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CLINICAL RESEARCH

Influence of a gray background and the illuminant on tooth shade selection

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ABSTRACT

Statement of problem. Visual shade selection in dentistry may be influenced by factors that include the background color and the illuminant.

Purpose. The purpose of this clinical study was to evaluate the influence of using a gray background and a light-correcting device on visual shade selection.

Material and methods. Two experienced clinicians assessed the incisor color of 30 volunteers using the VITA 3D-MASTER shade guide. Visual analyses were carried out using or not (control) a gray background, with and without (control) a light-correcting device (Smile Lite). Furthermore, the use of a polarizing filter was evaluated. Data from a clinical spectrophotometer were defined as the standard instrumental analysis. The agreement and the similarity (based on the whitening indexes of tabs) were evaluated between instrumental and visual analyses. Statistical testing was conducted through ordinal logistic regression and repeated-measures ANOVA. The Shapiro-Wilk test was used to confirm the data distribution, and homogeneity of variance was assessed with the Levene test (α=.05)

Results. The use of Smile Lite resulted in lighter tabs than indicated by the instrumental analysis, and the opposite was observed in its absence. The polarizing filter did not affect the results (P>.05). For similarity, the illuminant improved the results (P<.001). The gray background reduced the differences between visual and instrumental analysis only in the absence of the Smile Lite (P<.001).

Conclusions. The color similarity between visual and instrumental analysis improved with the use of a light-correcting device with or without a polarization filter. A gray background was useful only without the light-correcting device. (J Prosthet Dent xxxx;xxx:xxx-xxx)

Adequate tooth shade selection is essential for obtaining satisfactory esthetic restorations.[1] Shade selection can be performed by either visual or instrumental methods with devices that include clinical spectrophotometers or intraoral digital scanners.[1–10] During visual tooth shade selection, the dentist may or may not use auxiliary instruments such as illuminants or specific backgrounds.

Different factors influence shade selection, including the surrounding area, the background, and the illuminant.[11–19] In practice, the background is most often represented by the darkness of the oral cavity.[17,20] The background color used

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Clinical Implications

Using a light-correcting device improved the reliability of visual shade selection with no beneficial effect by adding a polarizing filter. In addition, the use of a gray background can be useful only in the absence of a light-correcting device.

simultaneously with visual color determination has been reported to affect the results.[17] White and black backgrounds produced the best results, with no difference between them and neutral gray. Red backgrounds were less effective. Another study found that pink backgrounds led to higher levels of agreement than blue backgrounds.[18] Indeed, a gray, pink, or blue paper background may sensitize the eyes to the yellowness of the teeth and eliminates repeated comparisons.[18] In addition, the illuminant is an important factor for visual selection. In the past, natural daylight between 10 a.m. and 2 p.m. with a temperature of 6500 K was recommended.[21,22] More recently, other light sources with temperatures between 5000 K and 7500 K have been recommended to correct possible external interferences.[5,12,23] Devices such as the Smile Lite (Smile Line SA) delineate a rectangular window around the area of interest to provide natural, neutral clarity and assist in color selection using the visual method.[5,24]

Moreover, a polarizing filter together with the illuminant has been reported to help tooth shade selection by transforming a diffuse reflection into a specular one.[24] This change has been reported to facilitate visualizing the tooth color by optically eliminating the surface texture of the enamel.[24–26] The present study aimed to evaluate whether these auxiliary devices, including light and background, on visual shade selection. The research hypotheses tested were that using a light-correcting device and an 18% gray background would increase the agreement and similarity in shade selection compared with a standard instrumental method and that a polarizing filter would positively affect color selection with the visual method.

MATERIAL AND METHODS

The study protocol was approved by the local ethics committee (4 586 588). Two experienced female clinicians (E.N.A.–22 years old and W.L.F.–29 years old) with superior shade selection competency, as assessed by the International Organization for Standardization (ISO) TR 28642:2011 standard, participated in the study. Each clinician had been screened for color deficiencies using the Ishihara plates (2006). The study sample included 30 volunteers aged between 18 and 30 years with a sound right maxillary central incisor without any severe enamel anomaly or pigmentation, as in a previous study.[5]

Visual shade selection was carried out separately once by each clinician at the same time of the day and in the same dental office with walls of neutral colors and a window with natural lighting and under a light source with a color temperature of 5500 K.[2] Each patient was seated on the dental chair, and each examiner performed a 1-time shade selection. Visual shade selection was carried out separately by each examiner, focusing on the middle third of the maxillary right central incisor of each participant. A shade guide with 29 tabs (VITA Toothguide 3D-MASTER; VITA Zahnfabrik) was used for this purpose. The visual analyses were performed with and without a gray background (Flexipalette Color Match FP 3004; Smile Line) behind the anterior teeth.

Six experimental conditions were determined for the visual analyses under the following illumination conditions: no light-correcting device (control), with the Smile Lite MDP (Smile Line SA) according to the manufacturer instructions, maintaining an average distance of 15 cm from the tooth, and the Smile Lite MDP together with a polarizing filter (Smile Line SA).

Instrumental shade evaluation was performed by a previously calibrated examiner (W.F.L) using a spectrophotometer (VITA Easyshade Advance 4.0; VITA Zahnfabrik). The clinical spectrophotometer was received preset with the illuminant D65 and a 2-degree observer angle and with a Ø6-mm reading area and had been reported to have a 93% accuracy rate high repeatability.[10] Three measurements were acquired from the right maxillary central incisor of each participant using the EasyShade device, and the average was established as the reference value. The equipment was positioned and maintained at the central point of the tooth throughout the measurements.

The agreements on lightness levels and tabs defined by the Easyshade (instrumental) and selected by the 2 evaluators (visual) were assessed using the Cohen kappa statistic. For lightness levels, the number corresponding to the level (0 to 5) selected by the evaluator was subtracted from those corresponding to the shade indicated by the instrumental analysis. The differences in lightness level were analyzed using an ordinal logistic regression, and the predictors were “illuminant,” “background,” and “evaluator.”

The tabs selected by instrumental and visual analyses were also submitted to the Cohen kappa statistic to assess the agreements. Afterward, the tabs were converted to numeric values corresponding to their whitening index for dentistry (WID). The WID values were calculated based on CIELab data measured for all tabs of VITA 3D Master in a previous study using the formula[27–29]:

$$WID = 0.551 \times L^* - 2.324 \times a^* - 1.1 \times b^*.$$

L* assessed the degree of brightness and can range from 0 (black) to 100 (white). The a* chromaticity parameter can vary from negative values (green) to positive values (red), while the b* chromaticity parameter can range from negative values (blue) to positive values (yellow).

The WID differences from the instrumental data were calculated for each corresponding visual analysis. Then, data were analyzed by repeated-measures ANOVA to assess the factors "illuminant," "background," and "evaluator." The normal distribution of the data was assessed using the Shapiro-Wilk test, and the homogeneity of variance was evaluated using the Levene test (α=.05 for all analyses).

RESULTS

Results for agreements on lightness levels are shown in Table 1. In general, the highest percentages of agreements were observed in the absence of the illuminant, but similar overall kappa coefficients were observed under all experimental conditions (illuminant versus background). The agreements were higher between the evaluators when the lightness levels selected by them were compared with those measured with the instrumental analysis ($P<.05$).

Figure 1 shows the differences in the lightness levels measured by the evaluators and those indicated by the instrumental analysis. The results of the ordinal logistic regression are shown in Table 2. The evaluator and the presence of the gray background did not affect the differences in the lightness level. However, using the illuminant with or without a filter tended to reduce the differences.

The results for agreements on the tabs selected are shown in Table 3. The overall highest values of kappa coefficients and percentages were observed in the visual analyses performed without an illuminant. The agreements between the evaluators were higher than those comparing visual and instrumental analyses.

Figure 2 shows the ΔWID values according to the illuminant and background used in the visual analyses. Repeated-measures ANOVA showed that only the independent variables "background" ($P<.001$) and "illuminant" ($P<.001$) affected results. No difference was

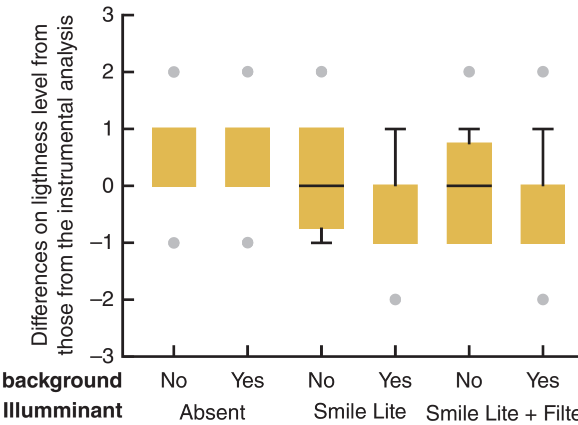

Figure 1. Box plot displaying data variability in lightness levels as assessed visually compared with instrumental analysis.

Table 2. Results of ordinal logistic regression estimating difference in lightness level of tab selected by evaluators/instrumental analysis

Predictor		Estimate	SE	*P*
Illuminant				
	Absent (ref.)	1.000		
	Smile lite	-0.962	0.246	<.001
	Smile lite + Filter	-1.107	0.249	<.001
Gray Background				
	No (ref.)	1.000		
	Yes	-0.333	0.200	.095
Evaluator				
	A (ref.)	1.000		
	B	-0.089	0.199	.684

SE, standard error.

Table 1. Percentages of agreements (bold); kappa coefficients assessing interrater reliability for lightness level selected

Illuminant Versus Background	Evaluations	Instrumental	Visual - A	Visual - B	Overall
Control	Instrumental	-	53.3%	60.0%	.300
No background	Visual - A	.184	-	73.3%	46.7%
	Visual - B	.317	.458	-	
Control	Instrumental	-	46.7%	60.0%	.334
Gray background	Visual - A	.089	-	80.0%	46.7%
	Visual - B	.319	.634	-	
Smile lite	Instrumental	-	43.3%	46.7%	.338
No background	Visual - A	.108	-	66.7%	36.7%
	Visual - B	.159	.585	-	
Smile lite	Instrumental	-	46.7%	50.0%	.359
Gray background	Visual - A	.220	-	73.3%	36.7%
	Visual - B	.255	.618	-	
Smile lite + Filter	Instrumental	-	40.0%	53.3%	.333
No background	Visual - A	.109	-	73.3%	33.3%
	Visual - B	.281	.617	-	
Smile lite + Filter	Instrumental	-	40.0%	46.7%	.332
Gray background	Visual - A	.165	-	76.7%	33.3%
	Visual - B	.231	.659	-	

Table 3. Percentages of agreements (bold); kappa coefficients assessing interrater reliability for tabs selected

Illuminant Versus Background	Evaluations	Instrumental	Visual - A	Visual - B	Overall
Control	Instrumental	-	**30.0%**	**33.3%**	.266
No background	Visual - A	.172	-	**53.3%**	**26.7%**
	Visual - B	.231	.435	-	
Control	Instrumental	-	**30.0%**	**30.0%**	.240
Gray background	Visual - A	.138	-	**50.0%**	**23.3%**
	Visual - B	.193	.422	-	
Smile lite	Instrumental	-	**23.3%**	**13.3%**	.192
No background	Visual - A	.055	-	**66.7%**	**10.0%**
	Visual - B	.022	.585	-	
Smile lite	Instrumental	-	**23.3%**	**20.0%**	.168
Gray background	Visual - A	.089	-	**53.3%**	**10.0%**
	Visual - B	.044	.414	-	
Smile lite + Filter	Instrumental	-	**13.3%**	**23.3%**	.096
No background	Visual - A	.024	-	**40.0%**	**0.0%**
	Visual - B	.099	.264	-	
Smile lite + Filter	Instrumental	-	**16.7%**	**20.0%**	.170
Gray background	Visual - A	.063	-	**56.7%**	**10.0%**
	Visual - B	.088	.451	-	

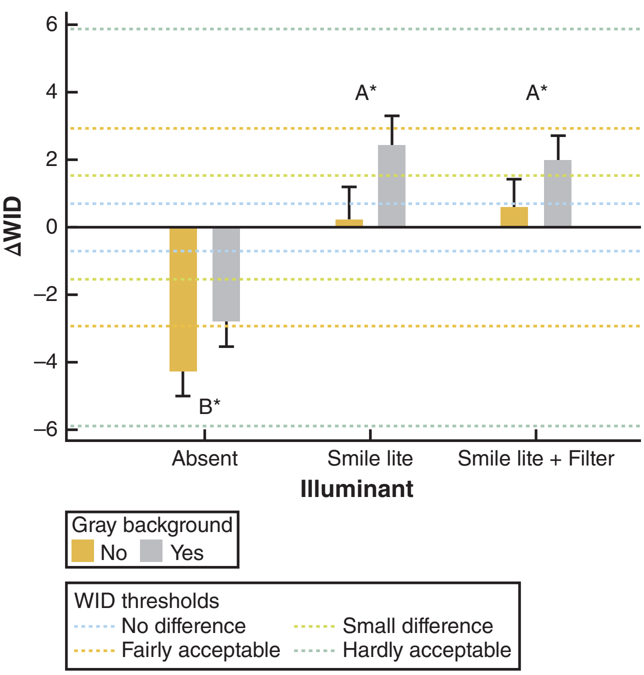

Figure 2. Means (standard errors) for ΔWID by illuminant/background used in visual analyses. WID thresholds calculated by previous study.[27] WID, Whitening index for dentistry.

observed between the "evaluators" (P=.214). All interactions were statistically insignificant (P>.05). In the absence of the illuminant, the visual analysis resulted in darker tabs (lower WID values) than those indicated by the instrumental analysis. The opposite was observed in the presence of the illuminant, and the additional use of a polarized filter did not affect the results. Without the illuminant, using a gray background reduced the differences between visual and instrumental analysis (P<.05). However, the gray background increased the discrepancy when the illuminant was used in the visual analyses (P<.05).

DISCUSSION

Precise and accurate shade selection reduces the possibility of restoration replacement for esthetic reasons and can reduce treatment costs. Some studies comparing the subjective and objective methods have shown better results for spectrophotometers than for visual shade selection[1–5]; associating both methods has also been recommended.[5,8] However, because of the equipment cost for instrumental shade selection, the visual method is most often used. Thus, the present study aimed to analyze the effectiveness of using some tools to support the visual tooth color analysis clinically, with the assessment focused in the middle third of the right maxillary central incisor. The research hypothesis that the light-correcting device combined with a gray background would increase the agreement and similarity in shade selection was rejected. However, the light-correcting device improved the similarity compared with a standard instrumental method. In addition, the gray background improved the similarity only in the absence of a light-correcting device. Moreover, the hypotheses of using the polarizing filter were also rejected, as it did not positively affect color selection by the visual method.

Education and previous training for shade selection has been reported to positively affect the correct use of the shade guide and to produce more predictable results.[13] In addition, biological sex (male/female) is a controversial factor influencing color shade selection.[15,16] Two experienced women with superior shade selection competency were responsible for the evaluations. However, a moderate agreement between the selected shade was observed (kappa coefficient=.442). Nevertheless, similar behavior in the agreements of each evaluator and the instrumental analyses were observed, as shown in Table 4. Thus, as the 2 clinicians in the present study were experienced women with superior shade selection competency, no difference was observed between the evaluators.

Table 4. Interrater repeatability

Method	Cohen kappa for 2 Raters (Weights: Unweighted)
Subjects	30
Raters	2
Agreement %	50.0
Kappa	0.422
z	6.47
P	<.001

Data obtained from visual analyses have been evaluated by scoring the tabs from shade guides according to their lightness.[27,29] Despite allowing some color (lightness) differences to be determined numerically, this approach assumes a linear transition among sequential tabs, that the difference between 2 consecutive tabs is always 1 shade unit. Nevertheless, the perceptibility of color differences between 2 consecutive tabs may be negligible or clinically acceptable. Therefore, drawing conclusions based only on differences in shade guide units (agreement) can yield misinterpretations. In the present study, a WID value was ascribed to each tab based on its corresponding CIELab coordinates. This methodological approach was anticipated to facilitate a more equitable analysis. Utilizing WID-derived data enables the correlation of these values with thresholds previously established for perceptibility and acceptability (similarity).[28] The authors are unaware of a previous study that used this methodology, and its validation stands as a focal point for future investigations specifically tailored for this purpose.

Shade selection should be performed under ideal daylight conditions. However, these conditions are difficult to achieve.[12] Previous studies have shown that using a light-correcting device improved visual shade selection performance.[18–22] Controversially, the present findings showed lower agreement levels using the light-correcting device. These results might be because the visual shade selection of the present study had been conducted in an office under a standardized natural light during the morning. In addition, the evaluators were well-trained and experienced clinicians in color science, crucial factors for visual color selection.[11,12] Thus, the present study protocol should be further performed with more variations in light conditions.

The low agreement levels observed might be because of the optical properties of enamel and dentin being different from those of the shade guide.[12] In addition, natural teeth do not exhibit color homogeneity.[9,30] Consequently, when light reaches the tooth surface, phenomena such as light transmission, reflection, dispersion, and absorption may be observed.[25] The present study considered the instrumental readings only for the middle third. Moreover, as previously mentioned, conclusions cannot be drawn based only on the agreement levels. The WID results showed that the color mismatch between the tabs could be considered clinically acceptable, and selecting different tabs cannot be a clinical problem.[28]

The present findings showed that the light-correcting device improved the similarity (WID values of tabs) in color selection between visual and instrumental analysis. Hence, using a light-correcting device seems useful to enhance the reliability of visual shade selection. Another interesting finding was that the further use of a polarization filter did not affect the visual color selection. These findings were in accordance with those of previous studies, and, despite a polarization filter reducing the diffuse reflection, it seems not to be useful in improving visual shade selection.[12,21,24,25]

The color of the background and surrounding area has been reported to influence color selection.[17,18] Usually, the shade selection is performed with the oral cavity as the background. However, using the opposing dental arch, the lower lip, or a dental dam as a background has been suggested to improve the contrast.[17] Likewise, a standardized background such as the gray 18% can reduce any interference from surrounding colors on shade selection. In the present study, the gray background did not affect agreement levels, but the color similarity between visual and instrumental tabs selection improved in the absence of the light-correcting device. Darker tabs were more likely to be selected without the Smile Lite, and it is possible to hypothesize that using a gray background would reduce some effect of the oral cavity darkness on tooth color. A similar effect (increased lightness) was observed using the gray background with the light-correcting device. However, since the color was slightly lighter than that observed for the instrumental analysis, increasing the lightness tended also to enhance the color discrepancy.

The present study assessed the possible effects of auxiliary tools on visual shade analysis in dentistry. However, the shade guide tabs were not concealed during the evaluations, which could have introduced bias into the study. This is a limitation of the study, but it is important to note that most studies on tooth color evaluation have not blinded the shade guides. Future studies are needed to investigate the impact of blinding procedures on the precision of shade determination. Another limitation of the present study was that the tabs indicated by the clinical spectrophotometer were considered as the true tooth shade, but its accuracy has been reported to be lower than 80%.[31,32] The validity and repeatability of the Vita Easy Shade has been shown to be lacking compared with the spectroradiometer (PR 650).[32] However, Vita Easy Shade is commonly used clinically and the spectroradiometer (PR 650) is a referent laboratory color measuring instrument.

Easyshade measures the color coordinates and determines the tab based on the similarity between the coordinates measured and those defined as the default for each tab. Therefore, variations between the natural tooth color and the tab indicated are expected. In addition, visual color perception tends to be more clinically relevant than an instrumental analysis.[4,5] Another limitation of the present study was that only the color of the maxillary right central incisor was assessed; different results could be observed for other teeth.

CONCLUSIONS

Based on the findings of this clinical study, the following conclusions were drawn:

1. The use of a light-correcting device did not improve the agreement between visual and instrumental color analysis regarding the lightness levels and tabs.
2. Using the Smile Lite improved the color similarity calculated based on the whiteness of the tabs selected visually and instrumentally.
3. A gray background improved the color similarity between visual and instrumental shade selection only in the absence of the light-correcting device.
4. Using a polarization filter together with the Smile Lite did not affect the results.

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