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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Colorimetric (CIEDE2000) comparison between two shade guides used for visual evaluation of tooth whitening efficacy

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SUMMARY

Introduction/Objective The objective of this study was to perform colorimetric comparison between two shade guides used for visual tooth whitening monitoring.

Methods VITA Bleachedguide 3D-Master (BG) and value scale of VITA classical A1–D4 (VC) were evaluated (n = 3) using a non-contact spectroradiometer. Ranges, distribution, and correlation among color parameters were evaluated using CIEDE2000 color difference formula. In addition, optimized whiteness index for dentistry (WI_D), and Yellowness Index E313 (YI) were analyzed. ANOVA and Fisher's PLSD test at a 0.05 level of significance were used in statistical analysis.

Results The lightness (L′), chroma (C′), and hue (h′) ranges for BG were 20.4, 25.9, and 19.1, respectively. The corresponding ranges for VC were 15.3, 10.9, and 20.6. R^2 values for individual color coordinate/tab arrangement were higher for BG than VC. The same is true for R^2 values of pairs of color coordinates for BG/VC: L′C′ = 0.89/0.33, L′h′ = 0.88/0.53, and C′h′ = 0.70/0.51. BG also exhibited better agreement between the manufacturer's tab arrangement with ΔE′, WI_D and YI. The ΔE′ between the lightest and the darkest BG and VC tab were 20.6 and 13.2, respectively. The average ΔE′ among the adjacent tabs were 1.9 (0.5) for BG (corresponding to two shade guide units, SGU) and 3.0 (1.0) for VC (1 SGU).

Conclusion VITA Bleachedguide 3D-Master exhibited wider L′, C′, ΔE′, WI_D, and YI ranges compared to value scale of VITA classical A1–D4 shade guide and better distribution of evaluated color parameters. This, along with the presence of several shades lighter than B1 of VC, recommends the use of BG for visual evaluation of tooth whitening efficacy.

Keywords: tooth whitening; color; dentistry; psychophysics; shade guide

INTRODUCTION

Tooth whitening is probably one of the most popular cosmetic procedures in dentistry. A convincing evidence of the validity of this statement is presented on Medline search, where more than 3,000 papers show up with keywords *tooth* and *whitening* or *bleaching*. Tooth whitening is performed using the one or a combination of the three basic methods: in office (power bleaching), dentist-administered at-home bleaching and bleaching using over-the-counter products.

Tooth whitening efficacy ranges from barely noticeable to very pronounced and it can be monitored and documented using visual and/or instrumental method [1–5]. Visual method is more popular due to limited percentage of practices that have color measuring devices. Visual method implies the usage of dental shade guides, and is expressed in shade guide units (SGU). One SGU means that tooth become one shade tab lighter upon whitening. Consequently, whitening efficacy is calculated and shade tab number before whitening minus shade tab number after whitening.

VITA classical A1–D4 shade guide (VC) (VITA Zahnfabrik, Bad Säckingen, Germany), with the original A1–D4 tab arrangement modified to so-called value scale B1–C4 (Figure 1) is the most frequently used method of visual monitoring of tooth whitening efficacy. Another shade guide, VITA Bleachedguide 3D-Master (BG) (VITA Zahnfabrik) (Figure 1) is the only shade guide developed specifically for tooth whitening monitoring. Previously reported

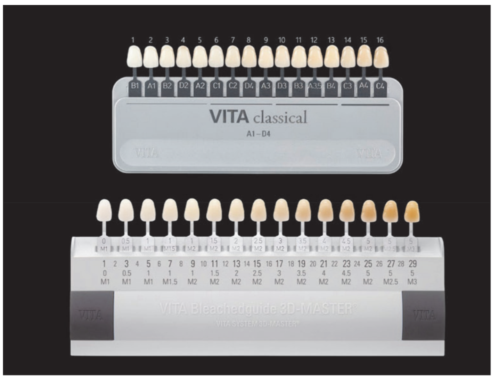

Figure 1. Top: value scale of VITA classical A1–D4 shade guide; bottom: VITA Bleachedguide 3D-Master shade guide

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performance and/or advantages of BG resulted in its recommendation as a shade guide of choice for tooth whitening monitoring by the American Dental Association in 2016 [6–11].

Color is a psychophysical phenomenon that can also be evaluated using instrumental method ("color by numbers") with the ultimate goal of providing objectivity and correlating with visual findings. The CIELAB color difference formula from 1976 has predominantly been used in color research in dentistry. However, new and more advanced formulas have been subsequently introduced, including the most recent CIEDE2000 formula. The agreement with visual finding greater than 95% is the main advantage of CIEDE2000 formula over the CIELAB formula with 75% agreement [12]. Although the advantages of BG compared to VC have been clearly demonstrated in the past, very limited data are available on their comparison utilizing CIEDE2000 color difference formula. The objective of this study was to provide a colorimetric comparison between these two shade guides using the CIEDE2000 formula. The null hypothesis was that there was no difference between BG and VC in any of evaluated color parameters.

METHODS

Colorimetric evaluation of BG and VC shade guides (n = 3) was performed by a non-contact spectroradiometer (SpectraScan PR-670, Photo Research, Syracuse, NY, USA). The instrument setup was as follows: bi-directional 45°/0° optical geometry, D65 illuminant and 2° standard observer, with 0.5° aperture (corresponding to 4 mm diameter at the 40 cm distance). The spectroradiometer was calibrated using white reflectance standard (SRS-3, PhotoResearch) under controlled illumination using Xenon lamp (Newport Corporation, Irvine, CA, USA) mounted inside the lamp housing (Newport Corporation). Shade tab positioning jigs were made using clear bite registration material (Clear Bite Matrix, Lompoc, CA, USA) and placed inside custom made clear acrylic holder to allow proper repositioning of shade tabs, thus enabling measurements with no background. The measured area corresponded to the middle of clinical crown, from incisal to gingival and from mesial to distal. The horizontal, x-positions of the left and right edge of shade tabs were recorded, and the middle x-position was defined as the center x-position, with the zeroed horizontal instrument readout. After determining the vertical, y-positions of shade tabs, the vertical readout was also set to zero. Spectral reflection data (in 2 nm intervals) were obtained for each shade tab five times with repositioning and further processed using the Commission Internationale De l'Eclairage (International Commission on Illumination) (CIE) CEIDE2000 formula as follows:

Computations with the CIEDE2000 (ΔE_{00}) total color difference formula were made according to the following equation [13]:

$$\Delta E_{00} = [(\frac{\Delta L'}{K_L S_L})^2 + (\frac{\Delta C'}{K_C S_C})^2 + (\frac{\Delta H'}{K_H S_H})^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)]^{1/2} \quad /1/$$

where $\Delta L'$, $\Delta C'$, and $\Delta H'$ are the differences in lightness, chroma, and hue for a pair of samples in CIEDE2000, and R_T is a function (the so-called rotation function) that accounts for the interaction between chroma and hue differences in the blue region. Weighting functions, S_L, S_C, S_H, adjust the total color difference for variation in the location of the color difference pair in L', a', b' coordinates and the parametric factors K_L, K_c, K_h, are correction terms for experimental conditions. For calculation performed in this study, all parametric factors were set to 1. Discontinuities due to mean hue computation and hue-difference computation were taken into account [14].

The Whiteness Index for Dentistry (WI_D) is an optimized, CIELAB-based whiteness index specifically designed for dentistry, which computation is given by the following equation [15]:

$$WI_D = 0.511\ L^* - 2.324\ a^* - 1.10\ b^* \quad /2/$$

The yellowness of the samples can be evaluated from instrumentally measured color coordinates using the YI E313 Yellowness Index [16]:

$$YI\ E313 = \frac{100(C_X X - C_Z Z)}{Y} \quad /3/$$

where X, Y and Z are the tristimulus values of the sample, while C_X and C_Z are illuminant and observer specific constants (in this case, C_X = 1.2985 and C_Z = 1.13335 as recommended for D65/2° Illuminant/Observer combination)

Means and standard deviations were determined. Anova and Fisher's PLSD test at a 0.05 level of significance were used in statistical analysis.

RESULTS

CIEDE2000 color coordinate values for of BG and VC shade guides are presented in Table 1. The L'C'h' ranges for BG were 20.4, 25.9, and 19.1, respectively. The corresponding ranges for VC were 15.3, 10.9 and 20.6. The L' and C' ranges were wider, while h' range of BG was slightly narrower as compared to VC. Based on R^2 values, all three-color coordinates exhibited more uniform distribution in BG (Figure 2). The R^2 values for pairs of color coordinates for BG were as follows: L'C' = 0.89, L'h' = 0.88, and C'h' = 0.70. Corresponding values for VC were 0.33, 0.53, and 0.51, respectively. Fisher's PLSD intervals ($p < 0.0001$) for comparisons among L'C'h' values for BG were 0.26, 0.28, and 0.49, respectively. Corresponding values for VC were 0.35, 0.29, and 0.59.

Color differences (ΔE') from the lightest to the darkest BG and VC tab (according to manufacturer's tab arrangement/order) and corresponding color distribution are shown in Figure 3. The ΔE' ranges for BG and VC were 20.6 and 13.2 respectively. The recorded R^2 values clearly demonstrate more uniform color distribution of BG. When the average ΔE' values (s.d.) from two to 14 (BG) and 15 (VC) tabs apart were compared (Table 2), the

Table 1. CIEDE2000 color coordinate values (s.d.) for of VITA Bleachedguide 3D-Master and value scale of VITA classical A1–D4 shade guides: lightness (L′), chroma (C′), and hue (h′)

VITA Bleachedguide 3D-Master				VITA classical A1–D4, Value scale			
Tab	L′	C′	h′	Tab	L′	C′	h′
1	81.5 (0.5)	5.6 (0.1)	87.1 (1.2)	1	75.6 (0.6)	12.8 (0.2)	99.3 (0.6)
3	79.3 (0.5)	8.4 (0.3)	92.9 (1)	2	76.4 (0.5)	14.0 (0.2)	91.4 (0.6)
5	76.4 (0.3)	10.8 (0.1)	91.6 (0.6)	3	74.1 (0.3)	17.7 (0.2)	92.7 (0.9)
7	76.3 (0.2)	13.7 (0.1)	92.5 (0.7)	4	70.1 (0.6)	13.7 (0.6)	87.0 (1.3)
9	76.9 (0.4)	16.7 (0.3)	93.4 (0.4)	5	74.1 (0.2)	18.4 (0.3)	86.3 (1.2)
11	74.8 (0.2)	16.7 (0.3)	89.8 (0.7)	6	70.9 (0.6)	13.7 (0.6)	91.7 (1.4)
13	73.3 (0.4)	17.0 (0.3)	87.6 (0.6)	7	68.3 (0.2)	19.0 (0.2)	88.4 (0.7)
15	71.6 (0.2)	18.2 (0.5)	85.6 (0.8)	8	68.2 (0.5)	21.0 (0.3)	90.6 (0.2)
17	69.4 (0.3)	19.6 (0.4)	83.0 (0.2)	9	71.4 (0.7)	20.5 (0.6)	84.7 (1)
19	66.8 (0.3)	21.2 (0.6)	80.6 (0.9)	10	68.6 (0.5)	17.5 (0.5)	83.7 (0.7)
21	64.8 (0.3)	21.9 (0.3)	78.4 (0.5)	11	70.2 (0.3)	23.3 (0.3)	86.3 (0.7)
23	62.3 (0.2)	23.9 (0.3)	75.8 (0.3)	12	68.2 (0.6)	24.1 (0.3)	82.4 (0.4)
25	61.3 (0.5)	24.9 (0.4)	73.8 (0.8)	13	69.5 (0.1)	25.7 (0.6)	85.1 (0.7)
27	61.1 (0.5)	29.2 (0.7)	74.8 (0.2)	14	65.8 (0.2)	19.0 (0.2)	87.2 (0.3)
29	61.8 (0.2)	31.5 (0.6)	75.8 (0.1)	15	64.5 (0.6)	23.8 (0.5)	78.7 (0.8)
				16	61.2 (0.5)	21.9 (0.4)	80.3 (0.5)

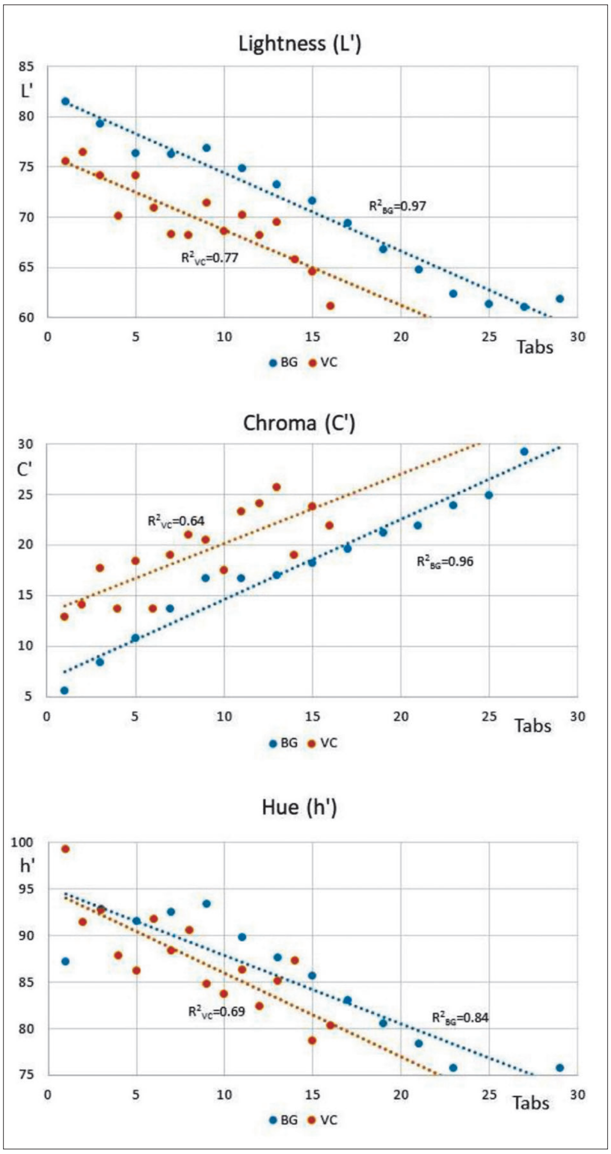

Figure 2. Color coordinate ranges and distribution of VITA Bleachedguide 3D-Master and value scale of VITA classical A1–D4 shade guide; top: lightness (L′); middle: chroma (C′); bottom: hue (h′)

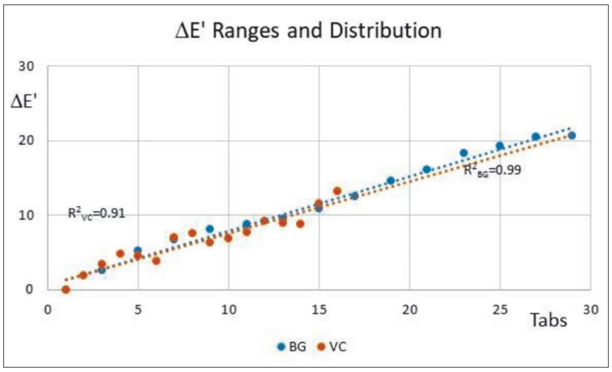

Figure 3. Color differences (ΔE′) from the lightest to the darkest tab of VITA Bleachedguide 3D-Master (BG) and value scale of VITA classical A1–D4 (VC) shade guide (according to manufacturer's tab arrangement/order) and corresponding color distribution

Table 2. Average ΔE′ values (s.d.) from adjacent tab pairs to 14 tabs apart for VITA Bleachedguide 3D-Master (BG), and from adjacent tab pairs to 15 tabs apart for value scale of VITA classical A1–D4 (VC)

Tab pairs	ΔE′ (BG)	ΔE′ (VC)
Adjacent tabs	1.9 (0.5)	3.0 (1)
2 tabs apart	3.5 (0.8)	3.2 (1.3)
3 tabs apart	5.0 (1.2)	3.8 (1.4)
4 tabs apart	6.5 (1.4)	3.8 (1.1)
5 tabs apart	8.0 (1.4)	4.8 (1.4)
6 tabs apart	9.5 (1.3)	5.0 (1.9)
7 tabs apart	11.1 (1.1)	5.7 (1.9)
8 tabs apart	12.6 (0.8)	5.6 (0.8)
9 tabs apart	14.0 (0.6)	6.8 (0.6)
10 tabs apart	15.3 (0.8)	7.5 (1.9)
11 tabs apart	16.6 (1.5)	8.5 (1.7)
12 tabs apart	17.9 (1.7)	8.8 (0.1)
13 tabs apart	19.5 (1.5)	10.3 (1.3)
14 tabs apart	20.6	12.3 (1)
15 tabs apart		13.2

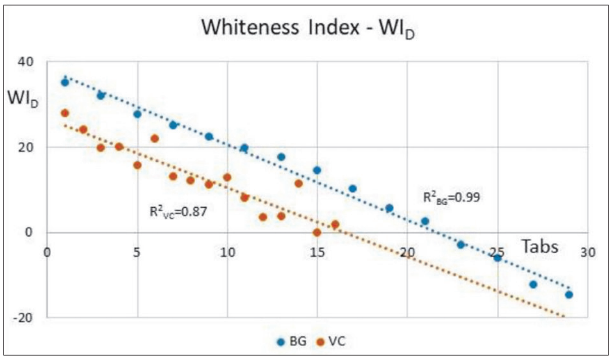

Figure 4. Ranges and distribution of whiteness index for dentistry (WID) for VITA Bleachedguide 3D-Master (BG) and value scale of VITA classical A1–D4 shade guide (VC)

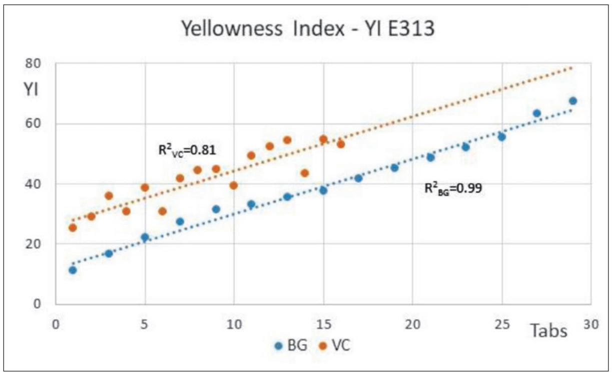

Figure 5. Ranges and distribution of yellowness index E313 (YI) for VITA Bleachedguide 3D-Master (BG) and value scale of VITA classical A1–D4 shade guide (VC)

BG exhibited almost perfect distribution of color differences $R^2 = 0.99$, while corresponding for VC was $R^2 = 0.91$.

WI_D ranges for BG and VC were 49.8 ($R^2 = 0.99$) and 28.0 ($R^2 = 0.87$), respectively, with much more consistent distribution in BG (Figure 4). Corresponding YI ranges were 56.4 ($R^2 = 0.99$) and 29.6 ($R^2 = 0.81$), respectively (Figure 5). Shadowed cells designate shade tabs that are not positioned in accordance with manufacturer order (1–29 tab arrangement for BG and B1–C4 for VC value scale).

The BG and VC comparison of the manufacturer's order (MO, tab arrangement from the lightest to the darkest: 1–29 for BG and 1–16 from B1 to C 4 for VC) and evaluated parameters are presented in Table 3 and Table 4.

Table 3. VITA Bleachedguide 3D-Master shade guide: comparison of the manufacturer's order: MO – tab arrangement from the lightest to the darkest, from 1–29; L' – lightness; C' – chroma; h' – hue; ΔE' – color difference compared to 0M1; WID – whiteness index for dentistry; YI – yellowness index E313

VITA Bleachedguide 3D-Master (1–29)						
MO	L'	C'	h'	ΔE' (1–15)	WID	YI
1	1	1	9	1	1	1
3	3	3	7	3	3	3
5	9	5	3	5	5	5
7	5	7	5	7	7	7
9	7	9	11	9	9	9
11	11	11	1	11	11	11
13	13	13	13	13	13	13
15	15	15	15	15	15	15
17	17	17	17	17	17	17
19	19	19	19	19	19	19
21	21	21	21	21	21	21
23	23	23	23	23	23	23
25	29	25	29	25	25	25
27	27	27	27	27	27	27
29	25	29	25	29	29	29

Table 4. Value scale of VITA classical A1–D4 shade guide: comparison of the manufacturer's order: MO – tab arrangement from the lightest to the darkest, from 1–16; L' – lightness; C' – chroma; h' – hue; ΔE' – color difference compared to 0M1; WID – whiteness index for dentistry; YI – yellowness index E313 (YI)

VITA classical A1–D4, Value scale (1–16)						
MO	L'	C'	h'	ΔE' (1–16)	WID	YI
1	2	1	1	1	1	1
2	1	4	3	2	2	2
3	3	6	2	3	6	4
4	5	2	6	6	3	6
5	9	8	7	5	4	3
6	11	10	4	4	5	5
7	6	3	14	9	10	10
8	4	5	11	10	7	7
9	13	7	13	7	8	14
10	10	14	5	8	14	8
11	8	9	9	11	9	9
12	12	16	10	14	11	11
13	7	11	12	13	13	12
14	14	15	16	12	12	16
15	15	12	15	15	16	13
16	16	13	8	16	15	15

DISCUSSION

The null hypothesis was rejected as difference between BG and VC were recorded in each of evaluated color parameters. L' and C' coordinate ranges were much wider than the corresponding VC ranges, while the h' range was slightly narrower. Differences among R^2 values for individual color coordinates vs. manufacturer-suggested tab order (from lightest to darkest), however, clearly demonstrated both the advantages of BG in terms of uniformity of shade distribution and inconsistencies of VC value scale tab arrangement. The same is true for R^2 values among pairs of color coordinates (L'/C', L'/h' and C'/h'). This is not very surprising given that VC, introduced in 1956, has not originally been developed for tooth whitening monitoring. The modern-day whitening practically started in 1989 [17]. It is also important to mention that color coordinates of BG consistently mimic the behavior of natural teeth upon whitening: from far right (tab #29 or 5M3) to far left (tab #1 or 0M1) the tabs become lighter (L'↑), less chromatic (C'↓) and less red (h'↓).

When it comes to color differences (ΔE') from the lightest to the darkest and tab of the two shade guides, the BG ΔE' range was 56% wider and more uniform ($R^2 = 0.99$) than the corresponding VC range. The average ΔE' among pair of adjacent tabs was 1.9 for BG and 3.0 for VC, with the former one representing 2 SGU as BG tabs are marked with odd numbers 1–29 (with maximal shade change of 28 SGU), and the later one corresponds to 1 SGU (with maximal shade change of 15 SGU). Hence, 1 SGU of BG corresponded to ΔE' = 1.0.

Another important consideration involves the overlapping of shades that reduces the quality of color distribution, i.e., color uniformity. Given the mean color difference between the adjacent tabs, the color difference for 14 tabs apart of BG would ideally be 1.9 × 14 = 26.6; corresponding calculation for 15 tabs apart of VC would be 3 × 15 = 45. This means that the shade overlapping for BG is 23% (BG range of ΔE' = 20.6 is 77% of the ideal range of ΔE' = 26.6), and 71% for VC (VC range of ΔE' = 13.2 is 29% of the ideal range of ΔE' = 45). Consequently, 1 SGU for BG would correspond to ΔE' = 0.7 (ΔE' = 1 was reported), while VC shade change of 1 SGU would correspond to ΔE' = 0.88 (ΔE' = 3 was reported). This result provides additional evidence of uniformity and lack of it for BG and VC, respectively.

Another concern with BG is that B1 is the lightest shade in value scale. If patient's teeth are very light before bleaching (close to B1 shade), visual monitoring for these patients becomes a problem, as the value scale has no tabs that would correspond to shade after whitening. The B1 shade, being the lightest shade in VC, has frequently resulted in recruitment exclusion of teeth that are lighter than A3 (#9 on a value scale) before bleaching. In this fashion, approximately 50% of patients would be excluded from the study [18], and these studies would, essentially, report on "tooth whitening efficacy for darker teeth." Using the parameter that is to be evaluated as inclusion/exclusion criterion does not contribute to objectivity of findings. The problem of the lack of very light shades has been resolved in BG as the closest match to B1 is 1M1.5 (ΔE' = 1.9), which is #7 in BG. This enables the inclusion of all patients into whitening studies, given that there are practically no patients with teeth lighter than 0M1, before or after bleaching. Adding of tabs from group "0" from Linearguide 3D Master to VC value scale can partly resolve the "B1 issue," but one should keep in mind that there is a huge gap (ΔE'≈ 5.0) between 0M3 and B1.

The first whiteness index optimized for dentistry (WIO) has been reported in 2009 and validated in subsequent publication [19]. However, the WI_D has been the first CIELAB-based whiteness index specifically designed for dental application as it was developed based on correlations with visual perception of tooth shaped shade tabs and dental materials [15]. In a recent study, the performance of existing equations that measure perceptual whiteness of teeth was assessed concluding that indexes that have been optimized for use with tooth whiteness (WIO and WI_D) performed better than the more general CIE whiteness index (WIC) [20]. Similarly to other results, the BG WI_D exhibited a wider range and more consistent color distribution as compared to VC. The same is true for the yellowness index YI E313. The BG is therefore expected to provide a better coverage for color of bleached teeth or for those teeth that present uncommon colorimetric coordinates.

It was reported that the visually determined order of BG tabs from 1–29 was identical with the manufacturer's tab arrangement, which was not the case with the VC value scale [7]. Shadowed cells in Table 3 and Table 4, designating tabs that are not positioned in accordance with manufacturer order, provide further evidence on the advantages of BG over VC. Here are some examples of VC inconsistencies and explanations from respective columns in Table 4:

- L': tabs #4, 6, 7, and 8 are darker than tabs #11 and 14; the tabs with lower number should be lighter (should have higher L' value);
- C': tab #9 is more chromatic (higher C' values) than tabs #11, 13, and 14; the tabs with lower number should be less chromatic (should have lower C' value);
- h': tab #9 has lower hue angle (redder) than tabs #11, 13, and 14; the tabs with lower number should be less red (should have greater h' value);
- ΔE' compared to B1: ΔE' between tabs 1 and 8 is greater than 1 to 9 and 1 to 10; the tabs with lower number should exhibit lower color difference to B1 (tab #1).
- WI_D: tab #9 have lower WI_D than tabs #10 and 14; the tabs with lower number should be "whiter" (should exhibit greater WI_D);
- YI: tab #14 has lower YI than tabs 8, 9, 11, 12, and 13; the tabs with lower number should be less "yellow" (should exhibit lower YI).

In addition to aforementioned, the overall color analysis revealed that VC was darker (L'), more chromatic (C'), redder (h'), whiter (WI_D), and less yellow (YI) than BG. Consequently, the BG was lighter, less chromatic, less red, less white, and more yellow.

CONCLUSION

VITA Bleachedguide 3D-Master exhibited wider L', C', ΔE', WI_D, and YI ranges compared to value scale of VITA classical A1–D4 shade guide and better distribution of evaluated color parameters. This, together with the presence of several shades lighter than B1 of VC, recommends the usage of BG for visual evaluation of tooth whitening efficacy.

CONFLICT OF INTEREST STATEMENT

VITA Bleachedguide 3D-Master shade guide was jointly developed by Dr. Rade D. Paravina and VITA Zahnfabrik. The University of Texas HSC at Houston has executed licensing agreements with VITA dealing with commercialization of these shade guides. Dr. Paravina is a paid consultant for VITA Zahnfabrik.

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Колориметријско (*CIEDE2000*) поређење два кључа за одређивање боје који се користе за визуелно процењивање ефикасности избељивања зуба

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САЖЕТАК

Увод/Циљ Циљ истраживања је био да се изврши колориметријско поређење два кључа за боју који се користе за визуелно процењивање ефикасности избељивања зуба.

Методе Кључеви за одређивање боје зуба *VITA Bleachedguide 3D-Master* (*BG*) и *VITA classical A1–D4, value scale* (*VC*) ($n = 3$) испитивани су помоћу неконтактног спектрорадиометра. Опсези, дистрибуција и однос између параметара боје су испитивани коришћењем једначине *CIEDE2000* за разлику у боји. Оптимизовани *whiteness index* за стоматологију (*WID*) и *yellowness index E313* (*YI*) такође су анализирани. При статистичкој обради података коришћени су *ANOVA* и Фишеров *PLSD* тест ($\alpha = 0,05$).

Резултати Светлина – *lightness* (*L'*), засићеност – *chroma* (*C'*) и основна боја – *hue* (*h'*), односно *L'C'h'* опсези од 20,4, 25,9 и 19,1 забележени су код *BG*. Одговарајући опсези за *VC* су били 15,3, 10,9 и 20,6. R^2 вредности за индивидуалне колор координате у односу на распоред узорака су биле више за *BG* него за *VC*. Исто важи и за R^2 вредности парова колор координата за *BG*/*VC*: *L'C'* = 0,89/0,33, *L'h'* = 0,88/0,53 и *C'h'* = 0,70/0,51. *BG* је имао бољи однос између оригиналног распореда узорака и разлике у боји ($\Delta E'$), WI_D и *YI* вредности. $\Delta E'$ између најсветлијег и најтамнијег узорка је био 20,6 за *BG* и 13,2 за *VC*. Просечна разлика у боји између суседних узорака је била 1,9 (0,5) за *BG* (2 *SGU*, *shade guide units*) и 3,0 (1,0) за *VC* (1 *SGU*).

Закључак Утврђено је да *BG* има шире *L'*, *C'*, $\Delta E'$, WI_D и *YI* опсеге и бољу дистрибуцију анализираних параметара боје у поређењу са *VC* кључем. Ово, као и присуство неколико нијанси светлијих од *B1* нијансе у *VC*, препоручује коришћење *BG* за визуелно процењивање ефикасности избељивања зуба.

Кључне речи: избељивање зуба; боја; стоматологија; психофизика; кључ боја