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Original Article

Influence of different light sources on visual shade matching performance

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Abstract

Introduction: The shade selection ability of dentists is a necessary element in natural tooth color recreation. Visual shade selection is affected by light source variables. The aim of this study was to compare the results of shade matching under three light conditions.

Materials &Methods: The Ishihara test was doneon58 volunteers participated in this study: 40 dental interns, 10 Postgraduate students of restorative dentistry, 8 Postgraduate students of prosthodontics. Totally, 9 classical vita shade tabs were randomly chosen and their codes were covered. The participants matched these 9 shades with a complete classical vita shade under the lighting condition in the dental office, natural light and corrected light source. Matching scores were computed and the mean of the color differences between the citation shades and the chosen shades counted with ΔE_{ab}^{*} formula. The data were analyzed using Mann-Whitney, Friedman and Wilcoxon test.

Results: The average of shade matching scores with correcting light (7.87) was higher than the lighting conditions in the dental office (3.94) and natural light(5.53). Comparison of ΔE between three light conditions was significant ($P<0.05$). No significant difference was found in shade matching scores by sex ($P>0.05$).There was a significant difference between scores of under-graduate and post-graduate students ($P<0.05$).

Conclusion: To achieve successful shade matching, it is recommended to use the corrected light source. The combination of using corrected light and training can improve shade matching performance .

Keywords: Dental student, Lighting, Color

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تأثیر منابع نوری مختلف برعملکرد تطابق رنگ بصری

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چکیده

مقدمه: توانایی انتخاب رنگ دندانپزشکان یک عامل ضروری جهت بازسازی رنگ دندان طبیعی است. انتخاب رنگ بصری تحت تاثیر متغیرهای منبع نوری قرار دارد. هدف از این مطالعه مقایسه نتایج انتخاب رنگ زیر سه منبع نوری است.

مواد و روش ها: پس از انجام تستIshihara ، ۵۸ داوطلب در این مطالعه شرکت کردند: ۴۰ دانشجوی دندانپزشکی سال آخر، ۱۰ دستیار تخصصی دندانپزشکی ترمیمی و زیبایی، ۸ دستیار تخصصی پروستودنتیکس. ۹ نمونه رنگ classical vita shade بطور تصادفی انتخاب شد و کد رنگی آنها پوشانده شد. شرکت کنندگان این ۹ نمونه رنگ را با نمونه رنگ کامل classical vita shade زیر نور کلینیک، نور طبیعی و نور تصحیح شده ،تطابق دادند. نمرات انطباق دهی محاسبه شده و میانگین تفاوت رنگ بین نمونه اصلی و نمونه انتخاب شده براساس ΔE_{ab}^{*} محاسبه شد. داده ها توسط تستهای Mann-Whitney , Friedman و Wilcoxon انالیز شدند.

یافته ها: میانگین انطباق رنگ زیر نور تصحیح شده (۷/۸۷) بیشتر از نور کلینیک (۳/۹۴) و نور طبیعی (۵/۵۳) بود. مقایسه ΔE بین سه منبع نوری معنادار بود ($p<0.05$). هیچ تفاوت معناداری بر اساس جنسیت نشان داده نشد ($p> 0.05$). تفاوت معنا داری بین نمرات دانشجویان فارغ التحصیل شده و نشده دیده شد ($p<0.05$).

نتیجه گیری: برای دستیابی به تطابق رنگ موفق توصیه می شود که از منبع نورتصحیح شده استفاده شود. ترکیب استفاده از نور اصلاح شده و آموزش می تواند منجر به بهبود انتخاب رنگ شود.

واژگان کلیدی: دانشجوی دندانپزشکی، نور، رنگ

Introduction

Reconstructing the typical form of altered or missing tooth structures using restorative materials demands correct control of shape, translucency and color of the restoration.[1]The shade selection ability of dentists and transferring it to the laboratory is a necessary aspect in natural tooth color recreation.[2]

The assessment of tooth shade is possible using visual and instrumental methods. A visual method is identified as shade matching and using of shade guide of tooth shaped tabs from ceramic or resin, it is carried out under more or less controlled situation .Instrumental measurement is performed using spectrophotometers, colorimeters, spectroradiometers, digital and spectral imaging .[3] Instrumental methods enable the account of CIE L*a*b*color parameters required for the computation of the color difference formula (ΔE Lab*).[4]ΔE is a number that illustrates the differentiation between the two colors and ΔE=3.3 is considered distinguishable clinically.[5]Although the instrumental method helps the clinicians, the high cost and restrict devices prevent their wide use in dental practices; therefore, color shade matching is performed through comparison of natural tooth with a commercially shade guides by clinicians.[6,7] Multiple variables related to observer, object and the light source cause complexities affecting the shade selection and restoration color in advance.[3,8] Ability of color perception is an individual factor therefore it is influenced by variables such as age, sex, experience, fatigue, color vision deficiencies, physical and psychological conditions.[1,2,6,9-12]

Also, some characters of subject affect the shade matching, tooth texture and contour, opacity, translucency, background, sample type and surface.[1,6,12] Another factor that affects color perception is the feature of light which can differ in type, intensity and angle of incidence.[1,2,6,7,8,10] Light condition in the dental office is extremely variable and depend on time of day, year and light sources in the office so on. Light may be a combination of daylight and fluorescent or incandescent light.[4] Dental students are proper to study the shade matching ability because they are mostly

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young population and often they do not have medical conditions that affect their color vision.[10] The aim of this study was to assess the shade matching ability of dental students, residents of prosthodontics and residents of restorative dentistry at various light conditions including clinical, natural and corrected light.

Materials & Methods

A total of 60 subjects (males and females) aged 22-32 years, participated in the research and 42 of them were dental interns and other 18 persons were postgraduate students of restorative dentistry and prosthodontics dentistry. To assign red-green color deficiencies, the Ishihara's test was performed and two under-graduate students were excluded from the present study.

Participants were inquired to match 9 tabs which were randomly chosen and their codes were covered (C_3, A_2, A_3, D_3, B_2, A_1, C_2, $A_{3.5}$, B_3) with a complete shade guide (VITA Classical, Ivoclar Vivadent, Schaan, Likhtenshtein). Time was not limited, but the participants noticed that the further time could increase the chance of error and ten minutes were sufficient in this examination. The evaluators were asked to perform matching tests under three light conditions: The lighting conditions in the dental office, natural light and corrected light. The lighting conditions in the dental office were the combination of daylight and fluorescent or incandescent light. The test was conducted in the area with the dimension of 16m×8m, four windows (1m×2m), twelve fluorescent lamps (FL, 40W, DL) and six incandescent lamps (FL, 20W, T10 DL). Shade matching test under natural light was done in late spring, from 9 A.M.to 3 P.M. A corrected light condition was provided in the light chamber (Kimia Behris, Yazd, Iran) usingD65 light (1300 lux intensity and CRI>90) with an angle of 45̊. A neutral color (gray) was used for background to decrease eye fatigue. Shade matching tests were done on three different days, at the same time and a break of one week between sessions to avoid the effect of previous subjective background.

Each participant had a specific questionnaire, and the selected tabs were entered and true matches were calculated. The total number of correct matches was scored and if a person did not have a mismatch, they would gain the highest score. A Vita Easy shade compact spectrophotometer (VI dent, California, USA) was used in the commission international de I'Eclairage L*, a*, b* (CIELAB) system for all tabs and average of L*, a*, b* was calculated for each shade, then the color difference between sample and chosen tabs was counted by using the following formula:

$$\Delta E=\sqrt{(\Delta a^2+\Delta b^2+\Delta l^2)}$$

The mean of ΔE between reference tabs and selected tabs was calculated for each sample under three light sources.

The Mann-Whitney test was used to compare the shade matching scores by gender and experience. The Friedman test was used for statistical analysis of the shade match scores and ΔE with different light sources. The Wilcoxon test was applied to determine scores and ΔE difference between each two light sources. Data were analyzed using SPSS.V22, and statistically, P value <0.05 was considered significant.

Results

The percentage of right and false matches for each sample was counted and three items with the most percent ages were sequentially shown. The most mismatches were A_2 with D_2, A_1 with B_1, C_2 with D_4, $A_{3.5}$ with B_3 and B_3 with B_4 (Table 1). A statically significant difference was observed among shade matching scores under three light sources (P<0.001). The number of correct shades matching under corrected light statistically was better than the lighting conditions in the dental office and natural light (P<0.001). In addition, there statistically was a significant difference between natural light and the lighting conditions in the dental office (P<0.001) (Table 2).

The Mann-Whitney test showed that there was no statistically significant difference between males and females (P>0.05) but there was statistically a significant difference between under graduate and post graduate students under three light conditions (P<0.05) (Fig 1).

The average of ΔE between presented and chosen shade for each item was calculated and Friedman test demonstrated that there statistically was a significant difference among three light of sources (P<0.05). A significant difference was found between the lighting conditions in the dental office and corrected light according to Wilcoxon test (P<0.05).

A significant difference in average of ΔE under the natural and corrected light was statistically found in all samples except for B_2 (P=0.231). Moreover, the difference of ΔE was not significant between the lighting conditions in the dental office and natural light (P>0.05); however, D_3 (P=0.006) and A_1 (P=0.002) were shown significant differences (P<0.05) (Table3).

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Table 1. The percentage of chosen shade tabs for each sample (three choices that have highest percentage) under three light condition

Sample	The lighting conditions in the dental office (L1)			Natural Light (L2)			Corrected light (L3)		
	Correct	In Correct		Correct	In Correct		Correct	In Correct	
C3	C3	D4	C2	C3	C4	C2	C3	C2	**A4**
	34.5	15.5	12.1	67.2	8.6	6.9	91.4	3.4	**1.7**
A2	A2	D2	C1	A2	D2	D4	A2	D2	**B1**
	46.6	20.7	8.6	56.9	10.3	8.6	91.4	3.4	**1.7**
A3	A3	A3.5	C3	A3	B3	A3.5	A3	C3	**A3.5**
	48.3	15.5	8.6	60.3	15.5	8.6	93.1	3.4	**1.7**
D3	D3	C3	D2	D3	C3	C2	D3	D4	**D2**
	39.7	17.2	8.6	56.9	8.6	8.6	86.2	5.2	**3.4**
B2	B2	C1	A2	B2	C1	A1	B2	D2	
	62.1	13.8	12.1	79.3	5.2	5.2	94.8	5.2	
A1	A1	B1	C1	A1	B1	D2	A1	B1	
	53.4	27.6	10.3	79.3	17.2	3.4	93.1	6.9	
C2	C2	D4	C3	C2	D4	A3.5	C2	D4	**C3**
	36.2	24.1	12.1	46.6	24.1	8.6	82.8	8.6	**5.2**
A3.5	A3.5	B4	B3	A3.5	B3	C4	A3.5	B3	**B4**
	31	19	15.5	60.3	12.1	10.3	81	8.6	**6.9**
B3	B3	B4	A3.5	B3	B4	A3	B3	B4	**A3**
	43.1	19	13.8	46.6	32.8	6.9	74.1	24.1	**1.7**

Table 2.Mean values of scores by three light conditions

Light source	Mean (SD)	Friedman test L1, L2,L3	Wilcoxon test	
The lighting conditions in the dental office(L1)	3.94 (1.98)		L1 , L2	P<0.001
Natural light (L2)	5.53 (2.25)	P<0.001	L2 , L3	P<0.001
Corrected light (L3)	7.87 (1.17)		L1 , L3	P<0.001

*L_1: the value under the lighting conditions in the dental office L2: the value under natural light L3: the value under corrected light

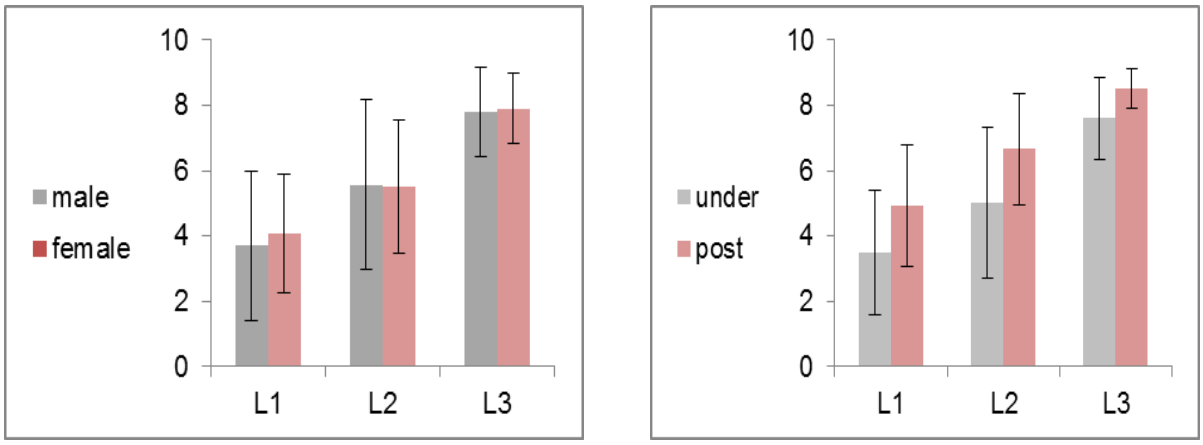

Figure 1. Mean values of score (SD) under three light conditions by the gender and the experience

*L_1: the value under the lighting conditions in the dental office L2: the value under natural light L3: the value under corrected light

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Table 3. Mean values and standard error of ΔE between samples and chosen shades under three light conditions

Item	ΔE_{1*}	ΔE_2	ΔE_3	p-value 1.2.3	P-value 1.2	p-value 2.3	p-value 1.3
C3	3.37(0.38)	1.95(0.39)	0.44(0.21)	<0.001	0.17	0.002	**<0.001**
A2	3.27(0.43)	2.55(0.41)	0.55(0.24)	<0.001	0.144	<0.001	**<0.001**
A3	2.97(0.42)	2.42(0.44)	0.43(0.21)	<0.001	0.405	0.001	**<0.001**
D3	2.73(0.32)	1.68(0.26)	0.62(0.21)	<0.001	0.006	0.005	**<0.001**
B2	1.78(0.34)	0.95(0.26)	0.37(0.21)	0.001	0.082	0.231	**0.001**
A1	1.98(0.32)	0.76(0.22)	0.20(0.97)	<0.001	0.002	0.019	**<0.001**
C2	2.07(0.3)	1.73(0.28)	0.44(.16)	<0.001	0.427	<0.001	**<0.001**
A3.5	2.84(0.32)	1.93(0.4)	0.53(0.15)	<0.001	0.066	0.001	**<0.001**
B3	2.02(0.35)	1.40(0.26)	0.37(0.1)	<0.001	0.133	<0.001	**<0.001**

*ΔE_1: ΔE between samples and chosen shades under the lighting conditions in the dental office

ΔE_2: ΔE between samples and chosen shades under natural light

ΔE_3: ΔE between samples and chosen shades under corrected light

Discussion

According to the present study, shade matching ability of dental students and postgraduate students was better in the condition of under corrected light in comparison with natural and the lighting conditions in the dental office. These results are consistent with other studies in which dental students and dental technicians gained better performance under correcting light.[1,2,4,10,13,14] The current study tried to compare the standard light condition with the light condition that the dentists often use for shade matching.

Although the natural light has been suggested as an ideal light for shade matching, the condition of this light is not permanent and affected by many factors.[1,2,6,8,10]The light of a dental office does not have sufficient intense to see color rendering and dental unit light is not appropriate for shade selection because it is too glorious and creates dazzle.[8] Since this light condition is inconstant, it is recommended that the shade selection and recreation color of teeth should be done under the corrected light source.[1,7]

Dentists should choose daylight (D65, D55 or similar) lamps and tubes with a color rendering index (CRI)≥ 90. The advanced light intensity is 1000 to 1500 lux.[15] The correct color temperature of the ideal light condition is white light and 6500 k. [10] The effect of clinical experience upon the ability of shade matching is controversially presented in the investigation. This study supports previous researches which reported that the clinical experience and education on shade matching ability is effective.[9,11,14,16,17] Moreover, the results of Gasparik et al, in 2014 indicated that clinical experience has no effect on shade matching ability.[1] But in the mentioned study, undergraduate dental students compared with general dentists with 5-6 years of clinical experience while in the present study, dental students were compared with postgraduate students of restorative dentistry and postgraduate students of prosthodontics who had more experience and knowledge than general dentists and they usually performed restorative and aesthetic procedures, too.

In the present study, data were collected from dental interns and the postgraduate students of restorative dentistry and postgraduate students of prosthodontics dentistry because they were young adults and they did not have the medical condition affected their color vision. [10] The results showed that there was no significant difference in terms of sex, which was predictable according to other studies [2,3,14,18,19] while Milagres et al. in 2012 stated that men than women had a better shade selection ability.[11] and Gasparik et al. in 2015 demonstrated that women obtained better scores only under clinical light condition.[4]

When the incorrect selections were surveyed, it was found that the participants often chose wrong hue and it had the same Chroma as the correct shade tab, for example the shade selection for tab A_1 was B_1 and for A_2 was D_2, these results were supported by previous studies. [2,10] The frequent mismatched of B_3 with B_4, $A_{3.5}$with B_3 and C_2 with $D_4$was observed as wrong choices of students, which was similar to the study of Gasparik et al in 2014. These results may be justified by the color division of the shade guides.[1] Shade tabs $A_{3.5}$, B_3, B_4 and C_2, D_4 are close to each other in color's measured parameters. [20] Further studies are essential to

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perform on matching shade guide with natural teeth and further more comparative investigation of Vita Classic and 3D Master are needed. In addition, it is recommended that more research should be conducted to evaluate the effect of light chamber and handheld light on shade matching.

According to previous studies which suggested that there was deficiency of knowledge among the general dentists about the consequence of intensity and light condition during shade matching and they reported that 80%dentists performed shade selection under inappropriate light's intensity[10], also based on the study of Saboori et al. who stated that no dentist used commercial light system[17] and as well as based on the result of the present study it is recommended to use proper light source to improve their knowledge in order to achieve the restorations with appropriate color and aesthetic. Perfect shade selection plays a vital role in patient satisfaction and saving cost and time.

Conclusion

The results of this study suggested that the use of corrected light source can improve the shade matching ability of operators. Shade matching ability has been increased by knowledge and experience.

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Conflict of interest disclosure: The authors state that they have no conflict of interest.

Authors' Contributions

The study was designed by Tolo Jafari. The study data were collected by Tolo Jafari and Romina Roodgarian. RCT Analysis was done by Soraya Khafri. interpretation of data, drafting of the manuscript, and critical revision of the manuscript for important intellectual content were pre-formed by Tolo Jafari. Study supervision was performed by Faezeh Abolghasemzadeh.

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