the L*a*b* values of shade tabs, the color difference, or ΔE, between shade tabs can be determined mathematically with the following formula:[10]

$$\Delta E = \sqrt{[(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2]}.$$

Seghi et al stated that color tolerances and the limits of acceptable color differences are important factors that need to be evaluated.[11] They also pointed out that an acceptable shade may have a color difference two to three times greater than the detectable difference.

MacDermid ColorSpan Inc. noted that the average, casual viewer can notice a $\Delta E = 5 - 6$, and a trained eye can detect a $\Delta E = 3 - 4$.[12] MacDermid Colorspan Inc. mentions however, that the human eye is very sensitive to changes when the values for a* and b* approach 0 (i.e., away from achromatic tones); then one can notice a difference between two "shifted" grays with a ΔE as small as 0.5. When it comes to selecting teeth shades, previous dental research on ΔE has shown that a $\Delta E = 1$ is perceptible by the human eye.[13] Other investigators reported that when $\Delta E > 2.75$ the shade selection is deemed clinically unacceptable.[14] Seghi et al found that sample pairs with color differences greater than 2 ΔE units were correctly judged by their observers 100% of the time.[11] The majority of observers correctly judged sample pairs with color differences between 1 and 2 ΔE units over 80% of the time, and over 60% of the time when the difference between the sample pairs was less than one ΔE unit. Gross et al considered a $\Delta E = 0 - 2$ as imperceptible, a $\Delta E = 2 - 3$ as just perceptible, a $\Delta E = 3 - 8$ as moderately perceptible, and a $\Delta E > 8$ as markedly perceptible.[15]

The purpose of this in vitro study was to evaluate and compare all sixteen shades from 25 Vitapan Classical Shade Guides. The variation in color within each shade will be determined to assess whether the shade guides are interchangeable.

Materials and Methods

The L*a*b* values of the shade tabs from 26 new Vitapan Classical Shade Guides were measured with a Labscan XE scanning spectrocolorimeter (Hunter Associates Laboratory, Reston, VA). Reflectance measurements were made at 45° with illumination at 0°. Measurements and calculations of ΔE and L*a*b* values were calculated with Universal Software V4.10 (Hunter Associates Laboratory). A LabScan XE port plate with a 30.5 mm port opening was modified by attaching a Vitapan Classical shade tab holder (Fig 1). The shade tab holder was positioned to center the body portion of the shade tab in the center of the port opening. The smallest area view size of 3.2 mm was selected for all readings. These steps were taken to minimize the variations in the readings that could be caused by the geometry of the specimen, i.e., the curvature of the shade tabs and gradation of shades from cervical to incisal.[16] An optical baffle was placed over the shade tab and the port opening to eliminate any ambient light. Prior to any reading session, the LabScan XE was standardized per manufacturer's recommendations with black and white standardization tiles. The calibrations with standard tiles are traceable to NIST (National Institute of Standards and Technology). In addition, prior to each reading session for the

Figure 1. LabScan XE port plate modified by attaching Vitapan Classical Shade tab holder.

specimens, the A1 standard shade tab was read, and that L*a*b* reading was compared with the previous readings of the A1 standard to verify consistency. All shade tabs were cleaned with 70% isopropyl alcohol (Cumberland Swan, Smyrna, TN) and wiped with a lens cloth to eliminate any oil or debris that may have been on the shade tabs. All the readings were done by a single operator. The operator wore lint-free cloth gloves while handling the shade tabs.

One of the 26 shade guides one was arbitrarily selected for a reproducibility test to validate the experimental method. Since many observations were made on this shade guide before the comparison test was performed, this shade guide was not included in the comparison test, because it could no longer be considered as new. The remaining 25 shade guides were measured and used as the sample.

Reproducibility Test

Each of the 16 shade tabs of the standard shade guide was read 10 times by the LabScan XE. The shade tab was removed and reinserted into the holder prior to each reading. By doing so, the variability of the L*a*b* measurements, as induced by machine and operator, was determined, and the lower detection limit of the method was established.

Comparison Test

For the 25 shade guides, the L*a*b* values were attained by reading each of the 16 shade tabs per guide five times. If a sample reading of a shade tab varied greatly from other tabs of the same shade, the position of the shade tab was verified. If the reading still varied greatly, the shade tab of the same shade from the reproducibility test was read and compared with previous standard values to detect any possible instrumental error. Once the accuracy of the spectrophotometer was verified, the sample shade tab was reinserted into the holder and the L*a*b* values were recorded.

The E values were calculated using the following formula:

$$E = \sqrt{[(L^*)^2 + (a^*)^2 + (b^*)^{*2}]}.$$

Data were analyzed by with Tukey-Kramer Honest Significant Difference (HSD) test, performed with statistical software (JMP ver. 3.2.6, SAS Institute Inc, Cary NC).

Results

From the recorded L*a*b* values, the range of E (E_r) for each of the 16 shades was calculated, as well as the standard deviation on the E values (E_{sd}) for each shade. The mean, standard deviation, and range of E from the reproducibility and comparison tests are given in Table 1. In addition, the standard deviation and range of E for all the shade guides tested were plotted on graphs using SlideWrite Software (Advanced Graphics Software Inc., Encinitas, CA) (Figs 2–5).

Table 1. Mean, Standard Deviation, and Range of E Values from Reproducibility and Comparison Tests for Vitapan Classical Shade Guide Tabs

	Reproducibility Test			Comparison Test		
Shade	E	E_{sd}	E_r	E	E_{sd}	E_r
A1	78.06	0.06	0.26	78.32	0.36	1.32
A2	76.97	0.11	0.36	76.03	0.22	0.75
A3	74.29	0.13	0.38	73.94	0.42	1.71
A3.5	72.39	0.07	0.23	72.37	0.43	2.01
A4	69.00	0.15	0.44	68.76	0.34	1.70
B1	77.30	0.08	0.23	76.44	0.45	2.11
B2	76.23	0.22	0.69	76.51	0.48	2.17
B3	74.65	0.18	0.55	74.75	0.54	2.62
B4	73.91	0.14	0.35	73.57	0.39	1.44
C1	73.10	0.04	0.11	72.65	0.54	3.05
C2	70.75	0.02	0.08	70.46	0.37	1.47
C3	68.53	0.04	0.11	63.37	0.29	1.15
C4	65.01	0.07	0.25	64.54	0.37	1.68
D2	70.29	0.06	0.21	71.04	0.54	2.07
D3	70.96	0.08	0.24	70.66	0.44	2.18
D4	71.14	0.07	0.22	71.12	0.29	1.20

For the reproducibility study, the E_r varied from 0.08 to 0.69; E_{sd} varied from 0.02 to 0.22.

For the group of 25 shade guides, E_r varied from 0.75 to 3.05, and E_{sd} from 0.22 to 0.54.

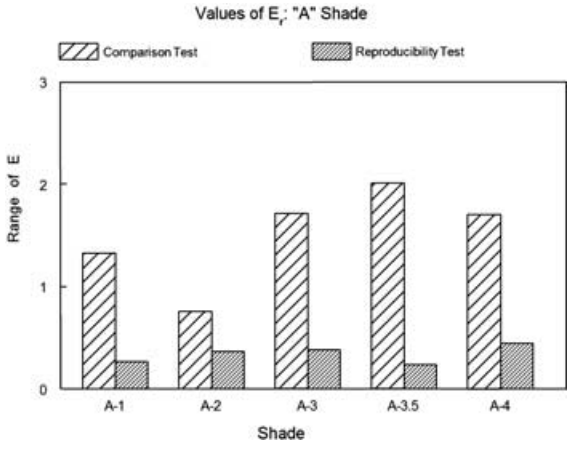

Figure 2. Values of E_r for Vitapan Shade "A" shade guide tabs.

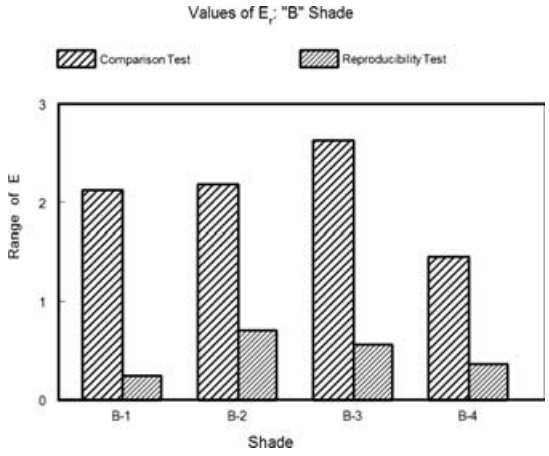

Figure 3. Values of E_r for Vitapan Shade "B" shade guide tabs.

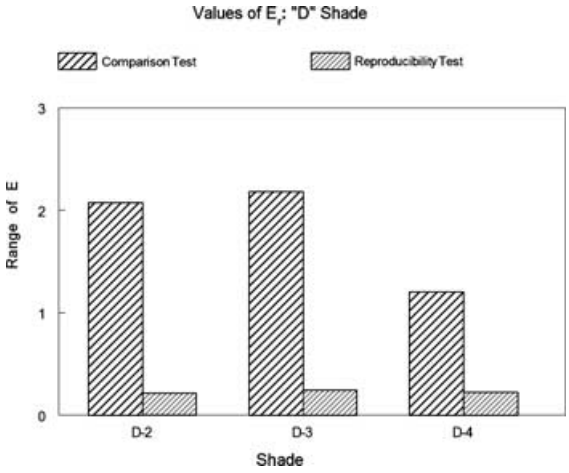

Figure 5. Values of E_r for Vitapan Shade "D" shade guide tabs.

The difference between the E_r values for the reproducibility group and the group of 25 shade guides is significant at $p < 0.05$. The values of E_{sd} for the reproducibility group and the group of 25 shade guides were also significant at $p < 0.05$. The largest value for E_r observed was 3.05 for shade C1.

For the purpose of this study, the observed changes in E (as expressed in E_r) will be treated as ΔE values, as used in color science.[12]

Discussion

Many variables affect the shade matching process. It would be beyond the scope of this study to investigate all factors involved with shade taking and communication with the ceramist. One variable rarely mentioned is the variability of the shade guide being used as a "standard" to communicate the color to the dental laboratory. The differences observed in this study between shade guides are larger than the variations induced by the experimental method. The lower detection limit of the experimental method was established with the reproducibility test E_r of 0.08 to 0.69. When comparing the L*a*b* values of the Vitapan Classical Shade Guide, with the values reported by O'Brien,[4,17] the values, though different, produced ΔE values consistent with the variability noted in this study.

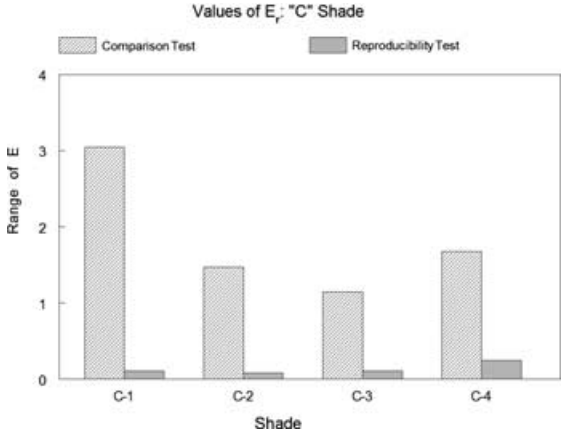

Figure 4. Valuse of E_r for Vitapan Shade "C" shade guide tabs.

For the purpose of this study, we were concerned with the range of E for the sample shade guide tabs that were greater than E = 1. Small color differences are more detectable by electronic means than by the human eye.[18] Using the findings of Kuehni et al,[13] 15 of the 16 Vitapan Classical Shade Guides had a difference between the shade of the same shade tab large enough to be considered perceptible to the observer. Including one of the shades having an E_r that would be considered clinically unacceptable (C1 = 3.05).[14]

According to this study, the Vitapan Classical Shade Guide, which has been used for years as a "standard" for shades,[5,6] is not standardized. Since there is no requirement for lot numbers on the Vitapan Classical Shade Guides, one is not able to minimize the shade variability by obtaining shade guides from the same "lot." The shade guide tab selected for the shade by the dentist may not

match same number designated shade guide tab being used by the ceramist in the fabrication of the prosthesis.[2] Because of these variations, the practice of sending the actual shade tab to the dental laboratory appears to have merit. If the actual shade guide tab is sent, it must be communicated to the ceramist that the submitted shade guide tab must be used in the fabrication of the prosthesis.[2] Another option may be standardizing the shade guides used within the dental office and the dental laboratory. Though time consuming, the use of custom shade tabs may also be an option.[19]

Conclusions

The differences observed in this study between shade guides are larger than the variations induced by the experimental method. The difference in E values between shades C1 and C2 is 2.19; hence the observed variation in the E_r of 3.05 between shade tabs of the same shade (C1) is larger than the differences between different shades. This large a variation between tabs of the same shade is deemed of clinical importance, and therefore, the Vitapan Classical Shade Guide tabs should not be considered interchangeable.

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