JOURNAL OF DENTISTRY 37S (2009) e40–e44

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/jden

Does gender and experience influence shade matching quality?

Helene J. Haddad [a,*], *Holger A. Jakstat* [b], *Gerwin Arnetzl* [c], *Judit Borbely* [d], *Alessandro Vichi* [e], *Herbert Dumfahrt* [f], *Patrick Renault* [g], *Nicoleta Corcodel* [h], *Bostjan Pohlen* [i], *Gyula Marada* [j], *Juan A. Martinez Vazquez de Parga* [k], *Mamaly Reshad* [l], *Thomas U. Klinke* [m], *Wolfgang B. Hannak* [n], *Rade D. Paravina* [o]

[a] *Dental School, St. Joseph University, Beirut, Lebanon*
[b] *Poliklinik für Zahnärztliche Prothetik und Werkstoffkunde, Leipzig, Germany*
[c] *Univ. Klinik für Zahn-, Mund- u.Kieferheillkunde der Medizinischen Universität, Graz, Austria*
[d] *Semmelweis University, Faculty of Dentistry, Budapest, Hungary*
[e] *Universita degli Studi di Siena, Italy*
[f] *Faculty of Dentistry, Universität of Innsbruk, Austria*
[g] *University of Paris V Montrouge, France*
[h] *Universitätsklinik für Mund-, Zahn- und Kieferkrankheiten, Heidelberg, Germany*
[i] *Medical Faculty of the University of Ljubljana, Slovenia*
[j] *University of Pecs, Dental School, Hungary*
[k] *Estomatologia I Universidad Complutense de Madrid, Spain*
[l] *University of Southern Califonia, United States of America*
[m] *Ernst-Moritz-Arndt-Universität, Greifswald, Germany*
[n] *Charite Centrum für Zahn-, Mund- und Kieferheilkunde, Berlin, Germany*
[o] *Department of Restorative Dentistry and Biomaterials, University of Texas Dental Branch at Houston, United States of America*

ARTICLE INFO

Article history:
Received 27 April 2009
Received in revised form
12 May 2009
Accepted 13 May 2009

Keywords:
Shade matching
Shade guide

ABSTRACT

Objectives: To evaluate the influence of gender and level of experience on shade matching quality.

Methods: A study was simultaneously performed at 15 universities located in 9 countries. A total of 614 color normal participants completed all phases of the experiment. Among them, there were 305 females and 309 males, 319 dental students and 295 dental professionals. A lecture on color matching in dentistry was given to all participants. Initial training was performed using Toothguide Trainer software (TT), while Toothguide Training Box (TTB) was used for both training and testing of participants' shade matching results. The test task was to successively match 15 shade guide tabs with the corresponding shade guide. The shade matching score for each participant was computed as a sum of color differences ($\sum \Delta E^*_{ab}$ score) between target tabs and selected tabs. Lower scores corresponded to better

* *Corresponding author*. Tel.: +961 3 85 82 13/+49 341 9721304; fax: +49 341 9739374.
E-mail addresses: helene.haddad@usj.edu.lb (H.J. Haddad), Holger.Jakstat@Medizin.uni-leipzig.de (H.A. Jakstat), gerwin.arnetzl@medunigraz.at (G. Arnetzl), juditborbely@t-online.hu (J. Borbely), vichialessandro@virgilio.it (A. Vichi), Herbert.Dumfahrt@i-med.ac.at (H. Dumfahrt), patrickrenault@mageos.com (P. Renault), nicoleta.corcodel@med.uni-heidelberg.de (N. Corcodel), pohlenb@yahoo.co.uk (B. Pohlen), gyulama@t-email.hu (G. Marada), mtzvdep@odon.ucm.es (de Parga), reshad@usc.edu (M. Reshad), klinke@uni-greifswald.de (T.U. Klinke), wolfgang.hannak@charite.de (W.B. Hannak), Rade.Paravina@uth.tmc.edu (R.D. Paravina).

0300-5712/$ – see front matter
doi:10.1016/j.jdent.2009.05.012

Science of color
Color perception
Gender
Toothguide Trainer software
Toothguide Training Box

shade matching results and vice versa. Means and standard deviations were calculated. Mann–Whitney *U* test was used for statistical analysis of the data ($\alpha = 0.05$).

Results: The mean shade matching score (S.D.) for all participants was 41 (21). The score for female and male participants was 38 (20) and 44 (21), respectfully ($p < 0.001$). The difference in scores between dental students, 42 (20), and dental professionals, 39 (21), was not statistically significant.

Conclusion: Within the limitations of this study, females achieved significantly better shade matching results than males, indicating that gender plays an important role in shade matching. The level of experience was not found to be significant factor in shade matching.

1. Introduction

The tooth color is complex as teeth are small, curved, multi-layered, and exhibit color transitions in all directions – gingivo-incisally/occlusaly, mesio-distaly, and labio/bucco-lingually. In addition, color of permanent teeth changes throughout the lifetime and always interacts with other appearance attributes such as translucency and opacity, gloss, fluorescence, opalescence and iridescence, and with color and other appearance attributes of surrounding tissues. Numerous variables regularly associated with the light–object–observer triplet certainly bring further complexity to the color matching and reproduction in dentistry.

The measurement of tooth color is possible using visual and instrumental methods. Visual method is known as shade matching and it is performed using dental shade guides under more or less controlled conditions. This is a comparison between a trial (natural tooth) and multiple standards – usually sets of tooth shaped tabs made of ceramic or resin. Instrumental assessment is performed using spectrophotometers, colorimeters, spectroradiometers, digital- and spectral imaging. Properly selected and implemented, instrumental methods are objective and more robust, therefore being an invaluable complement to visual shade matching in dentistry.

Although the inconsistencies in visual color matching between individuals and for the same individuals regardless of their gender (human variables) have been reported,[1] it is traditionally believed that women are better color matchers than men. Inconsistent research results provided evidence that this was either right or wrong. The opponents of this belief called it ''scientific'' fiction.[2] However, this is certainly truth when all females and males are compared as approximately 8% of men and only 0.5% for women are color deficient.[3] Studies that involved dental students and professionals reported percentage of color deficient males (6–14%) similar to the findings for general male population.[4–10] As far as color normal persons of both genders are concerned, vision science literature stated that differences between color normal men and women in red-green color discrimination were not significant if color deficient males and females and heterozygote female carriers (15%) were excluded from comparisons.[11] When color assessment and diagnosis test was performed on 150 color normal males and the same number of color normal females, no significant gender-related difference was recorded.[12]

Several dentistry-related studies offered evidence on non-significance of differences in shade matching results between color normal females and males.[8–10,13–15] In addition, it was

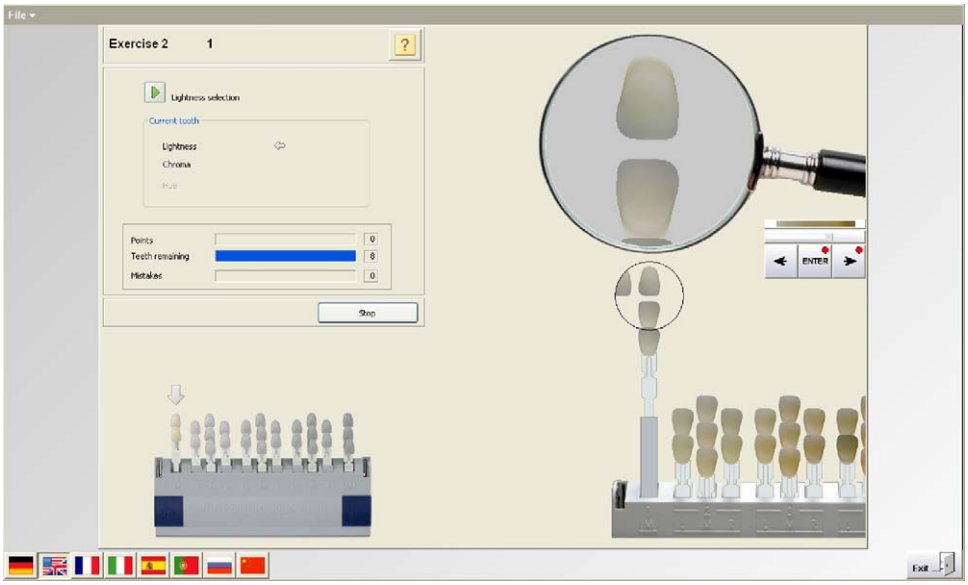

Fig. 1 – Toothguide Trainer software (TT).

reported that age and clinical experience did not play important role in shade matching.[15] Another study found that prosthodontists had superior intra-rater repeatability in shade selection compared to general practitioners.[16] Finally, several papers reported the influence of lighting and other conditions on shade matching results.[8–10]

The aim of this study was to compare shade matching results by gender (female vs. male) and by level of experience (dental students vs. dental professionals). The null hypothesis was that gender and experience did not influence shade matching results.

2. Materials and methods

The study was simultaneously performed at 15 universities in the following 9 countries: Austria, Czech Republic, France, Germany, Hungary, Lebanon, Slovenia, Spain, and United States of America. Upon obtaining the IRB approval, the participants were recruited for the study. Color vision was evaluated using Ishihara tests. A total of 614 color normal participants completed all phases of the experiment. Among them, there were 305 females (F) and 309 males (M), 319 dental students (S) and 295 dental professionals – dentists and dental technicians (P), with the range of age from 18 to 47 years. All participants filled out a form and provided the information on their age, gender and profession. A lecture on color matching in dentistry, with the information on color dimensions and instructions on Toothguide Trainer software (TT, Fig. 1) and Toothguide Training Box (TTB, Fig. 2) (Vita Zahnfabrik, Bad Säckingen, Germany), was given to all participants prior proceeding to these color training programs.

The exercises in TT and TTB were basically the same. The difference is that the images of 26 shade tabs of Toothguide 3D-Master tab (3D, Vita Zahnfabrik, Bad Säckingen, Germany) were used in TT, while the realistic shade tabs and color corrected light (Dialite Color, Eickhorst, Germany), with correlated color temperature of 5500 K were used in TTB (Fig. 3). The exercises were designed to simulate the 3-step shade matching procedure recommended for 3D (Fig. 4): Step 1 – lightness selection; step 2 – chroma selection; and step 3 – hue selection. The first set of TT and TTB exercises was related to the lightness selection (selection of appropriate 3D group, from 1 to 5), and four correct matches were needed in order to pass this step and proceed to the step 2. In step 2 there were 2 sub-steps in each exercise, initial lightness selection and chroma selection afterwards. Eight correctly solved lightness-chroma tasks were required in order to pass this step and proceed to step 3. Step 3 encompassed 3 sub-steps: 15 correct lightness–chroma–hue selections were required in order to pass this step and proceed to the final exam. Final exam consisted of a total of 15 lightness–chroma–hue tasks. The training was performed using the entire TT program and the training part of the TTB. The final TTB exam was used for testing of all participants. These shade matching results were recorded on laptop computers connected to TTBs and processed.

Fig. 2 – Toothguide Training Box (TTB) with the software support.

Fig. 3 – Toothguide Training Box (TTB) with the color corrected light source turned on.

Color difference (ΔE^*_{ab}) between the task tab and selected tab was computed as follows[17]:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

where ΔL^*, Δa^* and Δb^* denote differences in lightness, chroma and hue coordinate, respectively. $L^*a^*b^*$ values of all 26 shade tabs were provided by manufacturer.

The shade matching score, $\sum \Delta E^*_{ab}$, for each participant was computed as a sum of the color differences between all task tab and selected tabs. Lower $\sum \Delta E^*_{ab}$ scores corresponded to better shade matching results and vice versa. For all 15 exact matches, this score would be zero.

Means and standard deviations were calculated. Mann–Whitney U test was used for statistical analysis of the data ($\alpha = 0.05$). Data analysis was performed using the SPSS 10.0 for Windows (SPSS, Chicago, IL). Means, standard deviations, and descriptive statistics were calculated. Mean values were compared using the Mann–Whitney U test ($\alpha = 0.05$).

3. Results

The mean $\sum \Delta E^*_{ab}$ score of group M was higher than corresponding values of group F (Table 1). Women performed

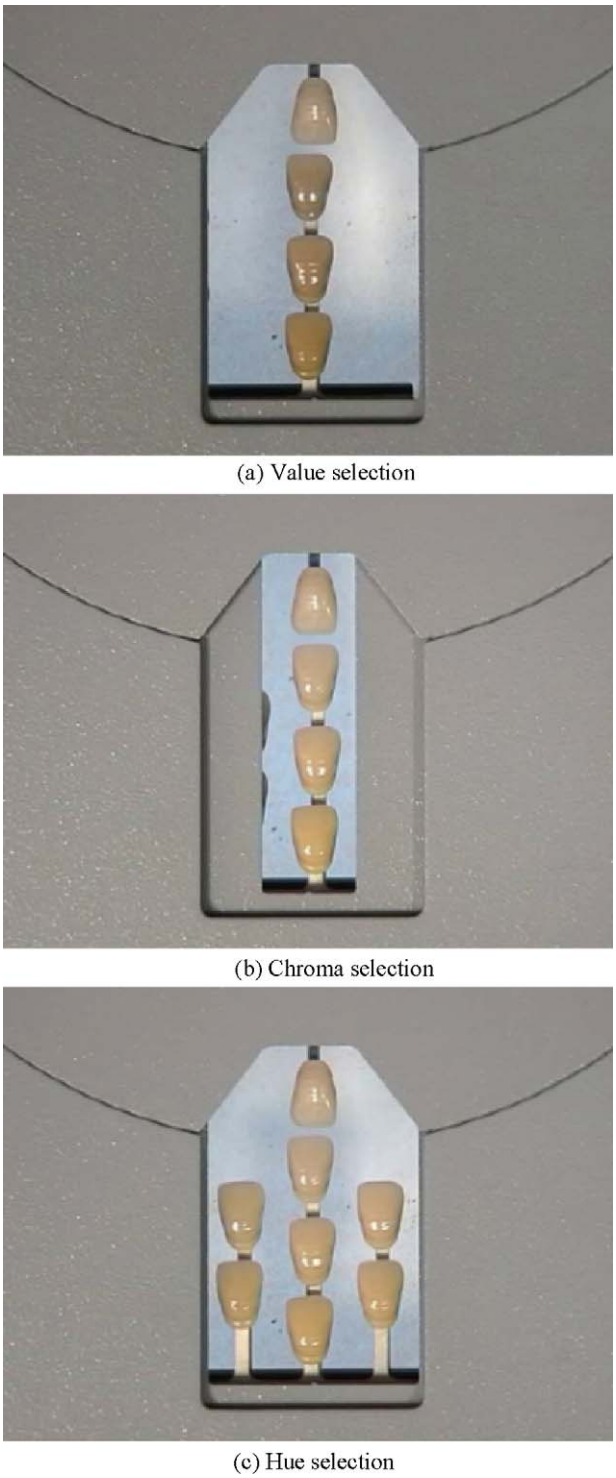

Fig. 4 – Toothguide Training Box (TTB): (a) value selection, (b) chroma selection, and (c) hue selection.

better in the final test and the difference between groups M and F was statistically significant (Table 2).

The mean $\sum \Delta E^*_{ab}$ score of group S was higher than corresponding values of group P (Table 3). However, the difference between groups S and P was not statistically significant (Table 4).

Table 1 – Shade matching results of female and male participants: mean, median $\sum \Delta E^*_{ab}$ scores and standard deviations.

Gender	N	Mean	Median	Standard deviation
F	305	38	36	20
M	309	44	42	21
Total	614	41	39	21

Table 2 – Statistical analyses results for gender groups.

	Sum
Mann–Whitney U test	40,122
Wilcoxon W	86,787
Z	−3.185
Asymp. Sig. (2-tailed)	0.0001

Table 3 – Shade matching results of dental students and dental professionals: mean, median $\sum \Delta E^*_{ab}$ scores and standard deviations.

Level of experience	N	Mean	Median	Standard deviation
S	319	42	40	20
P	295	39	37	21
Total	614	41	39	21

Table 4 – Statistical analyses results for level of experience.

	Sum
Mann–Whitney U test	43,019
Wilcoxon W	86,679
Z	−1.837
Asymp. Sig. (2-tailed)	0.066

4. Discussion

In one study, six female and six male dental students were tested for difference in color matching.[7] The students used three different shade guides and three different light sources to match each other's teeth. It was recommended that there was no reason to select the clinicians for shade matching according to gender; they also suggested that the clinicians should be rather screened for color vision.[7] However, the males showed borderline more uniform shade selection than the women (63–58%). The difference was small and only slightly significant.

Another study tested the ability of dental students to match shades under different light sources and also to find out whether there are differences based on the year in school and the gender of students.[9] A total of 165 male and 51 female students with an average age of 26 years performed a shade matching quiz and matched 5 preselected tabs from 14 items. It was found that shade matching results were better with a color corrected light compared to natural light; and gender and level of experience were not found to be relevant factors in shade matching. Results were similar when shade matching results of dental technicians were compared using color corrected light and daylight.[10]

One study reported that 7 (14%) of the 50 male dentists serving as subjects were color deficient.[4] A total of 670 dentists were testes in another study for red-green color deficiency.[6] Men accounted 94% of the test group. It was recorded that 66 (10%) of 670 professionals tested had some degree of color deficiency, whereas 19 (3%) were found to be severely color deficient.[6] To avoid all variables associated with color deficiency types and levels, only color normal participants were recruited for this study. However, is should be emphasized that they exist among dental students and professionals. Color vision screening might be organized for the applicants already admitted to dental schools as a confidential, informative, and non-excluding test.

This study tested a large group of dental students and professionals from different countries under the same color matching conditions and showed discrepancy to three mentioned studies in gender-related shade matching results. However, this study agreed with the findings that level of experience is not a factor to be considered in shade matching.[9,10,15] The study showed that students with no- or little experience in shade matching achieved the same results as experienced dental professionals.

Overall, there are three types of dental shade guides and shade matching systems: (a) Vitapan 3D-Master system, available as Linearguide, Toothguide and Bleachedguide (Vita Zahnfabrik, Bad Säckingen, Germany); (b) Vitapan Classical system by the same manufacturer and numerous Classical keyed products by different manufacturers; and (c) others – proprietary shade matching systems. The Toothguide 3D-Master color system was originally divided into 5 groups by value (1, 2, 3, 4 and 5). Within the groups, there are different levels of chroma (1, 2 and 3), while levels hue (M, L, R) are present in groups 2, 3 and 4. The suggested lightness–chroma–hue order was implemented in both TT and TTB.

TTB allows performing color training in dentistry under the same conditions regardless of different time and places. The exercises are essentially the same as in the TT, except the real ceramic shade tabs and a standard light source are used, which makes color matching test more similar to clinical situation. The future research might include other researchers and schools, and an additional aim of evaluating the influence of education and training on color matching results.

5. Conclusion

Within the limitations of this study, females achieved significantly better shade matching results than males, indicating that gender plays an important role in shade matching. The level of experience was not found to be significant factor in shade matching.

Conflict of interest statement

None declared.

Acknowledgements

Toothguide Trainer software and Toothguide Training box were developed by Prof. Dr. Holger Jakstat in collaboration with VITA Zahnfabrik, Bad Säckingen, Germany. Funded in part by VITA Zahnfabrik.

REFERENCES

1. Culpepper WD. A comparative study of shade-matching procedures. *Journal of Prosthetic Dentistry* 1970;**24**:166–73.
2. Reynolds LT. A note on the perpetuation of a ''scientific'' fiction. *Sociometry* 1966;**29**:85–8.
3. Chamberlain GJ, Chamberlain DG. Color—its measurement. Computation and application. 1st ed. London: Heyden; 1980.
4. Barna GJ, Taylor JW, King GE, Pelleu GB. The influence of selected light intensities on color perception within the color range of natural teeth. *Journal of Prosthetic Dentistry* 1981;**46**:450–3.
5. Davison SP, Myslinski NR. Shade selection by color vision-defective dental personal. *Journal of Prosthetic Dentistry* 1990;**63**:97–101.
6. Moser JB, Wozniak WT, Naleway CA, Ayer WA. Color vision in dentistry: a survey. *Journal of the American Dental Association* 1985;**110**:509–10.
7. Donahue JL, Goodkind RJ, Schwabacher WB, Aeppli DP. Shade color discrimination by men and women. *Journal of Prosthetic Dentistry* 1991;**65**:699–703.
8. Paravina RD. Evaluation of a newly developed visual shade-matching apparatus. *International Journal of Prosthodontics* 2002;**15**:528–34.
9. Curd FM, Jasinevicius TR, Graves A, Cox V, Sadan A. Comparison of the shade matching ability of dental students using two light sources. *Journal of Prosthetic Dentistry* 2006;**96**:391–6.
10. Jasinevicius TR, Curd FM, Schilling L, Sadan A. Shade-matching abilities of dental laboratory technicians using a commercial light source. *Journal of Prosthodontics* 2009;**18**:60–3.
11. Hood SM, Mollon JD, Purves L, Jordan G. Color discrimination in carriers of color deficiency. *Vision Research* 2006;**46**:2894–900.
12. Rodríguez-Carmona M, Sharpe LT, Harlow JA, Barbur JL. Sex-related differences in chromatic sensitivity. *Visual Neuroscience* 2008;**25**:433–40.
13. Barrett AA, Grimaudo NJ, Anusavice KJ, Yang MC. Influence of tab and disk design on shade matching of dental porcelain. *Journal of Prosthetic Dentistry* 2002;**88**:591–7.
14. Winkler S, Boberick KG, Weitz KS, Datikashvili I, Wood R. Shade matching by dental students. *Journal of Oral Implantology* 2006;**32**:256–8.
15. Anusavice KJ. Philip's science of dental materials. 10th ed. Philadelphia: Saunders; 1996. p. 42.
16. Hammad IA. Intrarater repeatability of shade selections with two shade guides. *Journal of Prosthetic Dentistry* 2003;**89**:50–3.
17. Berns RS. Billmayer and Saltzman's principles of color technology. 3rd ed. New York: Wiley; 2000.