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Original Article

Effects of individual factors and the training process of the shade-matching ability of dental students

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Abstract *Background/purpose:* In this study, we evaluated the ability of dental students to correctly match tooth shades and examined the influence of clinical practice years, gender, eye color, and the use of eye glasses or contact lenses on the ability to match tooth shades.
Materials and methods: In total, 244 dental students (138 females and 106 males, with a mean age of 22 years) in their 1st to 5th years of education were included in the study. Students were asked to match the color of artificial teeth (Vitapan acrylic denture teeth) using the Vita Toothguide 3D-Master. Three predefined test colors were used: 2L1.5, 1M2, and 2R1.5. Exact matching rates of all three color components (value, hue, and chroma) were calculated and analyzed by a Chi-squared test.
Results: Students in the 3rd, 4th, and 5th clinical years performed better with regard to exactly matching the three shades, compared to students in the 1st and 2nd preclinical years (29.4% *vs.* 22.5%, P = 0.034). On the other hand, gender, eye color, and use of eye glasses or contact lenses had no effect on the ability to correctly match the color. Higher rates of exact matches were found for 1M2, compared to 2L1.5 (31.1% *vs.* 20.5%, P = 0.007).
Conclusions: The shade-matching ability of dental students seemed to improve with more education because of the inclusion of clinical practice in the educational program. However, gender, eye color, and the use of eye glasses or contact lenses had no influence.

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Introduction

The success of fixed and removable prostheses is related to both functional and esthetic results. The esthetic result is influenced by the shape, form, and color of the restored or artificial teeth.[1] Shade matching is affected by different factors such as the light source, shade guide sufficiency, and skill of the dental practitioner.[2–10] Better skills of dentists for shade matching are related to acquired factors like education, experience, and individual factors such as age, gender, and health, especially eye health. Only a few studies evaluated the influence of educational level, clinical experience, and the physical status of the dental practitioners on the shade-matching ability.[11–15]

Different results were obtained in studies examining the influence of time spent in clinical practice on shade matching.[5,12] During the 5-year dental education period, older students are expected to be more successful because of their gradually increasing knowledge and clinical experience.[11]

Additionally, the influence of individual factors such as gender on tooth-shade matching was evaluated in several studies.[4,5,11,14,16] However, there is insufficient information on the role of eye color and health on the matching of shades. The first factor that was considered in eye health evaluation is detection of color-vision deficiencies in dental practitioners.[5,11] Myopia, hypermetropia, and astigmatism are refraction errors, and they can be corrected by eye glasses and contact lenses.[17,18] However, there is a scant information on whether the use of eye glasses or contact lenses to correct refraction errors has any effect on tooth-shade matching compared to healthy eyes. Information regarding the influence of differences in eye color as a result of different pigmentation of the iris[19,20] on tooth-shade matching is also unsatisfactory.[20–25]

The purpose of the present study was to evaluate the color-matching ability of dental students according to their clinical practice level. The second aim was to determine the influence of gender, eye color, and the presence of corrected refraction errors on their matching ability, which is a less-evaluated individual factor in the literature.

Materials and methods

Study subjects

In total, 244 dental students (138 females and 106 males) were included in the present study. Color testing was performed on 244 students undergoing dental education in the 1st to 5th years in the Faculty of Dentistry, Yeditepe University, during the 2008–2009 academic year. There were 61, 49, 45, 36, and 53 students in the 1st, 2nd, 3rd, 4th, and 5th classes respectively. The average age of the students was 22 years. All students were informed about the research and asked to sign a consent form before being allowed to participate in the study. The study was also approved by the Ethics Committee of the university. Students were subjected to Ishihara's test,[21] and three male students were excluded from the analysis because they were diagnosed with color-vision deficiencies. Before color selection, students filled out a questionnaire on personal information (name, age, and gender), eye color, eye glasses/contact lens use, and regular eye checkups.

The ability of students to match tooth shades was evaluated using the Vita Toothguide 3D-Master (Vita Zahnfabrik, Bad Sackingen, Germany). Students are involved in managing patients and receive information on shade matching and the use of shade guides in the 3rd academic year. Therefore, students were divided into two groups. Group 1 ($n = 110$) consisted of preclinical students (1st and 2nd academic years) who had received no information on shade matching. Group 2 ($n = 134$) consisted of clinical students (3rd to 5th academic years) who had been educated in methods of shade matching. Group 1 which also served as the control had no previous knowledge of the use of the Vita Toothguide 3D-Master, whereas Group 2 did. None of the students received any additional training on the use of the Vita Toothguide 3D-Master before the study. Gender, eye color, and refraction problems were evaluated in all students. All students were divided into two groups as described above to assess the effect of education.

Study procedures

The study was completed in 3 weeks (15 working days) during the last 2 weeks of June and the first week of July 2009. Care was taken not to make any selection on cloudy or rainy days. The color-selection test was performed in daylight between 10:00 and 14:00. To prevent influence from other students, only one student was taken into the testing room at a time. A room that received daylight through a window was selected as the test room, and tooth-color matching was done on a table situated in front of the window. The table was neutral gray, as this is the ideal background color. Each student completed the test in the same room, using the same table and in the same sitting position. Students were instructed to sit in an upright position in the chair, not to approach the samples closer than 25 cm, and make their shade selection at a 45° vision angle. This was further controlled by the instructor.

Three artificial maxillary right central incisors produced by Vita (Vitapan acrylic denture teeth, T 56 mold, Vita Zahnfabrik) with colors of 2L1.5, 1M2, and 2R1.5 were used. Numbers 1–3 were gently scraped in the back of the three artificial teeth, while ensuring that this caused no change in the tooth color. Students were asked to find the color of the artificial tooth in the Vita Toothguide 3D-Master and write down this color adjacent to the number of the specific tooth. No information was given to the students regarding the shade of the tooth. One minute was given to match the shade of each tooth, and thus the total time required was 3 minutes. When necessary, students were asked to rest their eyes by looking at a blue plaque placed on a corner of the table.

The exact matching rate, defined as the correct matching of all three shade components (hue, value, and chroma) for all three tooth shades by a student, was calculated and analyzed. Exact matching rates were calculated and compared in terms of the following parameters: availability of clinical training (preclinical *vs.* clinical academic terms), gender, eye color (brown, black, blue, green, or hazel), and the presence or absence of refractive errors (use of eye glasses or contact lenses). The variables likely to affect shade matching were separately analyzed.

Statistical analysis

Statistical analyses of the data were performed using the NCSS 2007 software package (NCSS, Utah, USA). Furthermore to descriptive statistics (mean, standard deviation, and frequency distribution), a Chi-squared test was used to compare the qualitative data. A P value of <0.05 was considered significant.

Results

Exact matching rates for all students and subgroups are presented in Table 1. Although there was a difference between academic years, it did not reach statistical significance. But when students were grouped based on their clinical experience and educational level, i.e., students in preclinical terms versus clinical years, students in the 3rd, 4th and 5th years performed better in terms of exact matching (29.4% *vs*. 22.5%, P = 0.034), compared with students in the 1st and 2nd years. On the other hand, neither gender, eye color, nor refraction error status had any effect on the ability to correctly match the colors.

Exact matching rates for each component of the color

Three test colors were compared for exact matching. A statistically significant difference was determined between the correct matching of colors 1M2 and 2L1.5 (31.1% *vs*. 20.5%, P = 0.007) (Table 2).

Test colors (2L1.5, 1M2, and 2R1.5) were compared in terms of the correct matching rates for each color component (value, hue, and chroma). For 2L1.5, the exact matching rate for the value was significantly higher compared with hue and chroma. For 1M2, the exact matching rate for hue was significantly higher than the other two color components. For 2R1.5, a higher rate of correct matches was found for value, compared with hue and chroma. Overall, the exact matching rate for the value was higher than for hue or chroma (Table 3).

The correct and incorrect match results of the groups for the three colors (2L1.5, 1M2, and 2R1.5) according to gender, eye color, status of eye, and dental education years are given in Table 4.

Discussion

The present study supports the favorable role of education and clinical experience in tooth-shade matching by dental students. Dental students represent a suitable population to test shade-matching abilities, because they are usually young adults in the same age range, have some or no experience in color matching, and are likely to have fewer systemic conditions that might affect shade perception.[1,18,22] Fiorentini et al.[23] reported a small, nonspecific decrease in the response of the visual system to luminance and color contrast with increasing age. The present study was conducted with students aged 20–24 years, representing an age range associated with the most-accurate color perception and discrimination.

Della Bona et al.[9] reported that previous training in shade matching and experience in dentistry had important roles in correct shade matching. However, in a study by Curd et al.,[11] experience did not affect the shade-matching

Table 1 Exact shade matching rates for all students and subgroups[b].

Students	Number of exact matches[a]	Percentage of exact matches (%)	P
Group 1			
1st and 2nd terms (Preclinical students)	74	22.4	0.034
Group 2			
3rd, 4th and 5th terms (Clinical students)	118	29.4	
Eye color			
Brown	131	25.2	0.433
Black	9	25.0	
Blue	11	40.7	
Green	24	29.6	
Hazel	17	24.6	
Refraction problems			
No refraction problems	96	26.2	0.445
Using eye glasses	43	29.9	
Using contact lenses	53	23.9	
Gender			
Female	115	27.8	0.277
Male	77	24.2	

A P value is for the difference between subgroups.
[a] Number of observations with correct match. A total of 3 observations were made in each student for three predefined shades (2L1.5, 1M2, and 2R1.5).
[b] Indicates a correct match of all three shade components (value, hue, and chroma).

Table 2 Three test colors compare exact shade matching.

	2L1.5		1M2		2R1.5		P*
	Number of matches	Percentage of exact matches	Number of matches	Percentage of exact matches	Number of matches	Percentage of exact matches	
Correct	50	20.5	76	31.1	66	27	0.02
Incorrect	194	79.6	168	68.9	178	73	
Total	244	100	244	100	244	100	

*A P value is for the difference between groups.

scores of dental students. In the present study, 1st and 2nd year dental students (Group 1) had no experience with shade matching. With increasing clinical experience during the 3rd, 4th and 5th years (Group 2), their ability to match colors improved. Furthermore to the beneficial effects of clinical practice, their information on tooth color and shade guides had developed through the aid of theoretical lectures. Thus, owing to their increased knowledge and clinical experience, they were expected to make more-precise shade matches. As expected, the success rate of Group 2 (29.4%) in exactly matching the tooth color was higher than that of Group 1 (22.4%).

Lighter shades (2L1.5, 1M2, and 2R1.5) were selected for matching in our tests. Test shades were similar colors, but they had different hue values, so that students had to focus considerable attention distinguishing the different colors. Among all tests, 1M2 was scored with a high success rate. The following interpretation was made for the statistically significant difference between 1M2 and 2L1.5. With the Vita Toothguide 3D-Master, L represents yellowish and R reddish tooth colors.[6,7,11] As a person ages, the cornea turns yellowish-brown, and a tendency begins towards these colors at an age of about 30 years.[1,18,22] We believe that our students had not yet been affected by these changes in the eye, since they were all under 30 years of age. Capa et al.[15] reported that older participants with more-professional experience may have matched shade 2L1.5 more easily because of these age-related eye changes.

The Vita Toothguide 3D-Master is a new-generation tool used for color matching in the last 10 years.[4,6] The manufacturer of the Vita Toothguide 3D-Master claims that it provides simple, consistent, and reproducible shade matching.[8] The Vita Toothguide 3D-Master is a system providing a more accurate shade matching capacity and value-based. The reason for this is because of our eye's sensitivity to changes in lightness—darkness and chroma rather than subtle changes in hue.[1,3] Considering the above mentioned advantages and plenty of color options, the Vita Toothguide 3D-Master was selected for tooth color matching in the present study.

The type of lighting can affect shade matching. Neutral light and north sky daylight were suggested as the best lighting conditions. In the present study, shade-matching tests were conducted in daylight at 10:00—14:00.[1,5] In some studies, better shade-matching abilities with a light-correcting source have been reported compared with natural light.[9,11] However, daylight was used in the present study because of its conviency, readily availability and the requirement of no additional instrument.

Many studies investigated the effect of the dentist's gender on tooth color matching.[5,11,14,16] There are also some differences between men and women in terms of color vision deficiencies and genetics.[5,14] Mollon stated that men are basically trichromatic.[14,16] If women are heterozygous for one of the photo pigments, they are in fact tetrachromatic, which may provide them with an additional advantage in terms of color discrimination.[5,11,16] Color vision deficiency is an X-linked recessive hereditary disorder for which women are carriers and men inherit the disease. Approximately 8% of men and up to 2% of women are color deficient in the general population. It is generally thought that women are more capable in color matching compared with men. Therefore, women may perform more-reproducible and communicable color matching.[8,11] However, contrary to this information, many studies did not identify any significant influence of gender on color-matching abilities. The dental shade color discrimination ability seems to be quite similar among the two genders, and gender was not found to be a factor in color matching.[4,5,11] In line with previous findings, male and female students had similar exact color matching rates in the present study.

The eye colors of subjects were black, brown, green, blue, and hazel, with brown being the most common. There are higher amounts of melanin in brown eyes, providing them with the capacity to absorb wavelengths better. On

Table 3 Comparison of correct and incorrect matches of value, hue and chroma of three colors.

		2L1.5		1M2		2R1.5		Total		
Value	Correct	181	74.2%	85	34.8%	146	59.8%	412	56.3%	χ^2: 78.63
	Incorrect	63	25.8%	159	65.2%	98	40.2%	320	43.7%	P = 0.0001
Hue	Correct	53	21.7%	156	63.9%	78	32.0%	287	39.2%	χ^2: 99.25
	Incorrect	191	78.3%	88	36.1%	166	68.0%	445	60.8%	P = 0.0001
Chroma	Correct	101	41.4%	96	39.3%	93	38.1%	290	39.6%	χ^2: 0.56
	Incorrect	143	58.6%	148	60.7%	151	61.9%	442	60.4%	P = 0.756

Table 4 Comparison of correct and incorrect matches of three colors according to the all variable factors.

	Shade		Correct		Incorrect		
Gender	2L1.5	Female	33	66.0%	105	54.1%	χ^2: 2.28
		Male	17	34.0%	89	45.9%	P = 0.131
	1M2	Female	46	60.5%	92	54.8%	χ^2: 0.708
		Male	30	39.5%	76	45.2%	P = 0.4
	2R1.5	Female	36	54.5%	102	57.3%	χ^2: 0.149
		Male	30	45.5%	76	42.7%	P = 0.699
Years of dental students	2L1.5	1.year	11	22.0%	50	25.8%	
		2.year	9	18.0%	40	20.6%	
		3.year	9	18.0%	36	18.6%	
		4.year	12	24.0%	24	12.4%	χ^2: 4.41
		5.year	9	18.0%	44	22.7%	P = 0.353
	1M2	1.year	22	28.9%	39	23.2%	
		2.year	10	13.2%	39	23.2%	
		3.year	18	23.7%	27	16.1%	
		4.year	12	15.8%	24	14.3%	χ^2: 5.6
		5.year	14	18.4%	39	23.2%	P = 0.231
	2R1.5	1.year	14	21.2%	47	26.4%	
		2.year	8	12.1%	41	23.0%	
		3.year	11	16.7%	34	19.1%	
		4.year	14	21.2%	22	12.4%	χ^2: 8.16
		5.year	19	28.8%	34	19.1%	P = 0.086
Eye color	2L1.5	Brown	36	72.0%	137	70.6%	
		Black	2	4.0%	10	5.2%	
		Blue	4	8.0%	5	2.6%	
		Green	6	12.0%	21	10.8%	χ^2: 5.3
		Hazel	2	4.0%	21	10.8%	P = 0.258
	1M2	Brown	53	69.7%	120	71.4%	
		Black	5	6.6%	7	4.2%	
		Blue	3	3.9%	6	3.6%	
		Green	8	10.5%	19	11.3%	χ^2: 0.695
		Hazel	7	9.2%	16	9.5%	P = 0.952
	2R1.5	Brown	42	63.6%	131	73.6%	
		Black	2	3.0%	10	5.6%	
		Blue	4	6.1%	5	2.8%	
		Green	10	15.2%	17	9.6%	χ^2: 4.77
		Hazel	8	12.1%	15	8.4%	P = 0.312
Eye status	2L1.5	No refraction problems	28	56.0%	94	48.5%	
		Eye-glasses	10	20.0%	38	19.6%	χ^2: 1.28
		Contact lens	12	24.0%	62	32.0%	P = 0.526
	1M2	No refraction problems	36	47.4%	86	51.2%	
		Eye-glasses	18	23.7%	30	17.9%	χ^2:1.12
		Contact lens	22	28.9%	52	31.0%	P = 0.57
	2R1.5	No refraction problems	32	48.5%	90	50.6%	
		Eye-glasses	15	22.7%	33	18.5%	χ^2:0.542
		Contact lens	19	28.8%	55	30.9%	P = 0.763

the other hand, light-colored eyes such as blue eyes reflect wavelengths.[20,25,26] Although sight may be affected by this difference, it exerts no influence on the perception of color. Cones located in the eyes serve as receptors of color and the way color originates in the human brain is by qualitative differences in photosensitivity.[1] Distinct perception is achieved by eye and mind through comparison and contrast. As a result, structures forming eye color have no influence on perception of color. In the present study, in line with this information, there was no significant difference between the shade-matching ability of subjects with different eye colors. However, to provide firm conclusions, studies with larger sample sizes are warranted.

In case a person who has uncorrected refraction errors, there is a difficulty in discrimination of colors with different wavelengths. This may influence the overall result. This implies that a person with myopia or hypermetropia has difficulty in the perception of green and red causing him or her to be more prone to make incorrect matches.[18] Individuals with uncorrected refraction errors were not included in the present study; but those with eye glasses or contact lenses were. There was no association between the presence of a corrected refraction error and a weaker shade matching ability. Although some individuals may need to undergo slight changes in eye refraction corrections as a result of periodical checkups, the influence of such matching is considered negligible. On the other hand, more detailed investigation on this topic is warranted for definite conclusions.

It is noteworthy to mention the limitations of the present investigation. This study attempted to evaluate the effects of individual factors and education on tooth-shade matching. To comment on possible influences that might have resulted from eye color and the use of eye glasses or contact lens, all students at a certain education level were considered. However, the number of assessed individuals is one of the drawbacks of the study, because a relatively limited number of students had different eye colors and used eye glasses or contact lens. Furthermore, in clinical studies, it is practically impossible to provide exact standardization.

Conclusions

The results of the present study indicate that individual factors such as gender, eye color, and eye health had no significant influence on tooth-color selection. On the other hand, acquired factors such as clinical education and experience gained later in life did have a positive effect on this ability. Considering the positive effects of education and practical experience on tooth-shade matching, it seems clear that more emphasis should be placed on educational programs for tooth-shade matching. The shade-matching ability of dental students can be improved with advanced education by inclusion of clinical practice into dental programs.

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