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Research Article

Comparison of Shade Matching Performance of Dental Professionals and Untrained Individuals in Visual Shade Matching Method

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Comparison of Shade Matching Performance of Dental Professionals and Untrained Individuals in Visual Shade Matching Method

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Abstract

Statement of the problem: It is unclear how the success of color selection with custom shade guides is influenced by the observer's level of color education and the type of light source.

Objective: The aim of this study is to compare the color matching ability under different light sources between observers with and without color education and to investigate in which shade tabs they are more successful, using a custom-made shade guide.

Materials & Methods: The study included 5 prosthodontists (PD), 5 general dentists (GD), 5 dental ceramists (DC), 5 removable denture technicians (RDT), and 10 participants with no color education (NP). Using dentin powder from feldspathic dental porcelain, 2 sets of 16 shade tabs matching those in the Vita Lumin Classic shade guide were produced. The Lab values of the produced shade tabs with the same shade code were measured using a colorimeter device, and those with ΔE values below 0.1 were used for shade matching. Each participant conducted a total of 48 shade matches under 3 different light sources (tungsten-TG, fluorescent-FL, and D65).

Results: It was found that the shade matching success of dental professionals in the PD, GD, RDT, and DC groups significantly differed from that of the participants in the NP group ($\chi^2 = 23.417$; $P < 0.001$). Shade matches conducted under the D65 light source were more successful than those under the TG and FL light sources, and participants were found to match shade tabs with higher saturation, such as A4 and C4, more successfully.

Conclusions: Color matching performed with a custom color scale is influenced by the observer's training and the light source. As the saturation of shade tabs increases, the matching success also increases.

Keywords: Instrumental Shade Matching, Visual Shade Matching, Custom Shade Guide, Color Training, Light Sources.

Introduction

In today's world, not only facial aesthetics but also dental aesthetics has become a factor that influences individuals' self-confidence and social success. One of the most important parameters of dental aesthetics is the presence of a harmonious alignment or distribution among dental arches in terms of size, surface characteristics, and color.[1] Achieving a perfect shade match between restorations and natural teeth is of great importance for patient satisfaction and the success of the restorations.[2,3] Determining the color accurately, effectively communicating it to the dental laboratory, and producing the restoration with impeccable aesthetics still encompass some of the most challenging procedures in aesthetic Dentistry.[2,4,5]

The accurate appearance characteristics and color of the intended restoration can be achieved through either the traditional visual method, which involves the use of shade guides consisting of tooth-shaped shade tabs, or the instrumental method, which utilizes color measuring devices.[2,6,7] Color matching devices used in instrumental methods such as intraoral spectrophotometers, spectroradiometers, or colorimeters have the potential to significantly shorten and simplify this process. Additionally, these devices offer high accuracy and repeatability. However, they still come with high costs and are therefore underutilized in dental practice.[8,9]

The traditional visual shade matching method is still the most commonly used approach today.[8] However, this method relies entirely on the practitioner's visual perception, which, like all our perceptions, is highly subjective. To date, numerous studies have attempted to determine whether factors such as the age, gender, medications used, and physiological condition of the practitioner have any impact on color matching ability in the visual method.[3,9,10] Some researchers have reported that females have a higher shade matching ability than males, while others have argued that gender has no influence on this clinical procedure. While some studies have reported that factors such as age, experience, or education do not significantly affect the shade

matching process, there is still a lack of consensus on this issue.[3,9,10] The only factor believed to influence and even achieve unanimous agreement on its impact on the success of visual shade matching appears to be the type of light source.[3,9]

The aim of this study is to compare the shade matching performance under different light sources between dental professionals who have received color education at different levels and individuals who have never received color education. The null hypothesis of the study posits that the participants' level of color education and training will not affect the success of the shade matching procedure.

Materials & Methods

The study was conducted in a total of 4 stages: enrollment of participants, fabrication of two custom shade guides to be used in shade matchings, participants matching the shade tabs of two different shade guides under 3 different light sources, and statistical analysis.

-Enrollment of participants

This study was approved by the Ethical Committee of Gulhane Military Medical Academy and executed in line with the Helsinki Declaration.

The study included a total of 10 dentists, with 5 being prosthodontists (PD) and 5 being general dentists (GD), as well as 10 dental technicians, with 5 being ceramists (DC) and 5 being removable denture technicians (RDT). Additionally, 10 participants who had not received any color education (NP) were included in the study. The inclusion criteria for the study are as follows:

-Not having any visual perception disorders, including refractive errors,

-Not using any medication known to affect visual perception,

-Voluntary participation.

-Fabrication of two custom shade guides to be used in shade matchings

A total of 32 color tabs were produced, with two tabs for each of the shade tab coded as A1, A2, A3, A3.5, A4, B1, B2, B3, B4, C1, C2, C3, C4, D2, D3, and D4, which are part of the Vita Lumin Classic color scale. The shape and dimensions of the shade tabs to be produced were determined with reference to the shape and width of the reading end of the colorimeter

device (BYK-Gardner Inc., Columbia, USA), where the L*a*b* values of each tabs would be measured (Figure 1).

Figure 1. The reading tip of the colorimeter device used as a guide for determining the shape and diameter of the porcelain discs.

After determining the dimensions of the reading tip of the colorimeter device, the dimensions of the mold to be used in obtaining the porcelain discs were also determined, taking into account the new size due to the contraction that would occur during the porcelain firing. The mold with the specified dimensions was fabricated from a stainless steel alloy using special lathe machines (Figure 2).

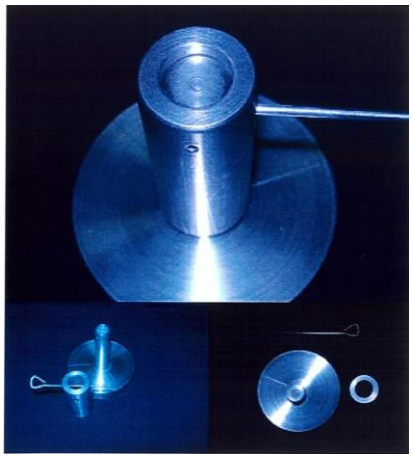

Figure 2. Stainless steel metal mold prepared for the production of porcelain discs.

After the metal mold was cleaned with ethyl alcohol and distilled water in an ultrasonic cleaner, the dentin powder of a feldspathic porcelain material was mixed with its liquid according to the manufacturer's instructions and placed into the metal mold by condensation method. After the condensation process, each porcelain disc removed from the mold was fired in an oven at the temperature and pressure recommended by the manufacturer. As a result, two porcelain discs representing the dentin shade for each shade tab found in the Vita Lumin shade guide were prepared for grinding. The obtained porcelain discs, before colorimetric examination, were ground with 360, 320, and 160 grit silicon carbide abrasives for the same duration and pressure. After the grinding process, no glaze or any finishing process was applied to the discs. The thickness of all discs was measured with calipers, and any discs with thickness variations were reproduced. Finally, 32 porcelain discs with a diameter of 12 mm and a thickness of 2.1 mm were prepared and made ready for colorimetric measurements (Figure 3).

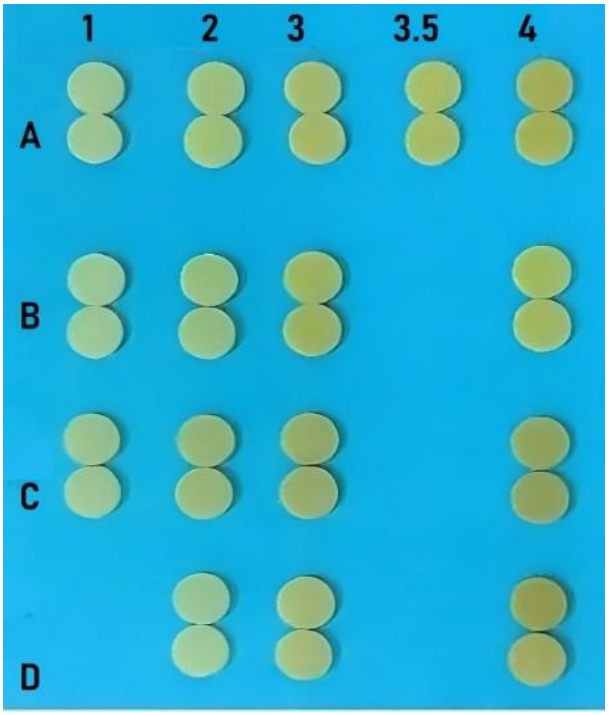

Figure 3. The total of 32 porcelain discs used by the participants for matching.

Before the colorimetric measurement of each porcelain disc, the colorimeter device was calibrated. Starting with two porcelain discs representing A1 on the color scale, the L*a*b* values of each disc were measured. Following the calculation using the formula $\Delta E = [(L^*_1 - L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1 - b^*_2)^2]^{(1/2)}$ porcelain discs with a ΔE value equal to or greater than 0.1 but having the same shade tab code were reproduced.

-Participants matching the shade tabs of two different shade guides under 3 different light sources.

Before starting the matching process, an apparatus was produced in the form of an inclined plane with a 45º tilt and a horizontal extension, painted in the same gray scale as the light cabin, to ensure that the position of the porcelain discs and the light beam from the light source remained fixed. The light cabin's fluorescent, D65, and tungsten light sources were opened sequentially, and participants were asked to match the given 32 shade tabs without any time constraints. The correct and incorrect matches of each participant who completed the matching were recorded.

-Statistical analysis

The SPSS 11.5 (SPSS Inc., Chicago, IL., USA) program was used for the analysis of the recorded data. Frequency tables were prepared for descriptive statistics. Whether there was a significant difference between participant groups was investigated using the Pearson Chi-Square test and frequency analysis. Values with $P<0.05$ were considered statistically significant.

Results

Each participant completed the study by making 48 matches using 2 custom shade guides, each containing a total of 16 shade tabs, under 3 different light sources. Regardless of the difference in light sources, the rates of unsuccessful shade matching (USM) and successful shade matching (SSM) for the PD, GD, DC, RDT, and NP groups are provided in Table 1.

Table 1. Results of the observer groups' matches without considering the difference in lighting sources.

Groups	USM	SSM
PD	132 (55%)	108 (45%)
GD	141 (58.9%)	99 (41.2%)
RDT	139 (57.9%)	101 (42.1%)
DC	127 (52.9%)	113 (47.1%)
NP	330 (68.8%)	150 (31.2%)
Total	869 (60.3%)	571 (39.7%)

When the light source is not considered, the results of the matching performed by each observer group have shown statistically significant differences from the other groups (χ^2=23.417; P<0.001).

The success rates of participants' shade matching under tungsten light source are given in Table 2.

Table 2. Shade matching results performed under tungsten light source.

Groups	USM	SSM
PD	58 (72.5%)	22 (27.5%)
GD	63 (78.8%)	17 (21.2%)
RDT	60 (75%)	20 (25%)
DC	59 (73.3%)	21 (26.3%)
NP	135 (84.4%)	25 (15.6%)
Total	375 (78.1%)	105 (21.9%)

The success rates of observer groups' shade matchings under the tungsten light source showed statistically significant differences (χ^2 =11.378, P<0.023).

The success rates of participants' shade matchings under florescent light source are given in Table 3.

Table 3. Shade matching results performed under florescent light source.

Groups	USM	SSM
PD	40 (%50)	40 (%50)
GD	44 (%55)	36 (%45)
RDT	45 (%56.3)	35 (%43.8)
DC	37 (%46.3)	43 (%53.8)
NP	108 (%67.5)	52 (%32.5)
Total	274 (%57.1)	206 (%42.9)

The success rates of observer groups' matches under the florescent light source showed statistically significant differences (χ^2 =12.722, P<0.013).

The success rates of participants' shade matchings under D65 light source are given in Table 4.

Table 4. Shade matching results performed under D65 light source.

Groups	USM	SSM
PD	40 (50%)	40 (50%)
GD	44 (55%)	36 (45%)
RDT	45 (56.3%)	35 (43.8%)
DC	37 (46.3%)	43 (53.8%)
NP	108 (67.5%)	52 (32.5%)
Total	274 (57.1%)	206 (42.9%)

The success rates of observer groups' matches under the florescent light source showed statistically significant differences (χ^2 =24.322, P<0.035).

The participants' matching rates for the 16 different shade tabs in the custom shade guide were also investigated. The results are presented in Tables 5, 6, 7, 8, and 9.

Table 5. Success rates of PD group participants in matching the 16 shade tabs in the custom shade guide.

Shade Tab	USM	SSM	Shade Tab	USM	SSM
A1	%80.0	%20.0	B4	%53.3	%46.7
A2	%46.7	%53.3	C1	%66.7	%33.3
A3	%80.0	%20.0	C2	%66.7	%33.3
A3.5	%46.7	%53.3	C3	%53.3	%46.7
A4	%26.7	%73.3	C4	%13.3	%86.7
B1	%73.3	%26.7	D2	%33.3	%66.7
B2	%53.3	%46.7	D3	%80.0	%20.0
B3	%73.3	%26.7	D4	%33.3	%66.7

Table 6. Success rates of GD group participants in matching the 16 shade tabs in the custom shade guide.

Shade Tab	USM	SSM	Shade Tab	USM	SSM
A1	%86.7	%13.3	B4	%46.7	%53.3
A2	%73.3	%26.7	C1	%60.0	%40.0
A3	%60.0	%40.0	C2	%80.0	%20.0
A3.5	%46.7	%53.3	C3	%46.7	%53.3
A4	%40.0	%60.0	C4	%13.3	%86.7
B1	%80.0	%20.0	D2	%46.7	%53.3
B2	%60.0	%40.0	D3	%86.7	%13.3
B3	%53.3	%46.7	D4	%60.0	%40.0

Table 7. Success rates of RDT group participants in matching the 16 shade tabs in the custom shade guide.

Shade Tab	USM	SSM	Shade Tab	USM	SSM
A1	%53.3	%46.7	B4	%46.7	%53.3
A2	%46.7	%53.3	C1	%60.0	%40.0
A3	%86.7	%13.3	C2	%73.3	%26.7
A3.5	%40.0	%60.0	C3	%66.7	%33.3
A4	%40.0	%60.0	C4	%53.3	%46.7
B1	%53.3	%46.7	D2	%20.0	%80.0
B2	%66.7	%33.3	D3	%100	%0.0
B3	%53.3	%46.7	D4	%66.7	%33.3

Table 8. Success rates of DC group participants in matching the 16 shade tabs in the custom shade guide.

Shade Tab	USM	SSM	Shade Tab	USM	SSM
A1	% 60.0	%40.0	B4	%46.7	%53.3
A2	%40.0	%60.0	C1	%66.7	%33.3
A3	%93.3	%6.7	C2	%60.0	%40.0
A3.5	%40.0	%60.0	C3	%40.0	%60.0
A4	%13.3	%86.7	C4	%46.7	%53.3
B1	%60.0	%40.0	D2	%33.3	%66.7
B2	%60.0	%40.0	D3	%80.0	%20.0
B3	%66.7	%33.3	D4	%40.0	%60.0

Table 9. Success rates of NP group participants in matching the 16 shade tabs in the custom shade guide.

Shade Tab	USM	SSM	Shade Tab	USM	SSM
A1	%90.0	%10.0	B4	%46.7	%53.3
A2	%50.0	%50.0	C1	%63.3	%36.7
A3	%83.3	%16.7	C2	%80.0	%20.0
A3.5	%66.7	%33.3	C3	%86.7	%13.3
A4	%40.0	%60.0	C4	%63.3	%36.7
B1	%83.3	%16.7	D2	%70.0	%30.0
B2	%76.7	%23.3	D3	%76.7	%23.3
B3	%76.7	%23.3	D4	%46.7	%53.3

Discussion

The shade matching success rates obtained from the NP group, consisting of individuals who have not received color education, are statistically significantly lower when compared to the success rates of the participants in the PD, GD, RDT, and DC groups who have received color education at different levels. Therefore, the null hypothesis of the study has been rejected.

Among all matches conducted under the three light sources, the highest matching success, at 47.1%, was achieved by the participants in the DC group. On the other hand, the lowest matching success rates among the five observer groups are 31.2%, belonging to the NP group, consisting of individuals who have not received any color education or trainning. The detailed statistical analysis results also support the intergroup difference (χ^2 =23.417; P<0.001). This part of the study is consistent with previous research that has compared and reported the color matching success of individuals who have received color education at different levels or not at all.[11-13] However, the results of the current study, while in harmony with previous studies, exhibit a significant methodological difference from them. In this study, the color tabs used for shade matching were produced using feldspathic porcelain obtained solely from dentin powder. Additionally, no glaze or other polishing processes were applied to the disc-shaped color tabs. This was because the aim of the study was to solely investigate the participants' color matching abilities. In most previous studies, fabricated shade guides such as Vita Classic and Vita 3D Master, were used, and no custom shade guide was produced.[3,11] This is due to some structural

issues with fabricated shade guides. One of the most significant problems among these issues is the difference in the porcelain used in the fabrication of shade tabs and restorative ceramics.[14,15] Another significant issue is the color mismatch between shade tabs from the same manufacturer and batches of restorative ceramics or the mismatches among restorative ceramics from different manufacturers ceramics.[14] While not directly relevant to the method used in the current study, fabricated shade guides have significant limitations when it comes to replicating the color distribution found in natural teeth.[14]

The results of the current study once again emphasize the importance of the light source and color training in the shade matching procedure. The findings of the study are consistent with numerous studies[16-18] that have shown that as the spectral distribution of the light source in the environment where shade matching is performed approaches a homogeneous distribution, the matches are more successful. The least successful shade matching among the participants was with the tungsten light source, which emits light in the narrowest spectral distribution range. The success rate of all observers in matching under this light source was only 21.9%. Similarly, as participants' color training increases, the success of the matches also increases (χ^2=11.378, P<0.023). However, the most significant difference of this study from the previous ones is that it provides clues about the shade tabs where the participants are most successful and least successful in matching. When all groups' matches were examined, it was observed that the most successfully matched shade tabs were A4 and C4. What's even more interesting is that as the light source changed, there was no significant change in the types of shade tabs in which the participants were successful. The explanation of this result we obtained can be illuminated by the findings of Bergen and McCasland's previous study.[17] Bergen and McCasland[17] reported that observers had the most difficulty in determining the hue parameter of the color shade matching, while chroma was discriminated more successfully. The A4 and C4 shade tabs are two shades away from the most saturated shade tab in both their groups and the overall shade guide.

The current study undoubtedly has important limitations. In our opinion, one of the most significant limitations is the small number of participants. Another important limitation is the use of only a single custom shade guide, with no verification of data accuracy with another shade guide. Additionally, the shade tabs belonging to the custom shade guide used in the study were produced using only dentin powder from feldspathic porcelain. Therefore, there is a need

for future studies with larger sample sizes and the use of more than one custom shade guide, including shade tabs produced using enamel powder, to confirm the obtained data.

Conclusions

In light of the data obtained from the current study, it can be concluded that;

1.The light source and color education are directly related to the success of the shade matching procedure,

2.As the spectral distribution of the light source becomes more homogeneous and the color training levels of the observers increase, the success of the shade matching process improves,

3.Observers tend to match shade tabs with higher saturation more successfully.

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