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INFLUENCE OF LIGHT SOURCE AND CLINICAL EXPERIENCE ON SHADE MATCHING

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Abstract

Introduction. *Shade is one of the most important attributes when evaluating the success of a restoration. Several factors can influence the visual shade matching process, and therefore the outcome of the final restoration.*

Objectives. *1. to assess the importance of clinical experience on shade matching accuracy; 2. to assess the influence of two standard light sources on the ability to match shade tabs; 3. to identify the area in a VITA Classical shade guide where matching errors are most likely to appear.*

Methods. *28 subjects were enrolled in the study: 14 undergraduate dental students and 14 dentists. All subjects had passed the Ishihara blindness test previously. Participants had to match 16 pairs of tabs from two shade guides, under two versions of illuminants of a viewing booth: D50 and D65, on a neutral background, 0°/45° viewing geometry. Paired and independent samples t tests were used to investigate the significant differences between the groups.*

Results. *The clinical experience had no significant influence on shade matching ($p>0.05$). According to participants' color discrimination competency, three groups were formed: superior competency, average competency and poor competency. The light source did not significantly influence the matching scores of subjects with superior or average color discrimination competency ($p>0.05$). However, in the group of subjects with poor competency the light source significantly influenced the results ($p<0.05$). Moreover, for the group of students the light source also influenced shade matching results ($p<0.05$). The most frequently mismatched tabs were C2 with D4 (11 subjects – 39.28%), B3 with B4 (11 subjects – 39.28%), B3 with A3.5 (8 subjects – 28.57%).*

Conclusions. *The light source was proved to influence the shade matching results for subjects with a low level of clinical experience and for subjects with poor competency in color discrimination.*

Keywords: shade matching, light source, clinical experience, shade guide.

Introduction

Recreating the natural appearance of missing tooth structures using restorative materials requires perfect control of shape, surface texture, translucency and color of the restoration [1]. Although each of these factors has a major importance in the appearance of a restoration, color is one of the first attributes noticed by the patients.

Tooth shade matching can be performed visually using dental shade guides or instrumentally using different intra-oral or extra-oral color measuring devices. Visual shade matching is a comparison between a sample (tooth) and multiple standards (shade guide tabs) [2]. Visual assessment is a subjective method and therefore it is influenced by many factors related to the observer (age,

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gender, fatigue, color vision deficiencies, ability of color discrimination, experience in color matching) or non-related to the observer (light source, background, sample type and surface) [3]. The human eye-brain complex can detect very small differences in color between two objects. Once a perceptible difference is detected, there will be a considerable variation in opinion among different observers [4]. The importance of the clinical experience of the observer involved in the process is questionable. As a result, in order to standardize color measurements in dentistry the ISO Committee elaborated a technical report which recommends the classification of observers in studies on acceptability or perceptibility in dentistry by their color discrimination competency [5].

Another factor that influences color perception is the nature of light generated by a light source, which can vary in type, intensity and angle of incidence [6]. Shade matching tests have been primarily conducted with daylight illumination generated by a standard illuminant (D65) with a spectrum corresponding to a typical mixture of direct sunlight and scattered skylight with 6504 K color temperature (natural, bluish white, daylight) [7]. Another standard illuminant for dentistry (D55) was defined as Washington, DC, June, noon to 1 PM, with a slight overcast, a color temperature of 5500 K, and a color rendering index (CRI) 90 [8]. Lighting in the dental office is a mixture of daylight and light generated by overhead lamps and dental chair lamp. Since these lighting conditions are extremely variable, light correcting sources have been recommended to be used during shade selection and reproduction in dentistry [3,9,10].

A limit of the visual shade matching is generated by the shade guide that is used in the process. Previous studies concluded that commercially available shade guides do not provide sufficient spectral coverage of colors present in teeth. Moreover, shade tab colors may not be distributed uniformly throughout the color space of natural teeth, resulting in close matches for some shades and gross mismatches for others [11].

The objectives of the present study were: 1. to assess the importance of clinical experience on shade matching accuracy; 2. to assess the influence of two standard light sources on the matching ability of shade tabs; 3. to identify the area in a VITA Classical shade guide where matching errors are most likely to appear.

The null hypotheses tested: 1. Clinical experience does not influence shade matching; 2. Light source does not influence shade matching.

Materials and methods

Upon the approval of the Ethics in Research Committee, a total of twenty-eight subjects, males and females, aged between 19-28 years were enrolled in the study: 14 were first year dental students and 14 were dentists with 5-6 years of clinical experience. Ishihara color blindness test (24 plate version) was used to assess red-green color deficiencies among the subjects participating in the study. All subjects had correctly recognized the 24 plates included in the test, proving normal color vision.

To assess the shade matching ability, participants were asked to match 16 pairs of tabs from two shade guides (VITA Classical, VITA, Bad Säckingen, Germany). One set of tabs had original markings on the tab holders (A1-A4, B1-B4, C1-C4, D2-D4), while the other set of tabs had the original markings covered with numbers (1-16), randomly assigned. The color of each shade tab was verified using the shade tab verifying mode of a dental spectrophotometer (VITA Easyshade Advance, VITA, Bad Säckingen, Germany) (Figure 1a, Figure 1b).

Figure 1a. Shade tabs with original markings

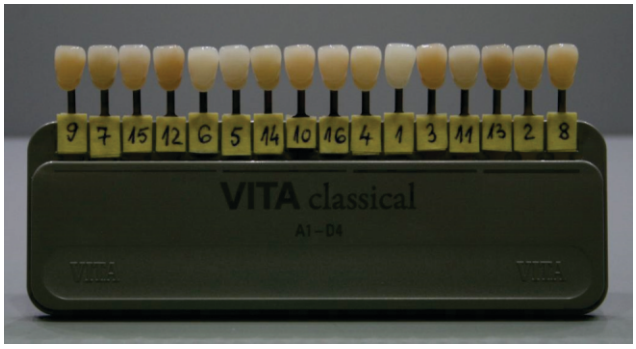

Figure 1b. Shade tabs with original markings covered with numbers

The shade matching tests were performed under standard illumination by using a viewing booth (JUST LED Color Viewing Light, JUST Normlicht, Weilheim/Teck, Germany). (Figure 2).

Figure 2. The viewing booth used for the shade matching tests

The subjects were asked to do the matching tests under two light sources: D65 and D50 light source. Visual comparisons were made at a distance of 30 cm, using a 0°/45° optical geometry, on a neutral (grey) background [12]. Tabs were removed from holders and placed on the floor of the viewing booth and mixed. After a period of adaptation, subjects started the tab arrangement. There was no time limit. At the end of the tests, two matching scores were assigned for each participant (corresponding for each of the two light sources). Matching scores were calculated as a percent, namely the number of correct matches divided by the total number of matches (e.g. 100% means 16 pairs matched, 87.5% means 14 pairs matched).

In order to be considered competent for color matching in dentistry, an observer should have correctly assigned at least 60%, 75% and 85% of the sample pairs presented in the test for poor, average or superior color discrimination competency respectively (ISO/TR 28642:2011) [5]. According to their ability to match shade tabs using the D65 light source, subjects in our study were further divided in three groups:

– poor competency (between 60% and 75% of pairs correctly assigned)

– average competency (between 75% and 85% of pairs correctly assigned)

– superior competency (at least 85% of pairs correctly assigned).

The relationship between clinical experience and color discrimination competency was evaluated.

Recorded data were analyzed graphically and with the Shapiro-Wilk test for the relevance of normal distribution and paired and independent samples *t* tests were used to investigate the significant differences between the groups. Statistical software (IBM SPSS Statistics v20.0.0, Chicago, Illinois, USA) was used for the analysis and α=0.05 values were considered statistically significant.

Results

Overall, the shade matching scores of dental students and dentists' were not significantly different ($p>0.05$). Moreover, when comparing the results of the dental students with those of the dentists separately for the D50 and D65 light sources respectively, no statistically significant differences were found ($p>0.05$) (Table 1).

Table I. Mean values and standard deviations of matching scores (%)

	Students group	Dentists group
Overall (D50+D65)	80.80 (±15.49)	81.02 (±16.88)
D50 light source	74.55 (±18.58)	83.92 (±16.39)
D65 light source	87.05 (±8.30)	78.12 (±17.46)

Regarding the color discrimination competency, only slight differences were observed in the two groups: in the students group more subjects had average competency while in the dentists group more subjects had superior competency (Table 2).

Table II. Distribution of subjects according to color discrimination competency

	Students group	Dentists group	Overall
Poor competency	4 (28.57%)	4 (28.57%)	8 (28.57%)
Average competency	6 (42.85%)	4 (28.57%)	10 (35.71%)
Superior competency	4 (28.57%)	6 (42.85%)	10 (35.71%)
Total	14 (100%)	14 (100%)	28 (100%)

The two light sources did not significantly influence the shade matching ability of subjects. However, when the two groups were compared separately, a significant statistical difference for shade matching under the two light sources was found for the student group. Under the D65 light source a higher matching rate was observed than under the D50 light source. Moreover, a significant difference was also found for subjects with poor color discrimination competency, for which the D65 light source had led to a higher matching rate than the D50 light source. No statistically significant difference was found between the two light sources for subjects with average and superior competency (Table 3).

Table III. Mean values and standard deviations of matching scores (%) - Same superscript symbols in the same row indicate statistically significant differences ($p<0.05$)

	D50	D65
Overall (Students and Dentists)	79.24 (±17.84)	82.58 (±14.16)
Dentists group	83.92 (±16.39)	78.12 (±17.46)
Students group	74.55 (±18.58)*	87.05 (±8.30)*
Superior competency	87.50 (±14.73)	93.75 (±6.58)
Average competency	75.00 (±17.43)	76.87 (±3.01)
Poor competency	58.59 (±9.41)^	75.78 (±12.69)^

The most frequently mismatched tabs were C2 with D4 (11 subjects – 39.28%), B3 with B4 (11 subjects – 39.28%) and B3 with A3.5 (8 subjects – 28.57%).

Discussion

The first null hypothesis could not be rejected since no statistically significant difference was found between students' and dentists' matching scores.

The influence of the clinical experience upon the results of color selection is controversially presented in the literature. Curd et al. and Jasinevicius et al. stated that clinical experience and profession (students, dental technicians, dentists or laypersons) are not relevant in shade selection and our results are in agreement with these findings [3,13].

The second null hypothesis was rejected because statistically significant differences were found between matching scores under the two lighting conditions for students and subjects with poor color discrimination competency.

In order to reproduce daylight standards and minimize shadows and glare in the dental office it is recommended to use overhead lamps with correlated color temperatures (CCT) ranging between 5000-5900 K [8]. The findings of

Curd et al. in 2006 demonstrated that shade matching abilities of students were better under a light-correcting source than under natural light [3]. These results are in accordance with the findings of another study which found that dental technicians obtained better shade matching scores using light-corrective devices than under conventional laboratory lighting conditions [13].

Although the two light sources in our study have close CCT, there are visible differences: the D50 light source generates a warmer light (horizon light), while the D65 a cooler, bluish light (noon-daylight). CIE Standard Illuminant D65 represents a phase of natural daylight with a CCT of approximately 6504 K, while the D50 illuminant has a CCT of 5003 K. In the interest of standardization, the CIE recommends that D65 be used whenever possible for color measurements [14].

According to a study conducted by Park et al. in 2006 it has been suggested that the value, chroma and hue of a shade guide vary significantly under different illuminants (D65, F2 and A) [10]. Another study emphasizing the importance of illuminants in dental practice is that of Gocke et al who found that color-vision deficient persons were less successful in performing visual color determination with the D65 illuminant [9].

In our study, the D50 light source had led to lower matching rates than the D65 light source, for both students (when clinical experience was considered) and subjects with poor color discrimination competency (when calibration by color competence discrimination was taken into account). These categories of subjects were more susceptible to changes in lighting conditions than subjects with higher levels of clinical experience and average or superior color discrimination competency.

The most frequently mismatched shade tabs in our study were C2 with D4 (11 subjects), B3 with B4 (11 subjects) and B3 with A3.5 (8 subjects). These findings may be explained by the color distribution of the shade tabs in the dental color space. Shade tabs A3.5, B3 and B4 have very close values for the L* parameter (55.5±0.3, 55.8±0.4 and 55.9±0.1 respectively), C* parameter (14.0±0.0, 14.9±0.2 and 16.1±0.7 respectively) and h* parameter (84.2±0.1, 86.9±0.4 and 86.8±0.3) [10]. Therefore, slight differences in hue or chroma are less perceptible than differences in value [13].

Conclusions

Within the limitation of this study, the following conclusions can be drawn:

1. Clinical experience does not influence shade matching;

2. The type of light source significantly influences shade matching results for subjects with low level of clinical experience and for subjects with poor competency in color discrimination,

3. Shade tabs with high chroma and close lightness values are the most difficult to match.

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