Open Access

Check for updates

International Journal of Medical Science and Dental Health (ISSN: 2454-4191)
Volume 11, Issue 12, December 2025
Doi: https://doi.org/10.55640/ijmsdh-11-12-13

The Impact of Education on the Ability to Determine Composite Color in Dental Students: A Semi-Experimental Study

Maryam Moradnia
MD, Oral and dental health research center, factulty of dentistry, Ilam University of Medical sciences, Ilam, Iran

Fahimeh Feili
MD, Oral and dental health research center, factulty of dentistry, Ilam University of Medical sciences, Ilam, Iran,
Assistant Professor of Restorative Dentistry, Department of Restorative Dentistry, School of Dentistry, Ilam University of Medical sciences, Ilam, Iran

Corresponding: - Fahimeh Feili

Received: 11 October 2025, **accepted:** 19 December 2025, **Published Date:** 27 December 2025

Abstract

Introduction: Matching tooth color with restoration is a crucial task in restorative dentistry. Aesthetic dental education plays a significant role in training individuals on color matching. Therefore, this study aims to investigate the impact of education on the ability to determine composite color in dental students.

Methods: In this semi-experimental study, 40 clinical dental students were randomly assigned to control and experimental groups. Initially, both groups were evaluated for their color assessment abilities. The experimental group then received one-hour training from a specialist in restorative and aesthetic dentistry on proper color determination, while the control group received no intervention. To assess their ability to determine tooth color, students were asked to match six composite samples with a color selection set made from the same composites. Statistical analysis of the data was performed using SPSS software and the Chi-square statistical test.

Results: The ability to determine composite color in all samples (except sample 1) significantly improved after training compared to before training ($P<0.05$). There were no significant statistical differences in the ability to determine composite color based on gender (except in sample 2). However, individuals without a history of wearing glasses performed significantly better than those with such a history in samples 2 and 6 ($P<0.05$). Additionally, ninth-semester students showed a significantly better ability to determine composite color compared to tenth and eleventh-semester students in samples 1, 2, 4, and 6 ($P<0.05$).

Conclusion: Education greatly influences the ability of dental students to determine composite color accurately. This study highlights the importance of proper training in color matching for dental students, particularly in restorative dentistry.

Keywords: Education, Color, Color Determination, Dental Students.

Introduction, Background

Today, attention to aesthetic aspects is one of the most important issues in the provision of dental treatments [1]. With the rise in cultural standards and the growth and development of oral health, people's focus on having beautiful-looking teeth is increasing day by day. When performing aesthetic treatments, dentists must not only possess the necessary knowledge but also consider other artistic factors such as composition, shape, symmetry, proportion, color, and translucency of the treated tooth, as well as its harmony with the remaining teeth and the patient's face, in order to achieve the desired outcome [2]. Accurate and predictable color matching for dental restorations can be challenging for dentists and dental technicians [2, 3]. Visual color matching using shade guides remains the most commonly used method [4]. This seemingly simple method of comparing and matching colors with shade guides often leads to errors that can range from minor to severe discrepancies [3, 5].

In contrast, tools and systems for dental color matching can significantly ease this process; however, they are still less utilized in practice and can cause confusion for clinicians in certain conditions due to their high precision. Furthermore, instrumental color assessment should be used as an aid for visual evaluation, as these tools do not account for some inherent characteristics of the dental environment, such as the complex geometry of teeth, surface texture, translucency, and color variability [2, 5]. The quality of color matching depends on several related factors, such as the eye's ability to perceive color differences, color matching tools, methods and conditions, as well as the physiological status of the dentist and medications used [6, 7].

The impact of gender on color matching skills remains a controversial topic among researchers. Some have concluded that women achieve better results than men [8]. Other studies reported no effect from differences in experience, profession, or age [9]. Conversely, numerous studies have shown that education has a positive impact on color matching skills [10]. Although color perception is subjective and varies among individuals, Egger demonstrated that recognition, understanding, and feeling of color improve with training in color science; patients tend to agree more with colors chosen by restorative or prosthetic specialists compared to those selected by general dentists [11]. It has also been observed that students face significant challenges in color selection [12]. In this context, another study showed that clinicians have greater abilities in color selection compared to dental students; this indicates that structured training courses play a crucial role in improving color understanding [13].

Therefore, this study aims to investigate the impact of education on the ability to determine composite color in dental students.

Materials and Methods

This research was a semi-experimental study conducted on 40 clinical dental students from the Faculty of Dentistry during the academic year 2021. The students were randomly divided into two groups of 20: a control group and an experimental group.

To determine the sample size, the study by Jasinevicius and colleagues was referenced [14]. The mean score of Shade-Matching Abilities in the control group was 10.1 ± 2.2, and in the training group, it was 12.01 ± 1.9. With a type I error rate of 5% and a power of 80%, the sample size was calculated to be 18 individuals in each group using a specific formula. To account for potential sample attrition, an additional 10% was added to this number, resulting in a final consideration of 20 individuals in each group (40 individuals in total).

$$n = 2 * \frac{\left(Z_{\frac{\alpha}{2}} + Z_{\beta}\right)^2 * {S_t}^2}{(\mu_1 - \mu_2)^2} \sim 18$$

Assessment of Color Determination Ability

The assessment of color determination ability was conducted in two phases, one month apart, under identical conditions. Participants in this study were tested for visual health and the detection of color blindness or color discrimination deficiencies using the Ishihara test. Those with color blindness or color discrimination defects were excluded from the study. The variables included education, age, academic semester, gender of participants, and history of using prescription glasses and contact lenses.

Initially, the ability to assess color was evaluated in both groups. Then, the intervention phase began. The training for the experimental group included participating in a one-hour lecture by a specialist in restorative and aesthetic dentistry on proper color determination, as well as providing a booklet for their reference. No intervention was performed for the control group.

To prepare the necessary samples, 12 transparent anatomical temporary crowns (Tor VM 1.910, Tranc Crown Kit) produced in Russia were used for central incisors. This ensured that all samples were similar in shape, contour, and dimensions to prevent any dimensional discrepancies from affecting the participants' visual assessments. Kerr nano filled composite from the United States was utilized in this study. The unknown samples and shade guide samples were equally made from various types of composite shades.

Six unknown color samples were placed on a specific panel, and students determined their colors in separate sessions but under identical conditions. A shade guide was created using six additional samples, which the participants used to select the color sample. To reduce confounding factors such as differences in materials between the unknown samples and shade guide, we ensured that both the unknown samples and the shade guide used for accurate color selection were made from the same material.

The order of the color samples, as follows, was provided to the student conducting the study by the supervising professor at the end of the study for data analysis. Throughout the study, the mentioned student was unaware of the order of the colors.

Considering that the tooth color of most people in society falls within group A (according to the Vita Classic shade guide), and the ability to identify this color is important for dental professionals, there is also an increasing desire among the public for whiter teeth. Therefore, distinguishing colors from group B and the shades used in cosmetic dentistry will also be significant. For this reason, we utilized colors from groups A and B, as well as translucent enamel, in this study. To create the samples, an incremental layering method was employed for placing the composite. Approximately 2 mm of composite was packed inside a transparent crown, which was then held with tweezers. The composite was cured from three sides: facially, palatally, and cervically, for about 20 seconds using a Demiplus light-curing device from the USA. To enhance bonding and structural integrity between layers, a sixth-generation self-adhesive Clearfil Liner Bond from Kuraray, Japan, was used. The subsequent layer was also packed to a thickness of 2 mm onto the previous layer and cured using the aforementioned method until the crown was completely filled, resulting in the complete shape of a central incisor. In samples related to the shade guide, when half of the transparent crown of composite was placed, the corresponding shade tab was positioned in the crown. The process of adding composite continued as described until the transparent crown was fully filled and shaped like a central incisor. Finally, the transparent crowns were cut from the palatal side with a scalpel. The resulting samples were first polished with fine-grit diamond burs and then finished with Kerr Optidisk discs and Kerr composite polishing rubbers to achieve a smooth and polished surface similar to that found in natural or polished teeth. The unknown samples (six samples) were fixed on a blue board (20 × 15 cm). The blue color complements the colors present in teeth and not only prevents misjudgment in color identification but also reduces eye fatigue. The blue board, labeled with numbers 1 to 6 for the unknown samples, was mounted on the unit's head so that participants could experience conditions similar to a clinical setting while seated in a dental chair. The shade guide samples were labeled with Latin letters U, V, W, X, Y, Z and were provided to students from both groups for testing. Students were asked to determine the colors of the samples and enter their selected color into researcher-created information charts. The test was conducted just like it would be in a clinic for each participant. The spatial, temporal, and environmental conditions were uniform for all participants. The color selection process took place between 11 AM and 12 PM in non-cloudy weather inside a room by a window under natural daylight (not under standardized conditions for visual tests).

Figure 1. Shedguide examples with Latin letters U, V, W, X, Y, Z

The students' information and their responses for determining the colors of the samples were recorded in researcher-created information charts. Each student's information included: their first and last name, academic term, gender, history of using glasses and contact lenses, and their color determination responses for each sample. The conditions for color determination for the two specialists in restorative and cosmetic dentistry participating in the study were the same, and the results from their tests were also noted in the corresponding questionnaire. It is important to mention that none of the participants were aware of a retest scheduled for one month later, to prevent any intentional efforts to enhance their color determination knowledge during this time, which could affect the results. Additionally, during both stages of color determination, students were instructed not to stare at each sample for more than 5 seconds. They were then asked to look at a gray card provided to them for 5 seconds to alleviate eye fatigue, allowing the color-detecting cells in their eyes to become sensitive again so they could better identify the correct color in the second stage. In determining the colors of the samples, responses were analyzed at two levels (Hue and Chroma). First, participants were asked to correctly guess the hue they perceived, and second, to identify the chroma value associated with each color sample. Additionally, the overall correctness of a response was evaluated without distinguishing between hue and chroma. The data obtained from both assessments were subjected to statistical analysis and compared before and after training. For qualitative data description, percentages and frequencies were used, while means and standard deviations were used for quantitative data description. To assess the percentage of correct identification between the two groups, a chi-square test was employed; if its assumptions were not met, Fisher's exact test was used. Furthermore, to evaluate individuals' agreement with themselves before and after testing, agreement percentages and kappa statistics were utilized. All analyses were conducted using SPSS software with a significance level set at 5%.

Results

According to Table 1, in samples 2, 3, 5, and 6, the selection of hue after training was significantly better than before training (P=0.016, P=0.031, P=0.008, and P=0.001). However, no statistically significant differences were found in the selection of hue before and after training for the other samples (P>0.05). Additionally, in samples 2, 3, and 6, the selection of chroma after training was significantly better than before training (P=0.016, P=0.001, and P=0.004). No statistically significant differences were observed in the selection of chroma before and after training for the remaining samples (P>0.05). Moreover, overall, the ability to determine the color of the composite in all samples except sample 1 was significantly better after training compared to before training (P=0.008, P=0.001, P=0.004, P=0.001, and P=0.008).

Table-1: Determining the ability to determine the color of the composite in students of the Faculty of Dentistry by the time of training (before and after training)

sample		response	N (Percent)		p-value
			Before education	after education	
hue&value	sample1	False	7 (17.5%)	6 (15%)	0.999
		True	33 (82.5%)	34 (85%)	
	sample2	False	18 (45%)	11 (27.5%)	0.016*
		True	22 (55%)	29 (72.5%)	
	sample3	False	11 (27.5%)	5 (12.5%)	0.031*
		True	29 (72.5%)	35 (87.5%)	
	sample4	False	19 (47.5%)	13 (32.5%)	0.070
		True	21 (52.5%)	27 (67.5%)	
	sample5	False	21 (52.5%)	13 (32.5%)	0.008*
		True	19 (47.5%)	27 (67.5%)	
	sample6	False	5 (12.5%)	0 (0%)	0.001*
		True	35 (87.5%)	40 (100%)	
chroma	sample1	False	14 (35%)	11 (27.5%)	0.375
		True	26 (65%)	29 (72.5%)	
	sample2	False	18 (45%)	11 (27.5%)	0.016*
		True	22 (55%)	29 (72.5%)	
	sample3	False	18 (45%)	6 (15%)	0.001*
		True	22 (55%)	34 (85%)	
	sample4	False	7 (17.5%)	3 (7.5%)	0.125
		True	33 (82.5%)	37 (92.5%)	
	sample5	False	5 (12.5%)	2 (5%)	0.250
		True	35 (87.5%)	38 (95%)	
	sample6	False	14 (35%)	5 (12.5%)	0.004*
		True	26 (65%)	35 (87.5%)	
total	sample1	False	15 (37.5%)	11 (27.5%)	0.219
		True	25 (62.5%)	29 (72.5%)	
	sample2	False	18 (45%)	10 (25%)	0.008*
		True	22 (55%)	30 (75%)	
	sample3	False	17 (42.5%)	6 (15%)	0.001*
		True	23 (57.5%)	34 (85%)	

	sample4	**False**	**25 (62.5%)**	**16 (40%)**	**0.004***
		True	**15 (37.5%)**	**24 (60%)**	
	sample5	**False**	**24 (60%)**	**13 (32.5%)**	**0.001***
		True	**16 (40%)**	**27 (67.5%)**	
	sample6	**False**	**13 (32.5%)**	**5 (12.5%)**	**0.008***
		True	**27 (67.5%)**	**35 (87.5%)**	
***: significant at 0.05**					

According to Table 2, in samples 1 and 2, the male participants in the experimental group showed significantly better hue selection compared to those in the control group (P=0.041 and P=0.001). However, no statistically significant differences were found in hue selection between the control and experimental groups for the other samples, for both men and women (P>0.05). Additionally, in samples 1 and 2, the male participants in the experimental group had significantly better chroma selection than those in the control group (P=0.002 and P=0.001). Again, no statistically significant differences were observed in chroma selection between the control and experimental groups for the other samples, for both men and women (P>0.05). Furthermore, overall, the ability to determine the color of the composite in samples 1, 2, and 4 was significantly better among male participants in the experimental group compared to those in the control group (P=0.002, P=0.001, and P=0.013). For the other samples, there were no statistically significant differences in color determination ability between the control and experimental groups for both men and women (P>0.05).

Table-2. Determining the ability to determine the color of the composite in students of the Faculty of Dentistry by gender (male and female)

sample		result	female			Male		
			N (Percent)		p-value	N (Percent)		p-value
			Cont	Interv		Cont	Interv	
hue&value	sample 1	False	0 (0)	0 (11.1)	0.999	5 (38.5)	0 (0)	0.041 *
		True	7 (100)	8 (88.9)		8 (61.5)	11 (100)	
	sample 2	False	1 (14.3)	1 (11.1)	0.999	9 (69.2)	0 (0)	0.001 *
		True	6 (85.7)	8 (88.9)		4 (30.8)	11 (100)	
	sample 3	False	1 (14.3)	0 (0)	0.438	4 (30.8)	0 (0)	0.098
		True	6 (85.7)	9 (100)		9 (69.2)	11 (100)	
	sample 4	False	5 (71.4)	2 (22.2)	0.126	5 (38.5)	1 (9.1)	0.166
		True	2 (28.6)	7 (77.8)		8 (61.5)	10 (90.9)	
	Sample 5	False	5 (71.4)	2 (22.2)	0.127	5 (38.5)	1 (9.1)	0.165
		True	2 (28.6)	7 (77.8)		8 (61.5)	10 (90.9)	
	sample 6	False	0 (0)	0 (0)	---	0 (0)	0 (0)	---
		True	7 (100)	9 (100)		13 (100)	11 (100)	

chroma	sample 1	False	1 (14.3)	2 (22.2)	0.999	8 (61.5)	0 (0)	0.002 *
		True	6 (85.7)	7 (77.8)		5 (38.5)	11 (100)	
	sample 2	False	1 (14.3)	1 (11.1)	0.999	9 (69.2)	0 (0)	0.001 *
		True	6 (85.7)	8 (88.9)		4 (30.8)	11 (100)	
	sample 3	False	1 (14.3)	1 (11.1)	0.999	4 (30.8)	0 (0)	0.098
		True	6 (85.7)	8 (88.9)		9 (69.2)	11 (100)	
	sample 4	False	0 (0)	0 (0)	---	3 (23.1)	0 (0)	0.223
		True	7 (100)	9 (100)		10 (76.9)	11 (100)	
	Sample 5	False	1 (14.3)	0 (0)	0.438	1 (7.7)	0 (0)	0.999
		True	6 (85.7)	9 (100)		12 (92.3)	11 (100)	
	sample 6	False	1 (14.3)	0 (0)	0.438	4 (30.8)	0 (0)	0.098
		True	6 (85.7)	9 (100)		9 (69.2)	11 (100)	
total	sample 1	False	1 (14.3)	2 (22.2)	0.999	8 (61.5)	0 (0)	0.002 *
		True	6 (85.7)	7 (77.8)		5 (38.5)	11 (100)	
	sample 2	False	1 (14.3)	0 (0)	0.438	9 (69.2)	0 (0)	0.001 *
		True	6 (85.7)	9 (100)		4 (30.8)	11 (100)	
	sample 3	False	1 (14.3)	1 (11.1)	0.999	4 (30.8)	0 (0)	0.098
		True	6 (85.7)	8 (88.9)		9 (69.2)	11 (100)	
	sample 4	False	5 (71.4)	2 (22.2)	0.126	8 (61.5)	1 (9.1)	0.013 *
		True	2 (28.6)	7 (77.8)		5 (38.5)	10 (90.9)	
	Sample 5	False	5 (71.4)	2 (22.2)	0.045*	5 (38.5)	1 (9.1)	0.166
		True	2 (28.6)	7 (77.8)		8 (61.5)	10 (90.9)	
	sample 6	False	1 (14.3)	0 (0)	0.438	4 (30.8)	0 (0)	0.098
		True	6 (85.7)	9 (100)		9 (69.2)	11 (100)	
*: significant at 0.05								

According to Table 3, in samples 2, 4, and 5, participants with glasses in the experimental group had significantly better hue selection compared to those in the control group (P=0.010, P=0.035, and P=0.035). However, there were no statistically significant differences in hue selection between the control and experimental groups for the other samples, whether participants wore glasses or not (P>0.05).

Additionally, in samples 1, 2, and 6, participants with glasses in the experimental group showed significantly better chroma selection than those in the control group (P=0.035, P=0.010, and P=0.044). Again, no statistically significant differences were found in chroma selection between the control and experimental groups for the other samples, regardless of whether participants wore glasses or not (P>0.05).

Furthermore, overall, the ability to determine the color of the composite in all samples except sample 3 was significantly better among participants with glasses in the experimental group compared to those in the control group (P=0.035, P=0.010, P=0.001, P=0.035, and P=0.044).

Table-3. Determining the ability to determine composite color in dental school students according to the type of visual aids (glasses and lenses)

Samples		Result	No			Yes		
			N (Percent)		p-value	N (Percent)		p-value
			Control	Intervention		Control	Intervention	
Hue	sample1	False	2 (20)	1 (7.7)	0.560	3 (30)	0 (0)	0.228
		True	8 (80)	12 (92.3)		7 (70)	7 (100)	
	sample2	False	3 (30)	1 (7.7)	0.281	7 (70)	0 (0)	0.010*
		True	7 (70)	12 (92.3)		3 (30)	7 (100)	
	sample3	False	1 (10)	0 (0)	0.435	4 (40)	0 (0)	0.103
		True	9 (90)	13 (100)		6 (60)	7 (100)	
	sample4	False	4 (40)	3 (23.1)	0.650	6 (60)	0 (0)	0.035*
		True	6 (60)	10 (76.9)		4 (40)	7 (100)	
	Sample5	False	4 (40)	3 (23.1)	0.650	6 (60)	0 (0)	0.035*
		True	6 (60)	10 (76.9)		4 (40)	7 (100)	
	sample6	False	0 (0)	0 (0)	---	0 (0)	0 (0)	---
		True	10 (100)	13 (100)		10 (100)	7 (100)	
Chroma	sample1	False	3 (30)	2 (15.4)	0.618	6 (60)	0 (0)	0.035*
		True	7 (70)	11 (84.6)		4 (40)	7 (100)	
	sample2	False	3 (30)	1 (7.7)	0.281	7 (70)	0 (0)	0.010*
		True	7 (70)	12 (92.3)		3 (30)	7 (100)	
	sample3	False	1 (10)	1 (7.7)	0.999	4 (40)	0 (0)	0.103
		True	9 (90)	12 (92.3)		6 (60)	7 (100)	
	sample4	False	0 (0)	0 (0)	---	3 (30)	0 (0)	0.228
		True	10 (100)	13 (100)		7 (70)	7 (100)	
	Sample5	False	0 (0)	0 (0)	---	2 (20)	0 (0)	0.485
		True	10 (100)	13 (100)		8 (80)	7 (100)	
	sample6	False	0 (0)	0 (0)	---	5 (50)	0 (0)	0.044*
		True	10 (100)	13 (100)		5 (50)	7 (100)	
Total	sample1	False	3 (30)	2 (15.4)	0.618	6 (60)	0 (0)	0.035*

		True	7 (70)	11 (84.6)		4 (40)	7 (100)	
	sample2	False	3 (30)	0 (0)	0.068	7 (70)	0 (0)	0.010*
		True	7 (70)	13 (100)		3 (30)	7 (100)	
	sample3	False	1 (10)	1 (7.7)	0.999	4 (40)	0 (0)	0.103
		True	9 (90)	12 (92.3)		6 (60)	7 (100)	
	sample4	False	4 (40)	3 (23.1)	0.650	9 (90)	0 (0)	0.001*
		True	6 (60)	10 (76.9)		1 (10)	7 (100)	
	Sample5	False	4 (40)	3 (23.1)	0.650	6 (60)	0 (0)	0.035*
		True	6 (60)	10 (76.9)		4 (40)	7 (100)	
	sample6	False	0 (0)	0 (0)	---	5 (50)	0 (0)	0.044*
		True	10 (100)	13 (100)		5 (50)	7 (100)	
*: significant at 0.05								

According to Figure 1, in all samples, there were no statistically significant differences in hue selection between the control and experimental groups for both ninth-term students and tenth and eleventh-term students (P>0.05). Additionally, in all samples, there were no statistically significant differences in chroma selection between the control and experimental groups for both ninth-term students and tenth and eleventh-term students (P>0.05). Overall, the ability to determine the color of the composite did not show any statistically significant differences between the control and experimental groups for both ninth-term students and tenth and eleventh-term students (P>0.05).

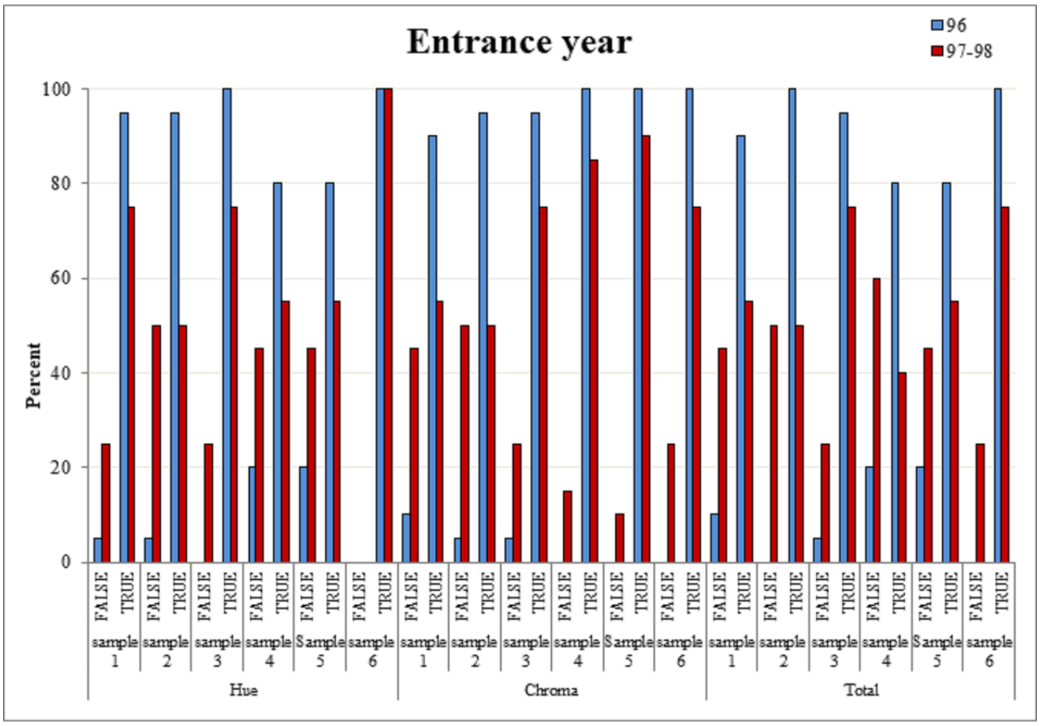

Figure-1 Determination of the ability to determine the color of composite in students of the Faculty of Dentistry by the year of entering the university (academic semester)

According to figure-1, in all samples, there was no statistically significant difference in Hue selection between the control and experimental groups, both in the 9th semester students and in the 10th and 11th semester students (P>0.05).

Discussion

The present study aimed to investigate the impact of training on the ability to determine the color of composite materials among dental students. The influence of various factors such as gender, use of visual aids, and the year of entry of the students on color determination ability was examined. In a study by Al-wahadni et al. [15], results indicated that patients were more satisfied with the colors chosen by specialists, which can be attributed to their greater work experience and familiarity with color selection principles [16]. The findings of the current study demonstrated that the ability to determine composite color improved significantly after training in all samples (except for sample one); in other words, training had a statistically significant effect on the ability to determine composite color. In the study by Samra et al. [5], which aimed to compare the Vita Classic and 3DM shade guides, results showed a clear improvement in the percentage of color matching following a video training session. Additionally, another study by Udiljak et al. [17] found that training influenced the color determination ability of the studied individuals (prosthodontic specialists, prosthodontic assistants, dental technicians, and dental students). Furthermore, Ristic et al. [18]observed that color matching scores improved significantly after training and practice, aligning with the findings of the present research. Due to the potential influence of gender on tooth color determination, gender differences were also examined in this study. Many studies have investigated the effect of gender on tooth color determination ability; however, there is no general consensus in this regard [4]. In this context, the results of the current study indicated that there were no statistically significant differences in color determination ability between women and men in all samples except for sample two, where 93.8% of women correctly identified the color compared to only 65.5% in men. Additionally, findings showed that training improved color determination ability in men from the experimental group compared to those in the control group in samples one, two, and four. In a study conducted by Abbasi et al. (22) examining the impact of two teaching methods (practical training and lecture-based training) on improving color determination skills among dental students, results indicated no significant differences between genders in most groups except for sample two regarding color determination. Moreover, another study by Nakhaei et al. [19]found no differences in the ability to identify Vita colors across different genders. Similarly, Curd et al. [20] showed that dental students did not exhibit significant differences in tooth color selection ability based on gender. Additionally, Daneshkazemi et al. [16] reported no statistically significant differences between men and women regarding their ability to correctly select all test colors; likewise, Aswini et al. [21]found no significant differences in color determination quality based on gender. Finally, studies by Davari et al. (14), Al-wahadni et al. [15], Winkler et al. [22], Samra et al. [5], and Capa et al. [12] also reported no statistically significant differences in color determination ability based on gender, aligning with the results of this study. However, Murray et al. [23] suggested that women have better color perception, particularly within red and green ranges, while men possess higher abilities to perceive brightness and darkness. Carsten hypothesized that individuals who do not select colors accurately may have difficulties in color discrimination; many men may experience this disorder known as color vision confusion, which can be temporary or permanent [24]. Based on existing studies and information, females may have superior color vision capabilities compared to males due to how genes related to light-sensitive cells are inherited within the retina [25]. In this regard, Haddad et al. [6]concluded that women exhibited better color selection compared to men; furthermore, Udiljak et al.'s study [17] indicated statistically significant differences in color matching quality between men and women. Pohlen et al. [26] also observed that gender significantly affected color matching abilities and that women had better matching capabilities—findings that differ from those obtained in this study. Additionally, in this research, previous experience with glasses was examined as another potentially influential factor on color determination ability. Results indicated that individuals without a history of using glasses performed better than those with such a history across all samples; however, this difference was statistically significant only in samples two and six. Moreover, results showed that training improved color determination ability among individuals with a history of using glasses across all samples except for sample three; whereas for individuals without a history of using glasses, training did not have a statistically significant effect. Abbasi et al. (22) also demonstrated that except for sample one where individuals without a history of glasses performed better, there were no statistically significant differences between individuals with and without a history of using glasses for other samples; additionally, Capa et al. [27]reported no statistically significant effects of wearing glasses or contact lenses on accurate color matching abilities—results that can be somewhat aligned with those of the present study. Furthermore, Davari et al.'s research (14) revealed no significant statistical differences between choices made by students wearing glasses or contact lenses compared to those who did not wear glasses and had direct vision; similarly, this study found no statistically significant differences between individuals with and without a history of using glasses across most samples. Kazemi et al. [16] also indicated that individuals who used glasses or lenses had poorer performance in identifying test colors compared to others; they attributed this weak performance to uncorrected refractive errors or new defects occurring in their eyes during examination; other potential reasons could include using photochromic lenses by these individuals. Furthermore, the results of this study showed that students in their tenth and eleventh terms performed significantly better than ninth-term students in all samples except for samples three and five. This difference may be attributed to the greater experience and work history among tenth- and eleventh-term students. The findings also indicated that training did not have a statistically significant effect on composite color determination abilities based on the year of entry among students. Similar observations were made by Davari et al. (14), who found that eleventh-term students exhibited significantly better color determination abilities than ninth-term students. Additionally, Winkler et al.'s research [22] revealed that fourth-year students had better color determination skills compared to third-year students. Furthermore, Capa et al.'s study [12]showed that third-, fourth-, and fifth-year students outperformed first- and second-year clinical students regarding accurate color matching abilities. In this context, studies by Hammad [4]and Al-wahadni [15] demonstrated that education and experience during academic years positively influence correct color selection, a trend observable to some extent within this current research.

Conclusion

The results of this study suggest that training has a positive impact on dental students' ability to accurately determine composite colors during shade guide pairing tests. This highlights the crucial role of education in dentistry and emphasizes the necessity for a lifelong dedication to learning in this field. It is recommended that future studies focus on assessing the color determination skills of general dentists and specialists for comparative purposes. Additionally, it is suggested that further research explore the influence of different educational approaches on dental students' ability to determine colors, both in real-life situations and through comparative evaluations.

Acknowledgements:

We would like to thank the Deputy of Research of Ilam University of Medical Science, Ilam, Iran.

Ethical issues

In order to carry out this research, the necessary permission was obtained from the Vice

Chancellor for Research of Ilam University of Medical Sciences. (Code ethical:

IR.MEDILAM.REC.1400.246). All ethical principles were considered in this article. The

participants were informed about the purpose of the research and its implementation stages; they

were also assured about the confidentiality of their information.

Competing interests

The authors declare that they have no conflict of interests.

Study highlights

Given the importance of correct tooth color selection and the inconsistencies observed in accurate tooth color diagnosis by dental students—who are the future dentists—this study was conducted to investigate the impact of education on the ability to determine composite color in dental students.

-This multifaceted approach ensures that research findings are not just known but effectively translated into improved patient care in everyday clinical settings.

- Use the study results to guide therapeutic choices, improving precision in treatment selection and management strategies, such as adopting biologically plausible interventions supported by randomized trials.

Contribution

FF and SHE developed and designed the evaluation, collected the clinical data (MM) and drafted the manuscript. FF, SHE and PR participated in the study conception and design, supervised the

study and revised the manuscript critically for important intellectual contents. FF revised the

manuscript critically for important intellectual contents. All authors read and approved the final

manuscript.

Funding: This study was supported by the Deputy of Research of Ilam University of Medical

Sciences.

Availability of data and materials

The datasets used and/or analyzed in the current study are attained from the corresponding author

on reasonable request.

Reference

1. Sturdevant CM, Roberson TM. The art and science of operative dentistry: Mosby Elsevier Health Science; 1995.
2. Chu SJ, Devigus A, Mieleszko AJC, IL. Fundamentals of color: shade matching and communication in esthetic dentistry. 2004.
3. Ivan R, Rade PJASN. COLOR MEASURING INSTRUMENTS. 2009;25(60).
4. Hammad IAJTJopd. Intrarater repeatability of shade selections with two shade guides. 2003;89(1):50-3.
5. Samra APB, Moro MG, Mazur RF, Vieira S, De Souza EM, Freire A, et al. Performance of dental students in shade matching: impact of training. 2017;29(2):E24-E32.
6. Haddad HJ, Jakstat HA, Arnetzl G, Borbely J, Vichi A, Dumfahrt H, et al. Does gender and experience influence shade matching quality? 2009;37:e40-e4.
7. Paravina RDJIJoP. Evaluation of a newly developed visual shade-matching apparatus. 2002;15(6).
8. Paravina RD, O'Neill PN, Swift Jr EJ, Nathanson D, Goodacre CJJJod. Teaching of color in predoctoral and postdoctoral dental education in 2009. 2010;38:e34-e40.
9. Sinmazisik G, Trakyali G, Tarcin BJTJoPD. Evaluating the ability of dental technician students and graduate dentists to match tooth color. 2014;112(6):1559-66.
10. Egger BJQ. Natural color concept: a systematic approach to visual shade selection. 2003;26:161-70.
11. Lagouvardos P, Diamanti H, Polyzois GJTEJoP, Dentistry R. Effect of individual shades on reliability and validity of observers in colour matching. 2004;12(2):51-6.
12. Capa N, Malkondu O, Kazazoglu E, Calikkocaoglu SJJoDS. Effects of individual factors and the training process of the shade-matching ability of dental students. 2011;6(3):147-52.
13. York WJBDJ. An Evaluation into dental shade matching. 2005;199(1):24-30.
14. Jasinevicius TR, Landers M, Nelson S, Urbankova A. An Evaluation of Two Dental Simulation Systems: Virtual Reality versus Contemporary Non-Computer-Assisted. Journal of Dental Education. 2004;68(11):1151-62.
15. Al-Wahadni A, Ajlouni R, Al-Omari Q, Cobb D, Dawson DJTJotADA. Shade-match perception of porcelain-fused-to-metal restorations: a comparison between dentist and patient. 2002;133(9):1220-5.
16. DANESHKAZEMI A, Besharati M, DAVARI A, KHANI BR. Assessment of color matching ability among the student of Yazd faculty of dentistry. 2008.
17. Udiljak Ž, Pezo H, Ćelić RJAsCIjoos, medicine d. Gender-Dependent Quality of Shade Matching of Dental Professionals and Students. 2020;54(4):363-70.
18. Ristic I, Stankovic S, Paravina RDJJoE, Dentistry R. Influence of color education and training on shade matching skills. 2016;28(5):287-94.
19. Nakhaei M, Ghanbarzadeh J, Keyvanloo S, Alavi S, Jafarzadeh HJTjocdp. Shade matching performance of dental students with three various lighting conditions. 2013;14(1):100.
20. Curd FM, Jasinevicius TR, Graves A, Cox V, Sadan AJTJopd. Comparison of the shade matching ability of dental students using two light sources. 2006;96(6):391-6.
21. Aswini KK, Ramanarayanan V, Rejithan A, Sajeev R, Suresh RJJoE, Dentistry R. The effect of gender and

clinical experience on shade perception. 2019;31(6):608-12.

22. Winkler S, Boberick KG, Weitz KS, Datikashvili I, Wood RJJoOI. Shade matching by dental students. 2006;32(5):256-8.

23. Murray IJ, Parry NR, McKeefry DJ, Panorgias AJJov. Sex-related differences in peripheral human color vision: a color matching study. 2012;12(1):18-.

24. Carsten DLJCoceid. Successful shade matching--what does it take? 2003;24(3):175-8, 80, 82 passim; quiz 88.

25. Fondriest JJIJoP, Dentistry R. Shade matching in restorative dentistry: the science and strategies. 2003;23(5):467-80.

26. Pohlen B, Hawlina M, Šober K, Kopač IJTIjop. Tooth Shade-Matching Ability Between Groups of Students with Different Color Knowledge. 2016;29(5):487-92.

27. Çapa N, Kazazoğlu E, Çalikkocaoğlu SJTJotADA. Evaluating factors that affect the shade-matching ability of dentists, dental staff members and laypeople. 2010;141(1):71-6.