Comparison of Time Consumption and Color Matching Results of Different Dental Occupational Groups

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Purpose: A study was conducted to compare the accuracy and time consumption of shade matching tasks performed by students, clinicians, and dental technicians. ***Materials and Methods:*** A total of 126 participants were asked to pair shade tabs and to choose the best shade match for three natural teeth using the Chromascop shade guide. Time consumption was recorded. The frequency of correct answers and time consumption results were compared across occupational groups and by levels of clinical experience. ***Results:*** No significant difference was found between occupational groups in shade tab pairing or natural tooth color matching. Experience did not affect the shade tab pairing, but experienced participants were better in natural tooth color matching. Clinicians performed the shade tab matching task faster than preclinical and clinical students, while technicians were faster than preclinical students. In the natural tooth color matching task, clinicians and technicians were faster than students. Regarding experience, novice observers were slower than experienced individuals. A significant negative correlation was observed between time consumption for visual shade matching and the frequency of correct matches for both shade tabs and natural teeth. ***Conclusion:*** The level of professional experience improved color matching of natural teeth. Overall, clinicians and dental technicians performed faster than students, while lower time consumption for shade matching was associated with better scores. *Int J Prosthodont 2013;26:478–486. doi: 10.11607/ijp.3398*

In today's world of growing esthetic demands and expectations for prosthodontic treatment, patients desire not only a healthy mouth, but also a perfect smile. Dissatisfaction with the appearance of teeth is considered a significant factor that negatively affects self-reported esthetics and quality of life.[1–4] Thus, when restoring teeth, especially in the esthetic region, color reproduction is very challenging.[5]

Tooth color is not uniform, but rather encompasses a wide range of different shades, translucencies, opacities, and characterizations that are sometimes difficult to detect with the human eye. Esthetic success depends on a shade match of a restoration with the adjacent teeth. Hence, shade selection is a very important step in prosthodontic therapy. Measurements of tooth color are generally divided into two categories: visual color matching and instrumental measurement. Visual color matching is based on the comparison of the object with a known color standard represented in shade guides. Some controllable and uncontrollable variables may affect the color perception, such as sex, age, external lighting conditions, metamerism, object position, previous experience, fundamental color matching ability, emotions, and fatigue.[6,7] Despite the limitations, visual color matching still remains the most commonly used method in everyday paractice[8] due to its low time consumption and cost effectiveness. As an attempt to overcome the subjectivity of visual color matching in dentistry, instruments such as spectrophotometers and colorimeters have been introduced. Instrumental readings can quantify color and make color matching more objective. However, the widespread use of the instrumental method in clinical practice has been hindered by the fact that the equipment is complex and expensive.[5]

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There have been several studies examining the influence of different factors on color matching accuracy within groups of clinicians, dental technicians, or dental students,[9,10] but studies investigating the differences in color matching accuracy and time consumed for the task between groups are scarce.[11] Many dental students are required to select tooth color in a teaching environment. Hence, the question arises if the dental student is competent to do so with no experience in this area. However, controversial opinions and findings regarding the influence of professional experience on color matching ability have been reported.[10,12–14]

Staring at an object for longer than a few seconds during the color selection process leads to eye fatigue due to overstimulation of color sensors of the retina.[15] It has been reported that the color vision capability of both eyes decreases when a tooth is viewed for longer than 10 seconds.[16] The observed color becomes less and less saturated while simultaneously increasing the chroma of complementary colors. Hence, rapid shade comparisons are recommended and first color impressions may be considered the most accurate.

The aims of this study were to compare the tooth color matching ability and time consumption for given tasks performed by preclinical dental students, final-year dental students, clinicians, and dental technicians with normal color vision as well as to evaluate the influence of professional experience.

Materials and Methods

Upon approval from the Ethics Committee of the School of Dental Medicine, University of Zagreb, every participant signed an informed consent form. Because color vision ability can affect shade selection, participants were initially tested for color deficiency using the Neitz test of color vision, and individuals suspected for color blindness were excluded.

The study involved 36 preclinical students (third year of study; 26 women, 10 men) without any clinical experience (mean age, 22.1 years), 32 final-year students (sixth year of study; 14 women, 18 men) with varying levels of shade matching experience in a teaching environment (mean age, 24.9 years), 32 clinicians (20 women, 12 men) with varying degrees of clinical experience who routinely performed tooth color matching (mean age, 35.2 years), and 26 dental technicians (24 women, 2 men) with varying clinical experience who routinely performed tooth color matching (mean age, 45.0 years). Besides the occupational groups, the participants were also categorized into three groups on the basis of their professional experience: *(1)* no experience (n = 68), *(2)* < 10 years experience (n = 24), and *(3)* ≥ 10 years experience (n = 34).

To achieve better standardization, the study was completed in the same room with neutral wall colors and a north-facing window, always at the same time between 10 am and 11 am.[17] Cloudy or rainy days were not included in the study.

The methods were similar to the concept described by Jaju et al,[9] except for the shade guide manufacturer. The ability of participants to match tooth color was evaluated by means of two tasks using three new Chromascop shade guides (Ivoclar Vivadent), assumed to be identical. Three shade tabs from the first set and an entire second shade guide were used for the first task (shade tab matching), while the third shade guide was used for the second task (natural tooth color matching). Thus, the selections for each participant were performed with the same shade guides. None of the participants received any additional training before testing. To prevent mutual influence, each participant was tested separately.

In the first task, participants were asked to perform a dentistry related color matching test by pairing three Chromascop shade tabs. Three shade tabs with masked identification codes on the tab handle from the first shade guide were numbered (tab 1 = 2A, tab 2 = 3E, and tab 3 = 4B). Before each observer's visual shade tab selection, the shade tabs and the corresponding pairs were identified instrumentally using the intraoral spectrophotometer (Spectroshade Micro, MHT) to make sure that the shade tabs were identical. This was done because shade guides from the same manufacturer can bear differences among shades that are stated to be the same.[18,19] The participants were asked to match each shade tab with its counterpart from the second shade guide. A gray panel, which is considered neutral, served as background.[20] The answers were recorded on a survey form where participants also provided information regarding their age, sex, profession, and number of years of professional experience. No time limit was set, but the participants were advised to complete the tasks as fast as possibile. The main investigator recorded the time required to choose and write down all answers in the shade pairing task for each observer.

The second task was to determine the color of three natural maxillary right central incisors of three staff members from the School of Dental Medicine in Zagreb. The teeth were numbered 1, 2, and 3, and the participants were asked to choose and write down the best matching color from the Chromascop shade guide. External visual influences, such as lipstick, were removed, and neutral gray clothing colors had to be worn during the testing. The survey form contained pictures of the teeth with a diagram

Fig 1 Instrumental color measurement of shade tabs.

Table 1 Frequencies of Correctly Matched Tabs and Teeth in Terms of Occupation and Professional Experience

	Tab			Tooth		
Group	1 (%)	2 (%)	3 (%)	1 (%)	2 (%)	3 (%)
Occupation						
Preclinical students	61	67	50	67	56	33
Final-year students	44	75	50	75	50	25
Dental technicians	69	77	54	77	62	46
Clinicians	69	81	69	81	81	50
Professional experience						
No experience	53	71	50	71	53	29
< 10 y	67	83	75	83	100	33
≥ 10 y	71	76	53	76	53	59

indicating the part of a tooth for which the color was to be determined. Generally, the middle third of the tooth is considered to best represent basic color[21]; thus, participants were asked to determine the color of that particular part of the tooth. The time required to complete the task was again recorded by the main investigator.

To analyze the color of each tooth, it was necessary to obtain CIE L*a*b* values. Thus, the main investigator measured the color of the three teeth using the spectrophotometer (Spectroshade Micro). Simultaneously, all shade tabs from the shade guide were also measured instrumentally and a color comparison was performed (Fig 1). The color difference ΔE* between each subject's tooth color and the color of each sample of the Chromascop shade guide was calculated according to the following equation[22,23]:

$$\Delta E^* = \{(L^*\text{target tooth} - L^*\text{shade guide})^2 + (a^*\text{ target tooth} - a^*\text{ shade guide})^2 + (b^*\text{ target tooth} - b^*\text{ shade guide})^2\}^{1/2}$$

The 20 ΔE* values that resulted from comparing the color parameters of each subject to those of the 20 samples of the shade guide were sorted. In the literature, results vary widely regarding the color difference between objects that are perceptible by the human eye.[24–26] In this study, among the samples from the shade guide, shades with $\Delta E^* \leq 2.69$[23] were considered acceptable matches and shades with $\Delta E^* > 2.7$ were considered mismatches.

The frequency of correct answers was calculated for both tasks. Comparisons between different occupational groups (preclinical dental students, final-year dental students, clinicians, and dental technicians) and between groups with different levels of professional experience (no experience, < 10 years experience, ≥ 10 years experience were performed by means of a chi-sqaure (χ^2) test (for each tab and each tooth; possible categories: correct or incorrect) and by the Fisher exact test for the total number of tabs and the total number of teeth (possible categories: 0, 1, 2, or 3 correct answers). One-way analysis of variance (ANOVA) and Sheffe post hoc tests were used to compare the time required to complete the tasks between different occupational groups and between groups with different levels of clinical experience. Correlations between the number of correct answers in both tasks and the time required to complete the tasks were analyzed using Spearman's rho. All computations were performed using the statistical software SPSS (version 15.0, SPSS, IBM) with significance set at .05.

Results

This study was conducted on a total of 126 participants who remained after three men were excluded in the beginning due to an insufficient Neitz test score.

The frequencies of correctly matched tabs or teeth for each of the three tabs or teeth are presented in Table 1. No significant differences in shade matching ability (percent of correct answers) for any of the three shade tabs were found between the different occupational groups (tab 1; $P = .139$; tab 2: $P = .568$; tab 3: $P = .371$), nor between groups with different levels of professional experience (tab 1: $P = .178$; tab 2: $P = .448$; tab 3: $P = .099$).

After comparing the color parameters of each tooth obtained instrumentally to those of the 20 samples of the Chromascop shade guide, according to the ΔE* value ≤ 2.69, acceptable colors for tooth 1 were 01 (ΔE* = 2.31) and 1A (ΔE* = 2.5); for tooth 2, acceptable colors were 01 (ΔE* = 1.65) and 1A

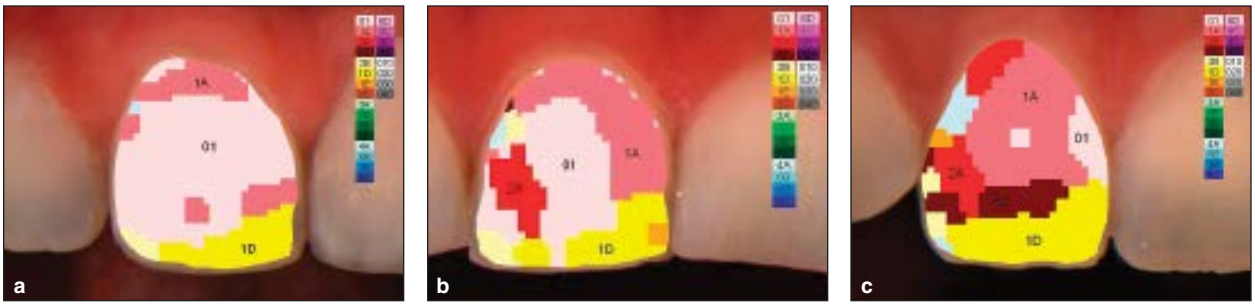


Fig 2 (a to c) Color map of the three teeth from task 2 obtained by instrumental analysis using the dental spectrophotometer Spectroshade Micro.

($\Delta E^* = 1.8$); and for tooth 3, acceptable colors were 1A ($\Delta E^* = 1.93$) and 2A ($\Delta E^* = 2.5$). The color map of the three teeth obtained by instrumental analysis revealed tooth 1 to be relatively uniform, while tooth 2 and especially tooth 3 were more complex with a greater color gradation (Fig 2). Accordingly, 75% of answers were correct for tooth 1, 63% for tooth 2, and 38% for tooth 3 (see Table 1). No statistically significant differences between groups were found for the number of correct shade matches for particular teeth (tooth 1: $P = .568$; tooth 2: $P = .055$; tooth 3: $P = .150$). Professional experience had no significant effect on the color matching accuracy for tooth 1 (simple case) ($P = .448$), while statistically significant differences were found for the more complex teeth 2 ($P < .001$) and 3 ($P = .014$) with better scores obtained from more experienced individuals.

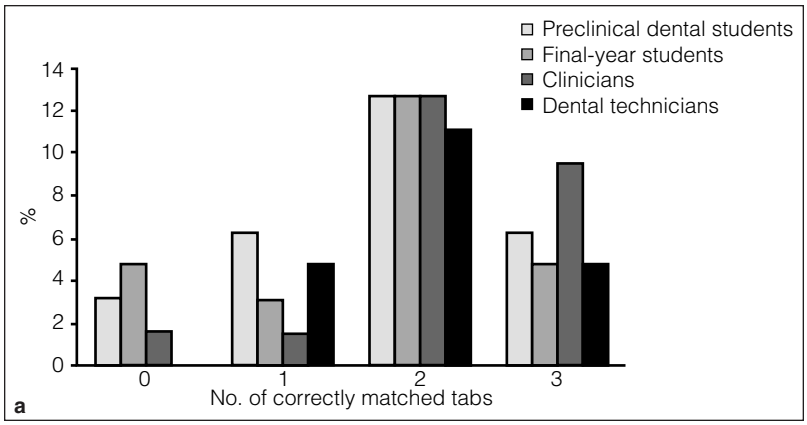
Considering the total number of correctly paired tabs and correctly matched teeth (possible categories were 0, 1, 2, or 3 correct matches for each task), comparisons between different occupational groups (Fig 3) and between different categories of professional experience (Fig 4) were performed. There were no significant differences for the total number of correctly paired tabs either between occupational groups ($P = .192$) or between different categories of professional experience ($P = .185$), as assessed by the Fisher exact test. For the total number of correctly matched teeth, there were no significant differences between occupational groups ($P = .112$), but there was a significant difference between different categories of professional experience ($P = .009$), with a higher frequency of 0, 1, and 2 correctly matched teeth in those with no experience and 2 or 3 correct matches in groups with more professional experience (< 10 and ≥ 10 years). The time consumption results for tab pairing and tooth color matching between different occupational groups are shown in Table 2. Sheffe post hoc tests revealed significant differences in the time required for pairing tabs between the preclinical students and clinicians ($P < .001$) as well as between the preclinical students and the technicians ($P = .046$). The clinicians and technicians required significantly less time to complete the given tasks. Moreover, the clinicians were significantly faster compared to the final-year students ($P = .045$).

For tooth color matching, significant differences in time consumption were found between preclinical students and clinicians ($P < .001$) and dental technicians ($P < .001$). Significant differences were also found between the final-year students and the clinicians ($P < .001$) and dental technicians ($P < .001$). Both preclinical and final-year students were significantly slower than clinicians and dental technicians.

The time consumption results regarding professional experience are shown in Table 3. Individuals without experience spent significantly more time completing the given tasks in comparison to individuals with experience.

Time consumption for tab or tooth matching regarding the number of correctly matched tabs or teeth are shown in Table 4. Individuals who correctly matched 2 or 3 tabs or teeth spent significantly less time than those individuals who correctly matched only 1 or 0 tab pairs or teeth.

A significant negative correlation was found between the time required for the tab pairing and the number of correctly paired tabs ($\rho = -0.459$, $P < .001$, $n = 126$) as well as between the time consumption for tooth matching and the number of correctly matched teeth ($\rho = -0.498$, $P < .001$, $n = 126$). The total number of correctly matched teeth was positively related to the total number of correctly paired shade tabs ($\rho = .603$, $P < .001$)



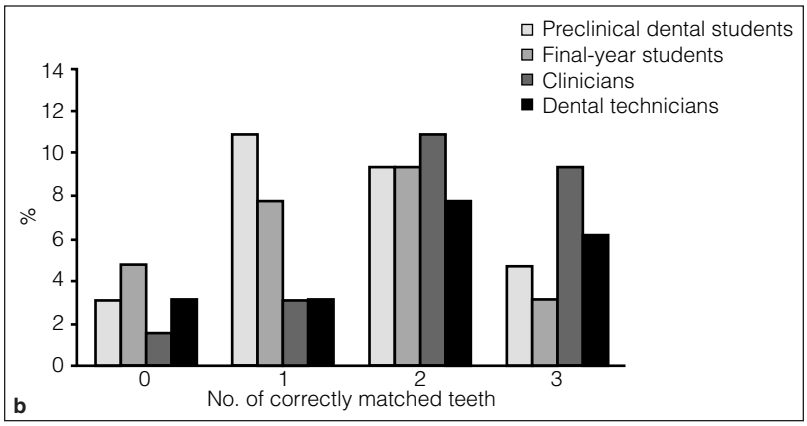
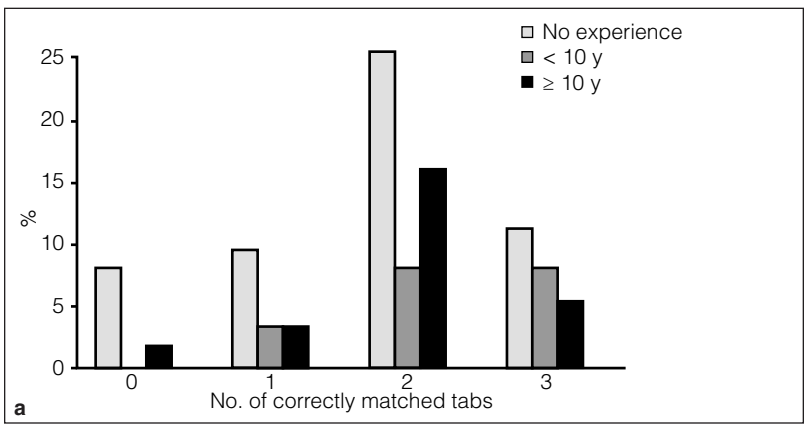


Fig 3 Comparison of the total number of **(a)** correctly matched tabs and **(b)** correctly matched teeth among different occupational groups.



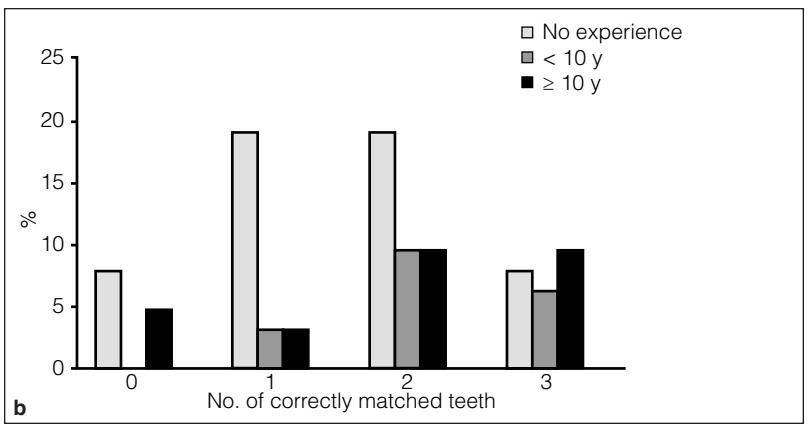


Fig 4 Comparison of the total number of **(a)** correctly matched tabs and **(b)** correctly matched teeth among the different categories of professional experience.

Table 2 Means, SDs, and Significance of Time Consumption for Tab Pairing or Tooth Color Matching

Group	n	Time (min)	SD	F	*P*
Time consumption for tab pairing					
Preclinical students	36	4.67	0.58	7.021	< .001**
Final-year students	32	4.44	0.72		
Dental technicians	26	4.15	0.54		
Clinicians	32	3.94	0.88		
Time consumption for natural tooth color matching					
Preclinical students	36	4.71	0.94	31.094	< .001**
Final-year students	32	4.45	0.57		
Dental technicians	26	3.46	0.58		
Clinicians	32	3.33	0.57		

Degree of freedom between groups = 2, and within groups 123. *Significance 95%, **significance 99%.

Table 3 Means, SDs, and Significance of the Difference for Time Consumption for Tab Pairing or Tooth Matching Regarding Professional Experience

	Professional experience	n	Time (min)	SD	F	*P*	Sheffe post hoc	
Time consumption for tab pairing	None	68	4.56	0.65	9,987	< .001**		None
	< 10 y	24	3.88	0.63			< 10 y	*
	≥ 10 y	34	4.15	0.81			≥ 10 y	*
Time consumption for natural tooth color matching	None	68	4.59	0.80	44,821	< .001**		None
	< 10 y	24	3.44	0.51			< 10 y	*
	≥ 10 y	34	3.35	0.62			≥ 10 y	*

Degree of freedom = 2. *Significance 95%, **significance 99%.

Table 4 Means, SDs, and Significance of Time Consumption for Matching Regarding the Number of Correctly Matched Tabs/Teeth

	No. of correct matches	n	Time (min)	SD	F	*P*	Sheffe post hoc	
Time consumption for tab pairing	0	12	4.88	0.29	9.986	< .001**		0
	1	20	4.80	0.83			1	NS
	2	62	4.26	0.72			2	*
	3	32	3.93	0.55			3	*
Time consumption for natural tooth color matching	0	16	4.56	1.22	17.37	< .001**		0
	1	32	4.70	0.88			1	NS
	2	48	3.78	0.63			2	*
	3	30	3.45	0.59			3	*

SD = standard deviation. Degree of freedom between groups = 2, and within groups 123. *Significance 95%, **significance 99%.

Discussion

Color match is one of the first characteristics of a dental restoration to be evaluated, which makes shade selection and reproduction the key determinant to the overall success of a restoration. Factors that influence visual color matching accuracy have constantly been investigated, but there is still a lot of controversy. Therefore, this study aimed to investigate simultaneously the number of correctly matched tabs/teeth and the time spent for matching as well as to compare different dental occupational groups with different levels of experience.

All testings in this study were performed under daylight, although it has been shown that color matching ability is better with a light-correcting source.[10,27] Daylight is not constant throughout the day. The reason why it was preferred in this study was to simulate the real environment used in everyday practice. Nevertheless, to achieve better standardization, all testings were perfomed in the same room in front of a north-facing window between 10 am and 11 am.

The two shade guides, the Vita Lumin Vacuum (VITA Zahnfabrik) introduced about 50 years ago and the Chromascop (Ivoclar Vivadent) guide introduced

in 1990, are among the most popular shade guides in clinical use. Most shade guides are susceptible to coverage errors, whereby the range of shades in the guides is not consistent with the color range of natural teeth.[28–30] Studies investigating the coverage error of the above-mentioned shade guides found no significant difference between them.[31] In a study with the Chromascop shade guide, the interobserver agreement in selecting the best shade match was approximately 48%,[32] whereby the rates varied between 20% and 30% for the Vita shade guides.[33,34] The Chromascop shade guide was used in the present study, although the Vita Lumin Vacuum has been very popular in other shade matching studies.

In the first task where three shade guide tabs had to be paired, no significant difference was found between preclinical students, final-year students, clinicians, and dental technicians. The color discrimination competency was similar among groups, although clinicians had slightly more correctly paired tabs (see Table 1). The results are in accordance with the results of other studies that found no difference in color matching between dental occupational groups.[35] Professional experience was also not found to be a contributing factor in the shade tab pairing score. The obtained results can be explained by the fact that the individual's dental profession or the professional experience does not have to be related to fundamental color matching ability and that even unexperienced individuals or laypeople can recognize and pair colors. However, when matching the color of natural teeth intraorally, experienced observers showed significantly better results for teeth 2 and 3 compared with novice observers. Regarding the fact that the color map obtained by instrumental analysis revealed tooth 1 to be relatively uniform in color, while tooth 2 and especially tooth 3 were more complex, the results support the idea that clinical experience and professional knowledge may be helpful for clinical shade matching in complex cases. This is in accordance with the results of the study performed by Jaju et al.[9] The number of years of experience for clinicians and dental technicians ranged from 2 to 42 years (mean, 15.4 years) in this study. The final-year students had no more than 2 years of varying levels of shade matching experience. Their scores were not significantly higher than those of preclinical students, suggesting that their limited experience did not improve their abilities to match shades easily. Some authors have reported that clinical experience does not play an important role in color matching,[33,36] although many studies show an association between clinical experience and the ability to match tooth color.[37–39] There are studies stating that experience in color matching is reduced to familiarity with the used shade guide and that the introduction of a new shade guide annulls the significance of previous experience.[40] The total number of correctly matched teeth was positively related to the total number of correctly paired shade tabs, which may be explained by better fundamental color matching ability.

The mean time required to pair shade guide tabs was longer for both groups of students than for the clinicians and dental technicians. Statistically significant differences in time consumed for shade tab pairing and tooth color matching were found between groups, whereby students performed the tasks slower than clinicians and dental technicians. Time consumption differences regarding professional experience were significant for both tasks between the group without experience and the groups with experience. These results may be explained by the familiarity with the procedure of color matching and with the use of shade guides, as most clinicians perform tooth color matching during their daily routine. Since the Chromascop shade guide is one of the most popular in Croatia, familiarity with the concept due to previous experience could accelerate the shade matching procedure.

A statistically significant difference was found for the number of correctly paired tabs dependent on the time consumed to complete the tasks. Participants with no correct answers spent more time, while participants who matched more pairs correctly needed less time. When matching tooth color, again participants with no matches spent more time, while those who matched all teeth correctly spent less time. There was a significant negative correlation between time consumption and the number of correctly paired shade tabs as well as between time consumption and the number of correctly matched teeth. In other studies, time spent for shade selection usually was limited because it has been suggested that allowing more time for selection increases the number of errors.[11] One possible reason might be the occurrence of eye fatigue due to overstimulation of photoreceptors. The receptors become less sensitive to further stimulation after a certain period of stimulation because the eyes become accommodated to the assessed colors. This may bias color perception. Under normal circumstances, eyes never stare fixedly at a single spot but rather roam the visual field continuously. When holding a shade guide close to a tooth, it is important to decide quickly because the two will soon begin to appear more and more alike.[41] When assessing different shade tabs, the eye should be rested by focusing on a neutral gray surface since this balances all the color sensors of the retina and resensitizes the eye to the

yellow color of the tooth.[42] It has also been recommended that observers choose a tooth color within 2 to 5 minutes. Once a patient's mouth has been opening and closing beyond that period of time, a difference in the color and translucency of the teeth becomes evident due to dehydration.[43] The only study in the available literature on this matter revealed no correlation between the time consumption for the visual shade matching method and the frequency of correct matches,[44] which is not in accordance with the findings of the present study. One possible reason might be that the observers rested their eyes between color assesments. That can be time-consuming but may positively affect the outcome. Thus, further research is needed to resolve this issue. However, the results of the present study reveal that individuals who spent more time matching tabs or teeth made significantly more errors, which could be due to either eye fatigue or lack of experience.

Conclusion

Within the limitations of this study, no significant differences were found between dental occupational groups for the tab matching tasks, but the level of professional experience positively affected natural tooth color matching scores, especially in cases with more complex tooth color. Overall, clinicians and dental technicians performed faster than students, with fewer errors. The time spent for shade matching was negatively correlated with the shade matching scores, whereby the best results were achieved in the shortest time.

Acknowledgments

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Literature Abstract

FDI resolution on global legally binding instrument on mercury

A global legally binding instrument on mercury prepared by the United Nations Environment Programme in January 2013 would likely restrict, phase down, phase out, or ban the use of dental amalgams. At present, the dental profession needs all available materials to provide safe and effective health care to address health and socioeconomic issues. Therefore, it is important that the prevention or treatment of oral diseases may be carried out through safe and cost-effective means. As such, governments and dental professions alike need to understand the impact of such a restriction on the oral health of the country. A resolution was presented by the FDI at the FDI World Dental Parliament in Hong Kong in August 2012 in support of the World Health Organization's phase-down of the use of dental amalgams through increased prevention, health promotion, and research on newer dental materials. In addition, the FDI and its partners pledged to work with national dental associations to support governments in providing clinicians with access to all dental materials, while ensuring the safe handling, effective waste management, and appropriate disposal of these materials.

FDI World Dental Federation. *Int Dent J* 2013;63:6. **References:** 1. **Reprints:** FDI World Dental Federation, Avenue Louis Casai 84, Case Postale 3, CH-1216 Geneva, Switzerland. **Email:** info@fdiworlddental.org—*Teo Juin Wei, Singapore*