Does Gender Influence Color Matching Quality?

SUMMARY

Objectives: To compare shade matching skills of color normal males and females.

Material and Methods: A total of 174 dental students of both genders (117 females and 57 males, 20 to 25 years old), with no experience in color matching in dentistry, participated in the study. All recruited students passed the Ishihara color vision test for color deficiency, and matched the colors of eight shade tabs using VITA Linearguide 3D-Master shade guide. Standardized lighting conditions were provided using Rite-Lite (Addent Danbury, CT, USA) hand-held shade matching unit. Color differences between the task tabs and selected tabs were calculated using two CIE color difference formulae and students results were evaluated from 10 (for the best match score) to 1 for the 10th best match score. Means and standard deviations were determined. Student's t-test was used for result analysis (p = .05).

Results: The mean shade matching scores and standard deviations for male and female students were 5.86 (SD 1.38) and 6.10 (SD 1.36), respectively (p = .266). No statistically significant differences in overall and individual target tab scores by gender were recorded.

Conclusion: Within the limitation of this study, it was concluded that gender did not influence color matching quality.

Keywords: color, dentistry, gender, shade matching, color-corrected light

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Introduction

Color could be the controlling factor in overall acceptance of a dental restoration by the patients[1]. Women have traditionally been considered to be better in matching colors than men[2], and this is certainly true when all females and males are compared, since approximately 8% of men (1 in 12 males) and only 0.5% of women (1 in 200 females) are color deficient[3]. However, research findings on color normal individuals are far from unison, ranging from supporting the traditional belief and reporting that females had significantly better results than males[4], to opposing it and reporting no gender-dependent differences in color matching[5-7].

Visual color assessment is a summation of individual responses to a color stimulus, and psychophysics is a scientific discipline dealing with mathematical relations between physical stimuli and sensations they cause[8]. Color difference is typically quantified using CIE (Commission Internationale de L'Eclairage - International Commission on Illumination) formulas: CIELAB (ΔE^*) and CIEDE2000 ($\Delta E'$) [9]. While CIELAB formula is used more frequently, the CIEDE2000 is newer formula and it is recommended by CIE because of its better agreement with visual findings[10,11].

The quality of the color match between a dental restoration and the adjacent natural tooth is determined by magnitude and direction of the color difference. According to color science, practical interpretation of color differences for a given industry/application can be done through visual thresholds, in particular 50:50% perceptibility threshold (PT) and 50:50% acceptability

threshold (AT) [12-18]. The same is true for dentistry. At 50:50% PT, 50% of observers would notice a difference in color between two objects, while the remaining 50% would see no difference in color. At 50:50% AT, 50% of observers would accept a difference in color between two objects, while the remaining 50% would either correct color or make a new restoration.

Light is one of the most important factors for color perception - there is no color without light[19]. The daylight, D, is recommended for shade selection in dentistry[20]. CIE D illuminants are used to mimic various daylight conditions[9]. The "D" illuminants represent average daylight (natural, bluish white, daylight) and has a correlated color temperature from 5000-7500 K (D50, D55, D65, and D75) [21]. The color temperature of natural daylight exhibits a wide range, and it is therefore unreliable for color matching. It depends of weather conditions, time of year, time of day, color of sunlight, and other factors[22]. CIE daylight illuminants cannot be reproduced exactly in practice, so they are called daylight simulators, and they are used as an alternative in shade matching[23]. Color corrected lights, such as D55, ensure consistent and appropriate conditions for tooth color matching[2].

In addition to gender and light, several papers reported the influence (or lack of it) of experience, education, and age, on color matching results[24-26]. The same is true for color training programs, that can significantly improve one's color matching skills[24,27,28].

The aim of this study was to compare the results of male and female participants in determining color of different shade tabs under standardized lighting conditions. The null hypothesis was that there was no difference in quality of tooth color matching between color normal females and males.

Materials and Methods

A total of 174 dental students of both genders (117 females and 57 males, 20 to 25 years old), with no experience in color matching in dentistry, were recruited for the study. All students underwent the Ishihara color vision deficiency test and no color deficient individuals were found[29]. The study was approved by the Ethics Committee of the University of Niš, School of Medicine (No: 01-244-11). All students signed the informed consent form prior to participating in the project.

Basic instructions for using the VITA Linearguide 3D Master shade guide (LG, VITA Zahnfabrik, Bad Säckingen, Germany) were given. Students matched the shade task in two steps. In the first step they determined the group (0 to 5) using the tabs in the dark-gray holder. In the second step, they completed shade matching by selecting the best matching tab from the light-gray holder that corresponded to the group selected in step one.

Standardized lighting conditions were provided by using Rite-Lite hand-held shade matching unit (Rite-Lite, Addent Danbury, CT, USA), with a correlated color temperature of 5500°K and color rendering index, CRI ≥ 92 (Fig. 1).

Figure 1. Shade matching using Rite-Lite hand-held unit

The students' task was to match 8 shade tabs, for a total of 1392 shade matchings. Four task tabs were from Vita Linearguide 3D Master and four from VITA classical A1-D4 shade guide (VC, VITA). Therefore, there were four "exact match" LG task tabs: 1M2, 2L2.5, 3R1.5, and 4M2 and four "closest match" VC task tabs (exact matches not available): A1, B2, A3.5 and C4. A custom holder for the target tabs (task tabs that were matched with the shade guide) was made of SR Triplex Hot acrylic resin (Ivoclar Vivadent, Schaan, Liechtenstein). The holder was designed so that the shape and color resembles a human face (Fig. 1).

Color difference between the target tabs and selected tabs was calculated using two CIE color difference formulae, CIELAB and CIEDE2000 as follows[9-11]:

$$\Delta E_{ab}^* = \sqrt{(L_2^* + L_1^*)^2 + (a_2^* + a_1^*)^2 + (b_2^* + b_1^*)^2},$$

where ΔE^* is difference in lightness-darkness, while Δa^*, and Δb^* are the differences in green–red and blue-yellow coordinate, respectively.

$$\Delta E_{00}^* = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \frac{\Delta C'}{K_C S_C} \frac{\Delta H'}{K_H S_H}},$$

where $\Delta L'$, $\Delta C'$, $\Delta H'$ are metric differences between the corresponding values of the samples, and $K_C S_C$, $K_C S_C$ and $K_H S_H$ are empirical terms used for correcting the metric differences to the CIEDE2000 differences for each coordinate[30].

If the best match was selected (VC shade tab with the smallest color difference or the exact LG tab), student was given 10 points, if the 2nd best match was selected, they obtained 9 points, the 3rd best match corresponded to 8 points, and so on up to 1 point if the 10th best match was selected. Any color match worse than the 10th best match was given 0 points.

Means and standard deviations were determined. Statistical significance of differences by gender was calculated using Student's t-test (SPSS v17 for Windows; IBM, New York, NY, USA) at $\alpha = .05$.

Results

The total scores for male and female were 5.86 ($\pm$1.38) and 6.10 ($\pm$1.36). No statistically significant difference was recorded (p = .266).

Shade matching scores for exact match (LG target tabs) and closest match tasks (VC target tabs) are presented in table 1. The mean scores, standard deviations and significance for each individual target tab are shown in table 2. No significant differences by gender were recorded for any of these comparisons.

Table 1. Mean scores, standard deviations (SD) and significance for male (M) and female (F) observers for the exact match task tabs (3D) and the closest match task tabs (VC).

	Gender	N	Scores	SD	p
LG	M	57	5.49	2.07	.237
	F	117	5.87	1.93	
VC	M	57	6.23	1.33	.630
	F	117	6.34	1.52	

Table 2. Mean scores, standard deviations (SD) and significance for male (M) and female (F) observers for each of target tabs.

Target Tab	Gender	N	Scores	SD	p
1M2	M	57	7.32	2.84	.644
	F	117	7.53	2.87	
2L2.5	M	57	4.74	3.49	.928
	F	117	4.79	3.35	
3R1.5	M	57	4.82	3.30	.269
	F	117	5.43	3.40	
4M2	M	57	5.07	3.21	.216
	F	117	5.72	3.24	
A1	M	57	6.82	1.21	.020
	F	117	7.32	1.36	
B2	M	57	5.33	3.30	.413
	F	117	5.74	2.90	
A3.5	M	57	7.16	3.18	.836
	F	117	7.26	2.81	
C4	M	57	5.60	2.73	.259
	F	117	5.05	3.10	

Students achieved the best scores for 1M2 and A3.5 task tabs. The worst score was achieved for the task tab 2L2.5.

The correlation between color differences in CIELAB and CIEDE2000 was $R^2 = .97$ for both exact and closest match task tabs. The equation for estimating $\Delta E'$ values based on the known ΔE^* values was as follows: $\Delta E'=0.63\times\Delta E^*+0.14$, while the equation for estimating ΔE^* values based on the known $\Delta E'^{**}$ values was as follows: $\Delta E^*=1.49\times\Delta E'+0.02$.

Table 3. Color differences (SD) according to CIELAB (ΔE^*) and CIEDE2000 ($\Delta E'$) for the exact match task tabs (3D) and the closest match task tabs (VC)

Points	ΔE^*, 3D	$\Delta E'$, 3D	ΔE^*, VC	$\Delta E'$, VC
10	0.0 (0.0)	0.0 (0.0)	2.5 (1.0)	1.9 (0.6)
9	2.2 (2.1)	1.5 (1.4)	3.1 (1.0)	2.0 (0.5)
8	3.6 (1.2)	2.3 (1.0)	3.7 (1.2)	2.9 (1.0)
7	4.5 (1.7)	3.4 (1.0)	4.6 (1.0)	3.2 (1.0)
6	5.1 (1.7)	3.5 (1.3)	4.7 (1.0)	3.2 (1.0)
5	5.3 (1.7)	3.5 (1.1)	5.0 (1.0)	3.3 (0.8)
4	5.6 (1.5)	3.6 (1.2)	6.1 (1.9)	4.0 (1.2)
3	5.7 (1.5)	4.0 (0.8)	6.2 (1.8)	4.1 (1.3)
2	6.6 (1.6)	3.9 (1.3)	6.9 (1.6)	4.5 (1.5)
1	6.8 (1.6)	4.3 (1.0)	7.1 (1.6)	5.3 (1.5)

* CIEDE2000 differences were calculated based on CIELAB order of matches

Discussion

As there was no statistically significant difference in quality of tooth color matching between color normal males and females, the null research hypotheses was accepted.

It is a traditional belief that women are more capable of matching colors than men. The fact that color deficiency is more frequent in males did not affect the results of the study, because all recruited students were color normal. In humans, two cone cell pigment genes are present on the X chromosome. If women are heterozygous they could be tetra-chromatic, which may provide them with an additional advantage in shade matching[31-34]. It was reported that that gender played an important role in shade matching, and females achieved significantly better results than males[4]. On the other hand, numerous studies showed that no gender-dependent difference in shade matching ability between genders[2,5,6,19,28,35-37].

When ten observers match 48 shade tabs of three VC shade guides under D65 and D50 lights and different

colors of background/surround, it was found that the influence of gender had no statistically significance on shade matching results[19]. In another study 20 male and 20 female dental technicians matched 10 VC target tabs using a commercially available light source. There were no significant differences between scores by gender. The study showed that dental laboratory technicians achieved better shade-matching results with the commercial corrected light source than under the usual lighting conditions in the dental laboratories[6].

Another report stated that gender and experience did not influence shade matching skills. A total of 165 male and 51 female students participated in this study. It was concluded that gender had no effect on shades matching ability and that dental students matched shades significantly better with a corrected light source than under natural light[7].

Some authors suggested that north natural daylight in late morning provides the best lighting conditions for shade matching, and D50 was one of the illuminants they used. They did not find statistically significant difference between genders[24]. Light sources can play a crucial role in shade matching. When a pair of different colors match under lighting conditions and mismatch under another, this phenomenon is called metamerism, which can also be defined as a conditional or non-spectral match[38].

In the present study, students used the Rite-Lite Shade Matching Light with a correlated color temperature of 5500 °K. Overall, results for exact (LG) and more demanding closest (VC) match, and results for each individual task tab did not show statistically significant difference between females and males.

Target tabs with a variety in lightness (medium-light. medium-dark. and dark) were selected for the experiment[39]. Best results for LG task tabs were achieved for 1M2. The 2L2.5 scores were the lowest of all task tabs. One explanation for such a low score could be extreme error by some students (as standard deviation was very high). Another reason could be the presence of a large number of similar shades in this part of tooth color space. Some authors obtained low average scores for shade 2L1.5 and reported that older participants with more-professional experience may have matched shade 2L1.5 with greater success[41]. As far as the VC task tabs are concerned, the best result was achieved for A3.5. It is interesting to note that the smallest standard deviation was recorded for the A1 task tab.

There were no statistically significant differences between genders at any of the stated tasks.

Color differences in dentistry could be presented with two major visual thresholds: the 50:50% perceptibility threshold (PT) and 50:50% acceptability threshold (AT). A recent study reported the CIELAB (ΔE^*) 50:50% PT of 1.2 and 50:50% AT of 2.7. Corresponding CIEDE2000 ($\Delta E'$) values were 0.8 and 1.8, respectively[17]. The first and second LG best match

(10 and 9 points, respectively) and the best match for VC, were lower than 50:50% AT in both CIELAB and CIEDE2000. However, the average score for all students was 6.0, which is the 5th best match (in average, there were four better matches than the selected one). The mean color differences between the task tabs and the 5th best match were $\Delta E^*=4.9$ and $\Delta E'=3.4$, which were much higher than the 50:50% AT. This raises a red flag and underlines the need for implementation of color education and training programs in dental schools and continuing education for dental professionals[42,43]. Furthermore, significant education and training-dependent improvements were reported in two recent publications[28,44].

Conclusion

Within the limitations of this study, it was concluded that:
- There were no statistically significant difference in color matching skills of color normal males and females. This encompasses the overall scores, type of task (exact/closest match), and the results for the individual shade tabs;
- The average score, corresponding to 5th best match, underlined the need for implementation of color education and training programs in dental schools and continuing education for dental professionals.

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References

1. Bergen SF. Color in esthetics. *NY State Dent J*, 1985; 51:470-471.
2. Donahue J, Goodkind R, Schwabacher W, Aeppli D. Shade color discrimination by man and woman. *J Prosthet Dent*, 1991; 65:699-703.
3. Chamberlain GJ, Chamberlain DG. Colour - its measurement, computation and application. 1st ed. London (UK): Heyden, 1980.
4. Haddad H, Jakstat H, Arnetzl G, Borbely J, Vichi A, Dumfahrt H, Renault P, Corcodel N, Pohlen B, Marada G, Martinez Vazquez de Parga J, Reshad M, Klinke T, Hannak W, Paravina R. Does gender and experience influence shade matching quality? *J Dent,* 2009; 37:40-44.
5. Paravina RD. Evaluation of a newly developed visual shade matching apparatus. *Int J Prosthodont*, 2002; 15:528-534.
6. Jasinevicius TR, Curd FM, Schilling L, Sadan A. Shade matching abilities of dental laboratory technicians using a commercial light source. *J Prosthodont*, 2009; 18:60-63.

7. Curd FM, Jasinevicius TR, Graves A, Cox V, Sadan A. Comparison of the shade matching ability of dental students using two light sources. *J Prosthet Dent*, 2006; 96:391-396.

8. Ishikawa-Nagai S, Yoshida A, Sakai M, Kristiansen J, Da Silva JD. Clinical evaluation of perceptibility of color differences between natural teeth and all-ceramic crowns. *J Dent*, 2009; 37:57-63.

9. Commission Internationale de l'Eclairage (CIE). CIE technical report: colorimetry, CIE Pub No.15.3, 2004.

10. Wyszecki G, Stiles WS. Color science: concepts and methods, quantitative data and formulae. 2nd ed. New York (NY): John Wiley & Sons, 2000.

11. Sharma G, Wu W, Dalal E. The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. *Color Res Appl*, 2005; 30:21-30.

12. Kuehni RG, Marcus RT. An experiment in visual scaling of small colour differences. *Color Res Appl*, 1979; 4:83-91.

13. Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. *Dent Mater*, 1987; 3:246-251.

14. Seghi RR, Hewlett ER, Kim J. Visual and instrumental colorimetric assessments of small color differences on translucent dental porcelain. *J Dent Res*, 1989; 68:1760-1764.

15. Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical *colorimetry. J Dent Res*, 1989; 68:819-822.

16. Khashayar G, Bain PA, Salari S. Dozic A, Kleverlaan CJ, Feilzer AJ. Perceptibility and acceptability thresholds for colour differences in dentistry. *J Dent*, 2014; 42:637-644.

17. Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, Sakai M, Takahashi H, Tashkandi E. Color Difference Thresholds in Dentistry. *J Esthet Restor Dent*, 2015; 27:1-9.

18. Ghinea R, Perez MM, Herrera LJ, Rivas MJ, Yebra A, Paravina RD. Color difference thresholds in dental ceramics. *J Dent*, 2010; 38:57-64.

19. Dudea D, Gasparik C, Botos A, Alb F, Irimie A, Paravina RD. Influence of background/ surrounding area on accuracy of visual color matching. *Clin Oral Investig*, 2015; in press.

20. Gokce HS, Piskin B, Ceyhan D, Gokce SM, Arisan V. Shade matching performance of normal and color vision-deficient dental professionals with standard daylight and tungsten illuminants. *J Prosthet Dent*, 2010; 103:139-147.

21. Amano K, Foster DH. Colour constancy under simultaneous changes in surface position and illuminant. *Proceedings of the Biological Society of Washington*, 2004; 271:2319-2326.

22. Ahn JS, Lee YK. Difference in the translucency of all-ceramics by the illuminant. *Dent Mat*, 2008; 24:1539–1544.

23. Sproull RC, Preston JD. Understanding color. In: *Goldstein RE* (ed). Esthetics in Dentistry. ed 2. London: BC Decker, 1998.

24. Paravina RD, Powers JM. Esthetic Color Training in Dentistry. 1st ed. St. Louis (MO): Elsevier Mosby, 2004.

25. Paravina RD. Techniques for improvement of clinical shade matching procedures. PhD Thesis, University of Nis School Medicine, 2000.

26. Jaju R, Nagai S, Karimbux N, Da Silva J. Evaluating Tooth Color Matching Ability of Dental Students. *J Dent Educ*, 2010; 75:1002-1010.

27. Goodkind R, Loupe M. Teaching of color in predoctoral and postdoctoral dental education in 1988. *J Prosthet Dent*, 1992; 67:713-717.

28. Ristic I, Stankovic S, Paravina RD. Influence of color education and training on shade matching skills. *J Esthet Restor Dent*, 2016; in press.

29. Colblindor. http://www.color-blindness.com/ishihara-38-plates-cvd-test/, accessed December 5, 2015.

30. Perez MM, Ghinea R, Herrera LJ, Ionescu AM, Pomares H, Pulgar R, Paravina RD. Dental ceramics: A CIEDE2000 acceptability thresholds for lightness, chroma and hue differences. *J Dent*, 2011; 39:37-44.

31. *Applebury ML, Hargrave PA. Molecular biology of the visual pigments. Vision Res, 1987; 26:1881-1895.*

32. Neitz J, Jacobs GH. Polymorphism of the long-wavelength cone in normal human color vision. *Nature*, 1986; 323:623-625.

33. Neitz J, Neitz M, Jacobs GH. More than three different cone pigments among people with normal color vision. *Vision Res*, 1993; 33:117-122.

34. Joiner A. Tooth colour: a review of the literature. *J Dent*, 2004; 32:3-12.

35. Vafaee F, Rakhshan V, Vafaei M, Khoshhal M. Accuracy of shade matching performed by colour blind and normal dental students using 3D Master and Vita Lumin shade guides. *Eur J Prosthodont Restor Dent*, 2012; 20:23-25.

36. Cal E, Sonugelen M, Guneri P, Kesercioglu A, Kose T. Application of a digital technique in evaluating the reliability of shade guides. *J Oral Rehabil*, 2004; 31:483-491.

37. Anusavice KJ. Philip's science of dental materials. 10th ed. Philadelphia: Saunders, 1996.

38. Berns RS. Billmeyer and Saltzman's Principles of Color Technology. 3rd ed. New York (NY): John Wiley & Sons, 2000.

39. Paravina RD, Majkic G, Imai FH, Powers JM. Optimization of tooth color and shade guide design. *J Prosthodont*, 2007; 16:269-276.

40. Capa N, Malkondu O, Kazazoglu E, Calikkocaoglu S. Evaluating factors that affect the shade-matching ability of dentists, dental staff members and laypeople. *J Am Dent Assoc*, 2010; 141:71-76.

41. Chu SJ, Devigus A, Paravina RD, Mieleszko AJ. Fundamentals of color: shade matching and communication in esthetic dentistry. 2nd ed. Hanover Park, IL: Quintessence Publishing, 2011.

42. Paravina RD, O'Neill PN, Swift EJ, Nathanson D, Goodacre CJ. Teaching of color on predoctoral and postdoctoral dental education in 2009. *J Dent*, 38s: e34–e40, 2010.

43. Clary J, Ontiveros JC, Cron SG, Paravina RD. Influence of light source, polarization, education and training, and sex on shade matching quality. *J Prosthet Dent*, in press.

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