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Evaluation of Color Changes in the Vitapan Classical Shade Guide After Disinfection

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Clinical Relevance

The shade guide must remain consistent in the shade-matching process. If there is a perceptible color change in the shade guide, the result will be inconsistent shade determination and, thus, an unacceptable restoration.

SUMMARY

The purpose of this study was to evaluate how one, two, and three years of simulated treatments affect the colors of Vitapan Classical Shade Guide tabs after being chemically disinfected. Ten shade tabs (one, control; nine, disinfection) were evaluated visually and by chromameter for color changes after disinfection. Results showed that 0.62 ΔE was found after three years of disinfection. The color changes in the shade guide tabs were perceptible or noticeable to the human eye in eight out of 45 shade tabs (17.8%) after two years and in 13 out of 45 shade tabs (28.9%) after three years of treatment. It was concluded that one shade guide should be retained as a control and periodically compared with the shade guide in use to determine when the shade tabs in use should be replaced or discarded.

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INTRODUCTION

The demand for esthetic dental restorations has grown significantly in recent years because of the development of new esthetic materials and increased patient awareness of and interest in improving their dental esthetics; this has also lead to an increased need for accurate shade-matching of the tooth being restored to the adjacent teeth.[1-3] In addition, the effects of advertisements in the popular media promoting the demand for various esthetic dental treatments cannot be ignored.[4] In a survey conducted in New Zealand, most participants reported an increased demand for tooth-whitening (77.8%) and veneers (54.8%) subsequent to the broadcasting of television programs promoting dental esthetics.[4] It has been reported, in a study of patients' perceptions of dental attractiveness, that one of the most important considerations in judging the attractiveness of a finished dental restoration is its shade,[5] which constituted 77% of the smile attractiveness variables for men and 61% for women; other variables, such as natural teeth, display, symmetry, and lip line, constituted the remaining 23% for men and 39% for women.[5] It has also been reported that any difference in the shade of the restoration compared with that of the natural tooth must be perceptible to the patient to be important.[6]

Shade selection is a critical and sometimes demanding step in the shade-matching process for a completed dental restoration. Inconsistencies in shade determination are the result of multiple factors, including the physiological and psychological color vision status of the person selecting the shade.[7,8] Environmental factors such as light conditions also play an important role in shade selection.[8-11]

Although there have been improvements in esthetic dental materials, intraoral shade matching has not changed appreciably since its initial use.[12,13] Visual shade selection based on a shade guide is the most frequently used method of color determination in dental practice.[14] It has been reported that a shade guide can reduce the precision of shade selection to approximately 48%, producing inconsistent results.[9,15]

Shade guides are usually used in dentistry to determine shade and evaluate tooth color in restorative and bleaching treatments. A shade guide is made of a set of shade tabs intended to cover the range of colors present in human teeth.[16]

The Vitapan Classical Shade Guide (Vita Zahnfabrik H. Rauter GmbH & Co KG, Bad Säckingen, Germany) is one of the guides used for shade selection in dentistry. It is important to note, however, that each Vita shade tab has cervical, body, and incisal colors over an opaque backing and is identified and named by the body shade.[17] The Vita shade range is divided into four groups designated by the letters A, B, C, or D. According to the manufacturer, these shades are reddish-brownish, reddish-yellowish, grayish, and reddish-gray, respectively. Shade tabs of a specific letter group have similar hue, and each hue group includes several tabs of increasing chroma and decreasing value, designated in numeric order (eg, A_1, A_2, A_3, $A_{3.5}$, and A_4).[18-20]

The CIE color system (CIELAB) was determined by the Commission Internationale de l'Eclairage (International Commission on Illumination) in 1978.[21] This method of color evaluation is related to human color perception according to three attributes or variables. The CIE system is becoming more widely used in dental research.[19,22] The three attributes are L*, a*, and b*, where L* is the lightness variable (increased L* value means a lighter shade) and a* and b* are chromaticity coordinates, which designate positions on the red/green and yellow/blue axes, respectively (+a = red, –a = green, while +b = yellow, –b = blue).[20,22]

Regardless of the shade guide used, it must remain consistent throughout the shade-matching process. It should not change color with routine clinical use. If a perceptible color change occurs in the shade guide, it could lead to inconsistent shade determination and unacceptable restorations. However, the shade guide must be disinfected after each use, in compliance with Occupational Safety and Health Administration (OSHA) requirements. It has been suggested that this procedure can cause color changes in the shade tabs, but few studies have investigated this. Disinfectants have been shown to alter the colors and surface characteristics of denture resins[23,24] and cast restorations.[25] In 1999, it was reported that there were no perceptible color changes in pressable ceramic and ceramometal porcelain after immersion in various surface disinfectants.[25] In 2007, in a study of how disinfectant use affects color changes of Vitapan Classical Shade Guide tabs, color changes (ΔE) of 2.5 and 1.8 were found after two and three years of simulated treatment, respectively.[26] Those authors also reported that there was a statistically significant increase in the value (L*) and chroma (C*) after two and three years of simulated treatments. This increase was not visually apparent to the investigators after three years of simulated treatments.[26] In 2008, it was reported that all disinfectant solutions used in the study produced perceptible changes in the colors of shade guide tabs (1.0 to 1.6 ΔE) with the immersion technique.[27]

The purpose of this study was to evaluate how one, two, and three years of simulated treatments affect the colors of Vitapan Classical Shade Guide tabs after being chemically disinfected.

MATERIALS AND METHODS

The Vitapan Classical Shade Guide was selected for use in this study because it is among the most widely used shade guides in dentistry. Shade tabs, labeled A_2, $A_{3.5}$, B_1, C_2, and D_3, were selected from 10 shade guides in order to include all basic hues and a wide range of saturations and values. The 10 shade guides were first evaluated visually for any perceptible or noticeable color differences among tabs within the same shade group. Two dentists who were not involved in the research methodology carried out the visual evaluation after passing an Ishihara color-blindness test. The shade tab name was blocked for all tabs used during the visual evaluation. Shade tabs were held over a light-blue card background and under a light-correcting device (Demetron Shade Light, Kerr, Orange, CA, USA) at the same angle

and distance, and any differences were recorded. A time restriction of 5-7 seconds was imposed for each assessment to minimize eye fatigue. A shade guide tab was ranked as visually different from the untreated tab at each evaluation period if the two visual evaluators simultaneously reported differences.

One tab of each shade group was randomly selected not to be disinfected and was used later for visual comparison with the treated tabs at each evaluation period (years 1, 2, and 3) by the same aforementioned visual evaluation method. The remaining nine tabs of each shade group were used for disinfectant application.

A ShadeEye NCC dental chromameter (SHOFU In., Kyoto, Japan) was used for measurements. The contact tip of the measuring device was placed on the body (middle third) of each tab, as recommended by the manufacturer, for all measurements. The plastic contact tip diameter is 5 mm, and the flash portion (actual measurement area) of the measuring device is 2 mm. A repositioning device was used to ensure that the same area was selected for each measurement (Figure 1). A light-blue card was used as background during all measurements. The chromameter was calibrated before measurements for each year, by means of the calibration cap supplied by the manufacturer. The chromameter measures the colors of shade tabs based on the CIE L* a* b* color space system. Total color differences or distances between two colors (ΔE) were calculated according to the following formula[21]:

$$\Delta E_{Lab\ *} = \left[(\Delta L\ *)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\right]^{1/2}$$

Three measurements for each shade tab were recorded and averaged to set the baseline data (year zero) before treatments.

MinutenSpray disinfectant (Arabian Products Factory for Medical Disinfectant, Riyadh, Saudi Arabia) was used in the study because it is the disinfectant used in the clinics of the College of Dentistry of King Saud University, and it complies with the recommendations of the shade guide manufacturer for the disinfection of shade guide tabs. According to the Material Safety Data Sheet, MinutenSpray is a colorless or transparent alcohol-based surface disinfectant with a 70% ethanol and isopropanol mixture. The remaining nine shade tabs of each shade group were sprayed until wet with MinutenSpray disinfectant and allowed to sit for one minute, as recommended by the manufacturer. The shade tabs were then rinsed with water and wiped dry with 2×2 gauze. It was assumed that each individual shade guide would be used twice per day for five days per week for 48 weeks per year. Thus, each shade guide is used and disinfected at least 480 times per year. The process of disinfection was repeated 480 times to simulate one year's usage. Color measurements for one year were recorded following the same procedure as for baseline measurements. The process was repeated to simulate two and three years of use, and color measurements were recorded for two and three years.

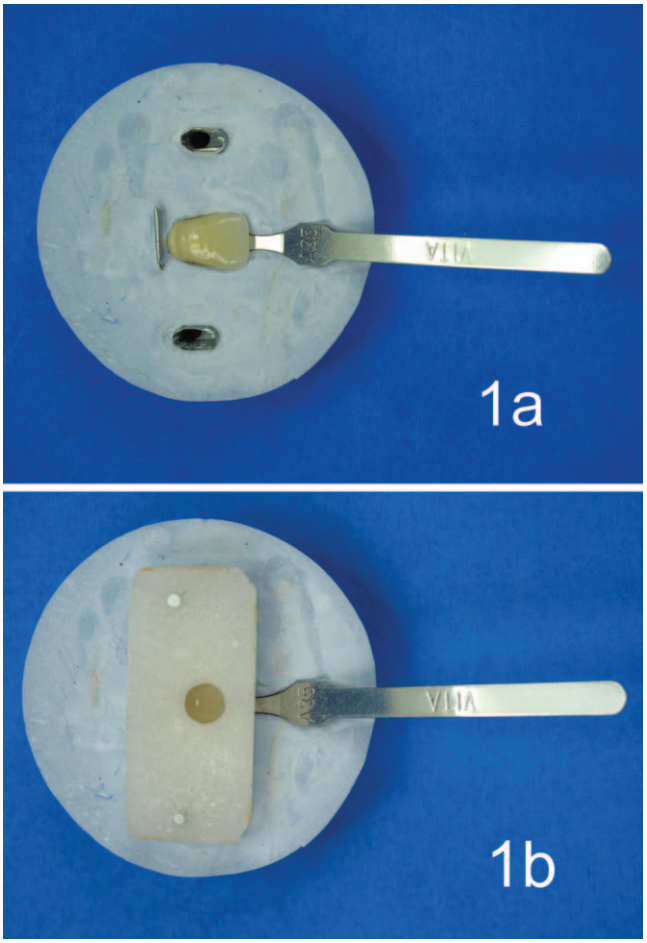

Figure 1. *Repositioning device used to ensure that the same area was selected for each measurement.*

Data were analyzed with SPSS Pc+ version 21.0 statistical software (IBM SPSS Statistics, Armonk, New York, USA). Descriptive statistics (mean, standard deviation, median, and interquartile range) were used to describe the symmetric and skewed variables. One-way analysis of variance (ANOVA) was used to compare the mean values of

Table 1: *Mean (SD) Values of Color Changes (ΔE) and Color Variable Changes (ΔL*, Δa*, and Δb*) of Shade Guides for Each Evaluation Period*

Evaluation Period	ΔL* Mean (SD)[a]	Δa* Mean (SD)[b]	Δb* Mean (SD)[c]	ΔE Mean (SD)[d]
Year 1	0.5215 (0.69)	0.0711 (0.09)	0.1585 (0.13)	0.6887 (0.57)
Year 2	0.4882 (0.67)	0.0859 (0.11)	0.1748 (0.16)	0.6129 (0.38)
Year 3	0.4778 (0.63)	–0.0348 (0.09)	0.1889 (0.13)	0.6171 (0.45)

[a] p=*0.94;*
[b] p<*0.0001;*
[c] p=*0.75 (Kruskal-Wallis test);*
[d] p>*0.05 (one-way ANOVA, F-test).*

symmetrical quantitative outcome variables in relation to the categorical study variables. The Kruskal-Wallis test was used to compare the mean ranks of skewed outcome variables in relation to the categorical study variables. Kappa statistics were computed to observe agreement between the categorical responses of the two examiners. A p-value of ≤ 0.05 was considered statistically significant.

RESULTS

The mean changes in color (ΔE) and color variables (ΔL*, Δa*, and Δb*) of shade guides for each evaluation period relative to baseline are shown in Table 1. Statistical analysis was done to test for significant association between changes in color and the evaluation period (one, two, and three years). Statistically significant differences were found only in the mean rank values of Δa*, in which the mean rank values of Δa* at year 3 were significantly lower than the values at year 1 and year 2, but no statistically significant differences were found between year 1 and year 2 values at $p<0.0001$ (Kruskal-Wallis test). Furthermore, there was no statistically significant difference in the mean rank values of other color variables (ΔL*and Δb*) at $p=0.94$ and $p=0.75$, respectively (Kruskal-Wallis test) and mean values of color change (ΔE) at $p>0.05$ (one-way ANOVA, F-test) among the three periods of evaluation.

It is important to examine the direction of the linear changes in the color variables (lightness and chromacity coordinates) for each evaluation period, because the overall changes in color (ΔE) are directionless. Table 2 shows the mean color components (L*, a*, and b*) for each evaluation period. Testing for significant association between changes in the color components (L*, a*, and b*) for each evaluation period in relation to baseline showed no statistically significant difference in the mean values of L* and b* at $p=0.81$ and $p=0.99$, respectively (one-way ANOVA, F-test) and in the mean rank values of a* at $p=0.76$ (Kruskal-Wallis test).

Table 3 shows the mean value of color changes (ΔE) in shade guide tab groups for each evaluation period. It shows that tab group B_1 had the lowest mean color changes at all evaluation periods, but the differences of ΔE_1, ΔE_2, and ΔE_3 were not statistically significant at $p=0.54$, $p=0.40$, and $p=0.86$, respectively (Kruskal-Wallis test).

When significant associations between changes in L*, a*, and b* and ΔL*, Δa*, and Δb* were examined for the three evaluation periods for each shade guide tab group (A_2, $A_{3.5}$, B_1, C_2, and D_3), only the mean rank values of Δa* of groups $A_{3.5}$, B_1, and D_3 were statistically significantly lower at year 3 compared with those of year 1 and year 2 at $p=0.47$, $p=0.2$, and $p=0.005$, respectively (Kruskal-Wallis test). There was no significant association between changes in other color variables at the three evaluation periods for each shade guide tab group.

It was decided in this study that a shade guide tab would be ranked as visually different from the untreated tab at each evaluation period if the two visual evaluators simultaneously reported a difference. Table 4 shows the examiners' visual evaluations for color differences when comparing treated shade guide tabs with untreated shade

Table 2: *Mean (SD) Values of Color Variables of Shade Guides (Lightness and Chromaticity Coordinates) for Each Evaluation Period*

Evaluation Period	L* Mean (SD)[a]	a* Mean (SD)[b]	b* Mean (SD)[c]
Baseline	69.1333 (3.0)	0.0511 (0.94)	13.1237 (3.12)
Year 1	69.6548 (2.9)	0.1222 (0.93)	13.2822 (3.10)
Year 2	69.6215 (2.9)	0.1370 (0.91)	13.2985 (3.10)
Year 3	69.6111 (2.9)	0.0163 (0.92)	13.3126 (3.10)

[a] p=*0.81 (one-way ANOVA, F-test);*
[b] p=*0.76 (Kruskal-Wallis test);*
[c] p=*0.99 (one-way ANOVA, F-test).*

Table 3: *Mean (SD) Values of Color Changes (ΔE) Among Shade Guide Tab Groups for Each Evaluation Period*

Shade Guide Tab Groups	ΔE_1 Mean (SD)[a]	ΔE_2 Mean (SD)[b]	ΔE_3 Mean (SD)[c]
A2	0.70 (0.43)	0.68 (0.42)	0.66 (0.37)
A3.5	0.86 (0.89)	0.72 (0.54)	0.65 (0.67)
B1	0.49 (0.33)	0.43 (0.26)	0.49 (0.32)
C2	0.71 (0.41)	0.66 (0.30)	0.62 (0.36)
D3	0.68 (0.57)	0.58 (0.31)	0.66 (0.50)

[a] p=*0.54;*
[b] p=*0.40;*
[c] p=*0.86 (Kruskal-Wallis test).*

guide tabs at all evaluation periods. It shows no visually perceptible color differences detected at baseline and year 1. The percentage of shade guide tabs ranked as different increased noticeably for years 2 and 3 (17.8% and 28.9%, respectively). The examiners' reliability for color difference comparison between treated and untreated shade guide tabs at all evaluation periods was analyzed (Table 5). It was found that the two examiners were consistent in their observations at the baseline and year 1 evaluation periods. There was a statistically significant agreement between the two examiners at years 2 and 3, when they compared treated shade guide tabs with untreated shade guide tabs for color differences. The overall agreement between the first examiner and second examiner for all four time periods was statistically significant (kappa= 0.45; $p<0.0001$). Table 6 shows the numbers and percentages of shade guide tabs visually evaluated by the two examiners as "different" among tab groups. This table shows that no visually perceptible color differences were detected in shade guide tab B_1 at all evaluation periods, while shade guide tab $A_{3.5}$ had higher

Table 4: *Examiners' Visual Evaluation of Color Differences, Comparing Treated Shade Guide Tabs With Control Shade Guide Tabs at All Evaluation Periods*

Time Period	No Difference Observed		Difference Observed[a]	
	Total	%	Total	%
Baseline	45	100.0	0	0
Year 1	45	100.0	0	0
Year 2	37	82.2	8	17.8
Year 3	32	71.1	13	28.9

[a] *The shade guide tab was ranked differently if both examiners detected differences simultaneously.*

Table 5: *Examiners' Reliability for Color Difference Comparisons Between Treated and Untreated Shade Guide Tabs at All Evaluation Periods*

Time Period	Examiner 1 vs Examiner2	
	Kappa Value	*p*-Value
Baseline[a]	–	–
Year 1[a]	–	–
Year 2	0.42	0.005
Year 3	0.54	< 0.0001

[a] *The two examiners were consistent in their observations.*

"different" scores (44.4% and 55.6% at years 2 and 3, respectively).

DISCUSSION

Surface disinfection is the most popular method used in dental clinics to disinfect and clean shade guides after use. This technique complies with regulations established by OSHA in 2005, which ranked shade guides as semi-critical items that can be disinfected with an intermediate-level disinfectant and approved by the Environmental Protection Agency. This technique is more convenient, and more aggressive methods can destroy some portions of shade guides.

Several studies have investigated how much of the color change detected by a chromameter or colorimeter is perceptible to the human eye. It was reported that one unit of ΔE was detectable by 50% of human observers in controlled conditions,[28] and color differences between 2.0 and 3.7 units were visually detectable under clinical conditions.[29] It was also reported that ΔE greater than 2.75 units is clinically unacceptable,[30,31] whereas other investigators have reported that ΔE greater than 3.0[32] or 3.3[33] is clinically unacceptable. All the afore-

Table 6: *Numbers and Percentages of Shade Guide Tabs Evaluated Visually by the Two Examiners as "Different" Among Shade Guide Tab Groups* [a]

Shade Guide Tabs	Baseline No (%) (n=9)	Year 1 No (%) (n=9)	Year 2 No (%) (n=9)	Year 3 No (%) (n=9)
A2	0	0	0	1 (11.1)
A3.5	0	0	4 (44.4)	5 (55.6)
B1	0	0	0	0
C2	0	0	2 (22.2)	3 (33.3)
D3	0	0	2 (22.2)	4 (44.4)

[a] *The shade guide tab was ranked differently if both examiners detected differences simultaneously.*

mentioned researchers were discussing two different points: visual perceptibility and the clinical acceptability of color difference. Douglas and Brewer[34] stated that the visual thresholds of perceptibility (mean 0.4 ΔE units) were significantly lower than the visual thresholds of acceptability (mean 1.7 ΔE units) for metal ceramic crowns differing in their chroma. They also reported that the visual thresholds of color acceptability were significantly lower for metal ceramic crowns differing in their red chroma or, in other words, differing in the a* coordinate (mean 1.1 ΔE units) compared with those of metal ceramic crowns differing in their yellow chroma, or b* coordinate (mean 2.1 ΔE units).[34] In this study and after 1440 cycles (1440 minutes) of disinfection, which simulated three years of clinical use, the mean ΔE for shade guide tabs was 0.62 units, which is almost one-third of that found by Pohjola and others,[26] who also used a spray technique to disinfect shade guide tabs. They found a statistically significant chromametric color change (1.8 ΔE units) after three years of simulated treatment, but they reported that this color change was not visually observable.[26] In the current study, the color change was observable in 17.8% of the sample (eight out of 45 shade tabs) after two years of treatment and in 28.9% of the sample (13 out of 45 shade tabs) after three years of treatment. The mean value of 0.62 ΔE units found in this study lies above the visual thresholds of perceptibility reported by Douglas and Brewer[34] (0.4 ΔE units). It is not known if this perceptible color difference in shade guide tabs will directly result in clinically acceptable restorations, as it is below the reported visual thresholds for acceptability (2.75 ΔE units), but it can be hypothesized that a perceptible color difference in shade guide can lead to incorrect shade selection, resulting in unacceptable restorations.

Another interesting point is that most of the chromametric color change took place after one year of treatment, after which no statistically significant difference occurred, but the color difference was visually perceptible after two and three years of treatment. It was found in this study that only the a* coordinate (red and green chroma) registered a significant change at year 3, while the L* and b* coordinates were consistent over years 1, 2, and 3 (Table 1). This concurs with the finding of Douglas and Brewer,[34] who reported that visual perception is more sensitive to objects differing in their red chroma. It is important to note that although the mean values are given in Tables 1, 2, and 3, the median values and the appropriate nonparametric statistical tests were used for statistical analysis; mean values are given for simplification of presentation.

When color change over time was examined relative to shade guide tab group, B_1 had the lowest mean chromametric color changes at all evaluation periods (Table 3), despite the fact that the differences in ΔE_1, ΔE_2, and ΔE_3 were not statistically significant, in agreement with the visual evaluation performed in this study. No visually perceptible color differences were detected in shade guide tab B_1 at all evaluation periods. It is also interesting to note that the visual detection of color change increased as chroma increased and value decreased, which can be explained by the shade tabs ranked as different (55.6% of $A_{3.5}$, 33.3% of C_2; and 44.4% of D_3). The $A_{3.5}$ tab has very high chroma and very low value, while C_2 is high in chroma and low in value. The D tab, as a group, has a red characteristic; meanwhile, the D_3 tab has very low value and high chroma. This could also be explained as was reported by Yab and others,[32] who reported that the difference in color-matching between visual evaluation and computerized colorimetry is shade dependent. They found that the differences occurred in very light or very dark shades. Generally, one shade guide should be retained as a control for comparison, and it should be periodically compared with the shade guide in use to determine when the guide in use should be replaced.

It is important to note that the overall agreement between the first and second examiners for all four time periods was nearly 50% for all observations, indicating that the two examiners did not agree in almost half of their observations, which supports the contention that color perception varies both between persons and within persons over time.[35-37]

Another concern about shade guide tabs is the fabrication of the tab itself. Some shade guide tabs are made of porcelain and prepared by a layering technique, as is the case of Vitapan Classical Shade Guide tabs; other guides use the technique of adding surface characteristics and staining, then glazing. Commercial shade guides are sometimes manufactured from plastics. The manufacturing technique used to fabricate shade guide tabs may affect any shade change caused by surface disinfection.[26] It is worth noting that most of the changes in overall color (ΔE) occurred after one year of treatment, whereas the changes after two and three years were

not statistically significant. Alamri[27] reported that immersion time has the most significant effect on color change and thus recommended a periodic check for color changes of shade guide tabs. In the present study, 1440 cycles (1440 minutes) of disinfection equaled a total of 24 hours, where there was direct contact between the disinfectant and the shade guide tabs, as they were sprayed wet. Recommendations from the American Dental Association Council on Scientific Affairs for the disinfection of prosthetic materials include spray or immersion with an appropriate material. The incorrect application of the disinfectant may affect the physical and/or mechanical properties of the material undergoing the disinfection process.[38,39] Agents containing organic solvent, such as alcohol, should be generally avoided, as they can cause degradation of some materials, such as plastics or resins.[24] The MinutenSpray disinfectant, as reported in its material safety and data sheet, is a highly alcohol-based disinfectant (a 70% ethanol and isopropanol mixture), which could account for the color changes after three years of simulated treatment. Pohjola and others[26] did not report whether the CaviCide disinfectant used in their study had low or high alcohol content.

Finally, any color change that occurred could be due to the effect of the chemical disinfectant or the wiping action during the disinfection process. In addition, surface residues from the disinfectant's components may cause some color change.

CONCLUSION

Within the limitations of this study, the following conclusions were drawn:

1. The mean chromametric color change (ΔE) found after three years of disinfection was 0.62 units. There was no statistically significant difference with evaluation periods.
2. The color changes in shade guide tabs were perceptible or noticeable to the human eye in eight out of 45 shade tabs (17.8%) after two years and in 13 out of 45 shade tabs (28.9%) after three years of treatment.
3. The color changes were perceptible or noticeable to the human eye in shade guide tabs with high chroma and low value ($A_{3.5}$, C_2, and D_3).
4. Generally, one shade guide should be retained as a control and periodically compared with the shade guide in use in order to determine when the shade tabs in use should be replaced or discarded.

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Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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