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Reliability of conventional shade guides in teeth color determination

Pouzdanost primene konvencionalnih ključeva za određivanje boje zuba

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Abstract

Background/Aim. Color matching in prosthodontic therapy is a very important task because it influences the esthetic value of dental restorations. Visual shade matching represents the most frequently applied method in clinical practice. Instrumental measurements provide objective and quantified data in color assessment of natural teeth and restorations. In instrumental shade analysis, the goal is to achieve the smallest ΔE value possible, indicating the most accurate shade match. The aim of this study was to evaluate the reliability of commercially available ceramic shade guides. **Methods.** VITA Easyshade spectrophotometer (VITA, Germany) was used for instrumental color determination. Utilizing this device, color samples of ten VITA Classical and ten VITA 3D – Master shade guides were analyzed. Each color sample from all shade guides was measured three times and the basic parameters of color quality were examined: ΔL, ΔC, ΔH, ΔE, ΔElc. Based on these parameters spectrophotometer marks the shade matching as good, fair or adjust. **Results.** After performing 1,248 measurements of ceramic color samples, frequency of evaluations adjust, fair and good were statistically significantly different between VITA Classical and VITA 3D Master shade guides (p = 0.002). There were 27.1% cases scored as adjust, 66.3% as fair and 6.7% as good. In VITA 3D – Master shade guides 30.9% cases were evaluated as adjust, 66.4% as fair and 2.7% cases as good. **Conclusion.** Color samples from different shade guides, produced by the same manufacturer, show variability in basic color parameters, which once again proves the lack of precision and nonuniformity of the conventional method.

Key words:
prosthesis coloring; spectrophotometry; esthetics, dental.

Apstrakt

Uvod/Cilj. Određivanje boje zuba u protetskoj terapiji predstavlja veoma važan zadatak jer utiče na prirodan izgled i estetsku vrednost zubnih nadoknada. Vizuelni metod određivanja boje zuba najčešće se koristi u kliničkoj praksi. Instrumentalna merenja pružaju objektivne i kvantifikovane podatke u proceni boje prirodnih zuba i restauracija. U instrumentalnoj analizi boje cilj je da se postigne najmanja moguća vrednost ΔE, što predstavlja najtačniji izbor nijanse. Cilj ovog istraživanja bio je da se utvrdi pouzdanost najčešće korišćenih ključeva za određivanje boje zuba. **Metode.** Za instrumentalni izbor boje korišćen je *VITA Easyshade* spektrofotometar (*VITA*, *Germany*). Uz pomoć ovog uređaja, analizirani su uzorci boja 10 *VITA Classical* i 10 *VITA* 3D – *Master* ključeva boja. Svaki uzorak boje analiziran je tri puta i ispitivani su osnovni parametri kvaliteta boje: ΔL, ΔC, ΔH, ΔE, ΔElc. Stepen poklapanje boje nadoknade sa ciljnom nijansom spektrofotometar izražava kroz tri ocene kvaliteta: *good*, *fair* i *adjust*. **Rezultati.** Nakon izvršenih 1 248 merenja keramičkih uzoraka boje, frekvencije ocena *adjust*, *fair* i *good* statistički su se značajno razlikovale između *VITA Classical* i *VITA* 3D – *Master* ključeva boja (p = 0.002). U *VITA Classical* ključu boja bilo je 27,1% ocene *adjust*, 66,3% *fair* i 6,7% ocene *good*. U *VITA* 3D – *Master* ključu boja bilo je 30,9% ocene *adjust*, 66,4% *fair* i 2,7% ocene *good*. **Zaključak.** Uzorci boje iz različitih ključeva boja proizvedenih od istog proizvođača, pokazuju varijabilnost u osnovnim parametrima boje, što ukazuje na nepreciznost i neuniformnost konvencionalne metode.

Ključne reči:
zubna proteza, boja; spektrofotometrija; zub, estetika.

Introduction

Color matching in prosthodontic therapy is a very important task because it influences the natural appearance and esthetic outcome of dental restorations. According to the research of Kawaragi et al. [1], over 80% of patients are not satisfied with the color of metal-ceramic crowns in esthetic region compared to natural tooth.

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Color is a special type of psychophysical sensation in the eye caused by visible light [2]. Color perception depends on four levels: light source, an observed object, the eye and the brain. Without light and proper illumination, color can be neither accurately perceived nor correctly evaluated. The human eye can perceive only the wavelengths of light from the visible light spectrum, in physical terms 400–700 nm [3]. Colorimetry, the science of color, has been developed to quantify and describe physically the human color perception. The only internationally recognized system for color measurement is Commision Internationale de l'Eclairage (CIE) system established in 1931 [4].

There are two color matching methods in dentistry: visual (conventional) and instrumental. Visual shade determination, when comparing to patient's tooth with color standard, is the most frequently applied method in clinical dentistry [5]. However, visual shade matching is unreliable, inconsistent and considered highly subjective. This is the result of multiple factors such as individual's physiological and psychological responses to radiant energy stimulation, aging, fatigue, emotions, lighting conditions, object and illumination position, previous eye exposure and metamerism [6, 7]. Furthermore, human eye can detect very small differences in color, the range of available shades in the shade guides is inadequate and it is not possible to translate results into CIE color specifications. Technology-based color matching has been developed to minimize color mismatches during visual color estimation [8, 9]. Most often used instruments are: tristimulus colorimeters, spectroradiometers, digital cameras and spectrophotometers [10]. Most of these instruments use CIELAB color system to determine the color differences (ΔE) between a tooth to be matched and a chosen shade. With CIELAB colorimetry, color can be expressed in terms of three coordinate values (L^*, a^*, b^*), which locate object in a three-dimensional color space. The L^* coordinate characterizes the brightness of a color, a^* represents the red-green axis and b^* value represents the yellow or blue chroma [11]. The ΔE is the shortest distance in the CIEL*a*b* color space between the colors being compared and is given by following equation: $\Delta E = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$ (Figure 1) [12].

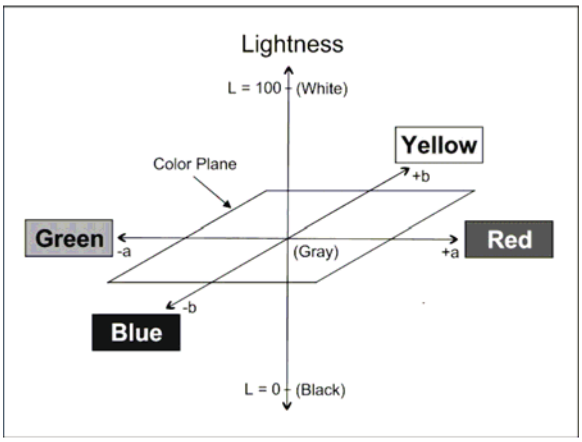

Fig. 1 – *Commision Internationale de e'Eclairage* (CIE) system which locates object in three demensional (brightness of color – L, red green axis-a*, yelow or blue axis – b*) color space.

The aim of this study was to determine the reliability of the most commonly used dental shade guides.

Methods

For instrumental shade selection a VITA Easyshade spectrophotometer (VITA Zahnfabrik Germany; Software version: 11R(b), light source D65, 2° observer) has been used. This device analyzed color samples of randomly selected ten unused VITA Classical and ten VITA 3D – Master shade guides (VITA Zahnfabrik, Germany). The middle third of the shade guide tab was selected for all readings. To ensure an identical position of all samples we made a transparent silicone mold as an attachment on the instrument's probe tip (Zhermack Elite Transparent, Italy). Prior to all the measurements, the instrument was calibrated according to manufacturers' recommendations. Each color sample from all shade guides was fixed and measured 3 separate times and the basic parameters of color quality were being examined: ΔL, ΔC, ΔH, ΔE, ΔElc. We observed these parameters individually and within four groups of colors of VITA Classical shade guides (A–D) and five groups of colors of VITA 3D – Master shade guides [1–5]. The instrument's software is programmed to provide results as differences (ΔE, ΔL, ΔC, ΔH, ΔE_{lc}) from color values, incorporated in the instrument database. There are three components of color: value (L) – the color brightness, chroma (C) – saturation or intensity of color, hue (H) – color itself or "name" of the color. Delta E (ΔE) is the color difference between two shade specimens, while ΔE_{LC} represents ΔE calculated excluding hue.

The degree to which the restoration matches the target shade is given by 3 color quality marks: good, fair and adjust. In this case "good" indicates that the base color of the restoration has very little or no color distinction from the target shade to which it has been established. "Fair" signifies that the base color of restoration may have visible but adequate distinction to which it has been verified. However, this might be unacceptable for an anterior restoration. "Adjust" indicates that the base color of the restoration has visible differences from the target shade from which it has been verified, and the restoration needs to be adjusted to acceptable shade match.

The obtained data were tested for normal distribution by the Kolmogorov-Smirnov test. Quantitative variables were compared (between observed groups of colors) using the Kruskal Wallis nonparametric test. The differences between two groups were assessed by the Mann-Whitney U-test. Qualitative data have been compared using the χ^2 test. The level of $p < 0.05$ was considered statistically significant. Statistical analysis was done using the SPSS 11.0.

Results

The basic parameters of color quality (ΔL, ΔC, ΔH, ΔE, ΔElc) for VITA Classical shade guides were statistically significantly different among the observed four groups of colors (Table 1).

Table 1

VITA Classical shade guide comparisons among the observed four groups of colors

Parameters	Colors	Colors b	Colors c	Colors d
ΔL [a]*	a	* *[b]	*	*
	b		*	*
	c			*
ΔC *	a	* *	*	* *
	b		*	* *
	c			*
ΔH *	a	*	*	*
	b		*	*
	c			*
ΔE *	a	*	*	*
	b		*	*
	c			*
ΔE_{lc}*	a	*	*	*
	b		*	*
	c			*

[a]Kruskal Wallis test (comparisons among all five color groups); [b]Mann Whitney U-test (multiple comparisons); *statistically significant; * *not statistically significant; L – color brightness; C – chroma saturation; H – "name" of the color; ΔE – color difference between two shade specimens; ΔE_{lc} – ΔE calculated excluding hue (H).

The highest value of ΔL parameter was observed in the group C of colors and the lowest in the group D (Figure 2). The lowest values of ΔE were observed in the group C and the highest in the group D of colors (Figure 3). For all the other observed parameters the results are shown in Table 2 and Figures 4, 5 and 6. Table 2 shows the value of these parameters for all colors of VITA Classical shade guides.

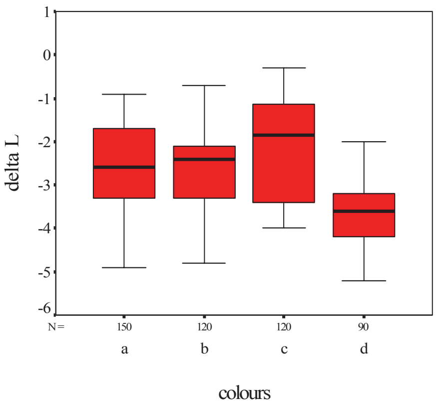

Fig. 2 – Color brightness difference (ΔL).

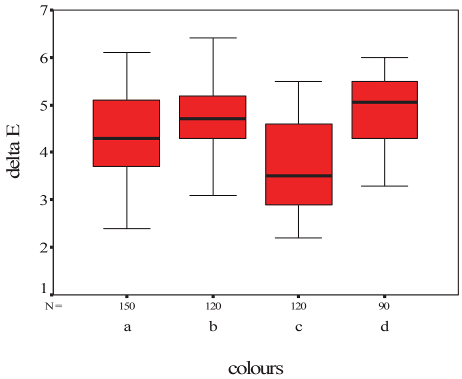

Fig. 3 – Color difference between two shade specimens (ΔE).

Comparisons of basic parameters of color quality (ΔL, ΔC, ΔH, ΔE, ΔElc) between the observed five groups of colors in VITA 3D – Master shade guides, showed statistically significant differences. Table 3 shows the results of multiple comparisons among the observed five groups of colors. ΔL parameter had the highest values in the group 5 of colors, and the

Table 2

VITA Classical shade guide – prameters of color quality

Colors	ΔL	ΔC	ΔH	ΔE	ΔE_{lc}
A1	-3,57 ± 0,74	-3,50 ± 0,43	1,60 ± 0,75	5,07 ± 0,52	5,05 ± 0,52
A2	-2,74 ± 0,44	-3,04 ± 0,64	1,73 ± 0,52	4,20 ± 0,33	4,18 ± 0,34
A3	-3,39 ± 0,60	-4,14 ± 0,39	2,28 ± 0,40	5,41 ± 0,57	5,36 ± 0,56
A3,5	-1,37 ± 0,26	-3,02 ± 0,69	2,14 ± 0,21	3,41 ± 0,61	3,33 ± 0,63
A4	-1,76 ± 0,24	-3,03 ± 0,29	4,15 ± 0,24	3,76 ± 0,33	3,54 ± 0,39
B1	-4,16 ± 0,37	-2,13 ± 1,39	1,27 ± 0,50	4,88 ± 0,39	4,87 ± 0,40
B2	-1,90 ± 0,48	-4,01 ± 0,80	4,36 ± 0,63	4,60 ± 0,79	4,44 ± 0,82
B3	-2,51 ± 0,48	-3,47 ± 3,55	2,84 ± 0,62	4,43 ± 0,55	4,32 ± 0,57
B4	-2,30 ± 0,31	-4,16 ± 0,67	3,72 ± 0,52	4,98 ± 0,63	4,77 ± 0,67
C1	-3,54 ± 0,38	-2,65 ± 0,38	-0,96 ± 3,19	4,43 ± 0,47	4,42 ± 0,46
C2	-3,06 ± 0,44	-3,74 ± 0,74	2,81 ± 0,81	4,82 ± 0,45	4,74 ± 0,47
C3	-1,32 ± 0,24	-2,16 ± 1,22	2,34 ± 0,92	2,86 ± 0,34	2,76 ± 0,32
C4	-0,84 ± 0,33	-2,74 ± 0,29	2,13 ± 0,67	2,97 ± 0,33	2,89 ± 0,34
D2	-3,73 ± 0,64	-3,45 ± 0,45	-1,40 ± 1,83	5,07 ± 0,52	5,11 ± 0,53
D3	-4,15 ± 0,23	-3,45 ± 0,57	1,50 ± 1,09	5,44 ± 2,89	5,43 ± 0,28
D4	-3,09 ± 0,40	-3,44 ± 0,24	0,33 ± 0,70	4,20 ± 0,38	4,62 ± 0,36

Note: results presented as mean ± standard deviation
L – color brightness; C – chroma saturation; H – "name" of the color; ΔE – color difference between two shade specimens; ΔE_{lc} – ΔE calculated excluding hue (H).

Table 3

VITA 3D – Master shade guide – comparisons between observed five groups of colors

Parameters	Colors	Colors 2	3	4	5
ΔL [a]*	1	* [b]	*	*	*
	2		*	*	*
	3			*	*
	4				*
ΔC *	1	*	*	*	*
	2		*	*	*
	3			*	*
	4				*
ΔH *	1	*	*	**	*
	2		*	*	*
	3			*	*
	4				*
ΔE *	1	**	*	*	*
	2		*	*	*
	3			*	*
	4				**
ΔE_{lc}*	1	**	*	*	*
	2		*	*	*
	3			*	*
	4				*

[a]Kruskal Wallis test (comparisons among all five color groups); [b]Mann Whitney U-test (multiple comparisons); *statistically significant; **not statistically significant; L – color brightness; C – chroma saturation; H – "name" of the color; ΔE – color difference between two shade specimens; ΔE_{lc} – ΔE calculated excluding hue (H).

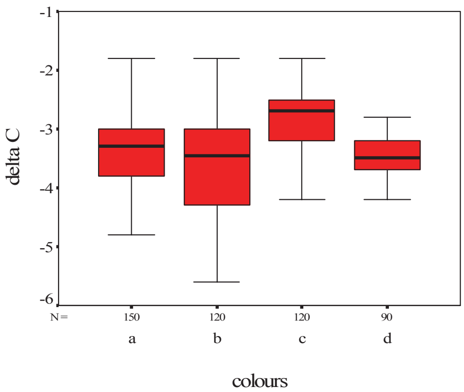

Fig. 4 –Intensity of color difference (ΔC) parameter.

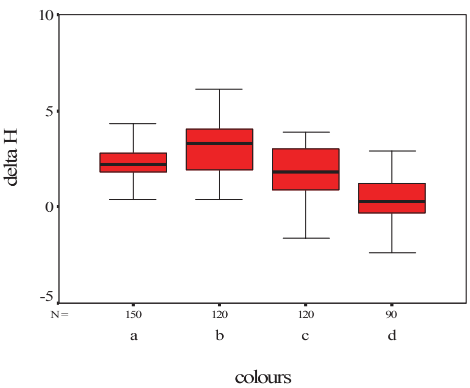

Fig. 5 –Color itself difference (ΔH) parameter.

lowest in the group 1 (Figure 7). For ΔE, the lowest values were observed in the groups 4 and 5 (in this two groups the value of ΔE was similar) and the highest in the group 2 of colors (Figure 8). Figures 9, 10 and 11 show the results of measurements for all the other observed parameters.

Frequencies of adjust, fair and good score were statistically significantly different between the VITA Classical and Vita 3D – Master shade guides ($p = 0.002$). In the VITA Classical shade guides, there were 27.1% cases scored as adjust, 66.3% had score fair and 6.7% score good. In the VITA 3D – Master shade guides 30.9% cases were evaluated as adjust, 66.4% as fair and 2.7% cases as good (Figure 12, Table 4).

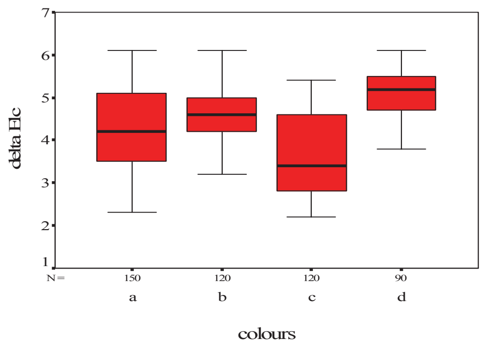

Fig. 6 – Color difference between two shade specimens (ΔE) parameter calculated excluding hue (H).

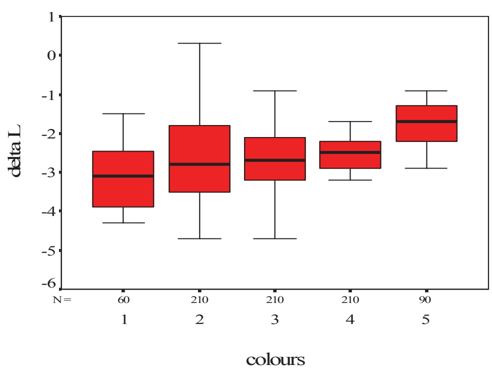

Fig. 7 – Color brightness difference (ΔL) parameter.

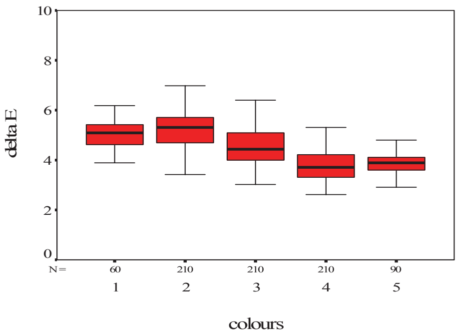

Fig. 8 – Color difference between two shade specimens (ΔE) parameter.

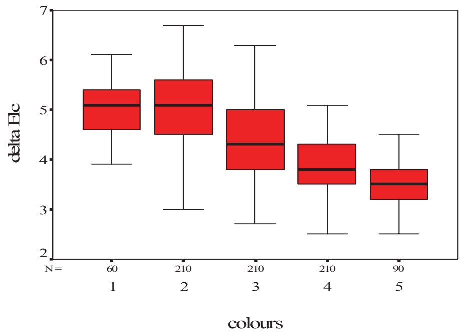

Fig. 11 – Color difference between two shade specimens (ΔE) parameter calculated excluding hue (H).

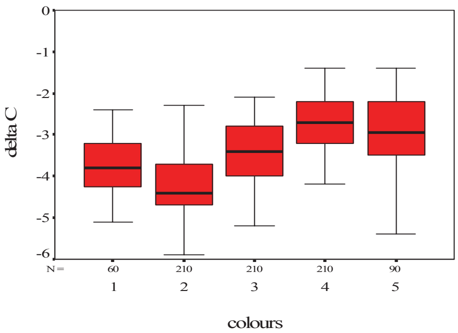

Fig. 9 – Intensity of color difference (ΔC) parameter.

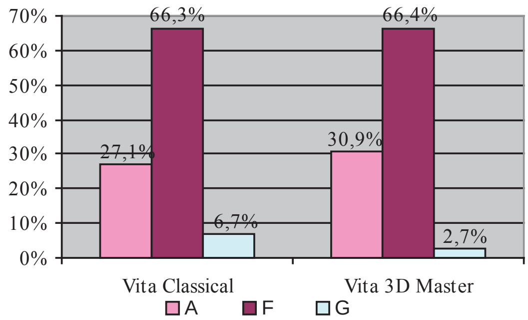

Fig. 12 – Color quality evaluated by two conventional shade guides (A – adjust; F – fair; G – good).

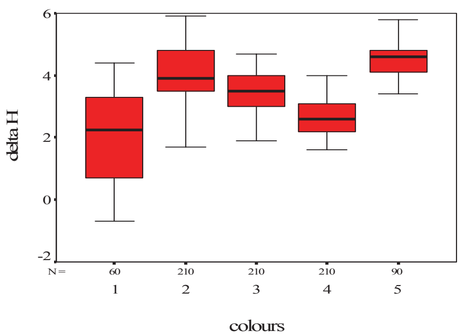

Fig. 10 – Color itself difference (ΔH) parameter.

stances [14]. It is also a color measurement instrument with both reliability and accuracy values grater than 90% [15].

In instrumental shade analysis, the goal is to achieve the smallest ΔE value possible, indicating the most accurate shade match. The ΔE value provides the quantification of the shade difference between the selected shade and the shade to be matched and it does not indicate whether one shade is darker or lighter than another. Brightness might be the most important component of color and must be prioritized during shade selection. Mostly, if the value and chroma are correct, the restoration will be clinically acceptable, even if the hue is slightly off. A hue is not of critical importance during shade selection because of the low concentration of hue in dental

Table 4

ΔE VITA Classical *versus* VITA 3D – Master shade guide

Shade guides	$\bar{x}$	Med	SD	Min	Max	95%CI
VITA Classical	4,49	4,50	0,93	2,10	8,70	4,43-4,56
VITA 3D Master	4,41	4,50	0,92	2,20	6,40	4,33-4,49

$\bar{x}$ = mean; Med = median; SD = standard deviation; min = minimum; max = maximum; 95 % CI = 95 % confidence interval for mean.

Discussion

Color determination is a delicate procedure considered to have the mayor role in clinical success of prosthodontic treatment. Previous studies showed that computer-assisted shade analysis is more accurate and more consistent compared with visual shade matching, while spectrophotometers are the most reliable standard for color matching studies [10, 13]. Dozić et al. [14] found VITA Easyshade spectrophotometer the most reliable instrument in both *in vitro* and *in vivo* circum-

shades. The ΔL (value) is the most significant parameter because human eye perceives changes in value faster than changes in hue. Clinically acceptable color matching shows a ΔL less than 2.0 and a total ΔE of less than 4.0 [16, 17]. For many years the VITA Classical shade guide has been considered the reference, one among all available guides for ceramic systems. Results of some studies showed, on the other hand, that VITA Classical shade guide is too low in chroma and to high in value when compared to extracted tooth samples [18–20]. In our study, the highest values of ΔL parameter among VITA Classical samples were observed in C and the lowest in D group of colors (Figure 2). The best value of ΔE got color C3 and the worst color D3 (Table 2, Figure 3).

The VITA 3D – Master shade guide was developed to overcome the disadvantages of the VITA Classical shade guide. It was found to have broader color range, better color distribution and smaller coverage error when compared to other shade guides [21]. As shown, the best values of ΔE were obtained in the groups 4 and 5 and the worst in group 2 of colors (Figure 8). VITA 3D – Master shade guide demonstrated lower average ΔE when compared to VITA Classical, but both shade guides showed the average value of this parameter higher than clinically acceptable (Table 4). It was expected that based on increased shade range selection of 26 3D shades rather than the familiar 16 VC shades as well as new 3D shade guide design, 3D – Master shade guide would have better results [22].

Problem of shade guides technology production has been present for many years, so there has been an attempt to design them using predefined average ΔE [23]. Analoui et al. [24] found that it is possible to design a shade guide for target average ΔE. As the target average ΔE decreases, the number of shade tabs will increase. Even though human observer can detect under controlled conditions ΔE 1.0, clinically acceptable values are much higher. The American Dental Association (ADA) has set the limit of ΔE 2, as the tolerance for shade guides and ΔE 3.7 as the average color difference between teeth and matched shade tabs in the oral environment [25, 26].

Conclusion

According to our results and similar studies, technology-based color matching has advantages over visual, because it is an objective method that provides quantified and reproducible data without the influence of surroundings and lighting conditions. Shade tabs, produced by the same manufacturer, may vary in the observed parameters within and among several guides witch, once again, proves the lack of precision and nonuniformity of a conventional method. Reasons can be found in a large human influence factor in the production of shade guides. It is therefore necessary to use some of the instrumental methods for shade selection or to change technology of shade guides production.

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