

# 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 10<sup>th</sup> 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<sup>1</sup>. Women have traditionally been considered to be better in matching colors than men<sup>2</sup>, 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<sup>3</sup>. 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<sup>4</sup>, to opposing it and reporting no gender-dependent differences in color matching<sup>5-7</sup>.

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<sup>8</sup>. Color difference is typically quantified using CIE (Commission Internationale de L'Eclairage - International Commission on Illumination) formulas: CIELAB ( $\Delta E^*$ ) and CIEDE2000 ( $\Delta E'$ )<sup>9</sup>. 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<sup>10,11</sup>.

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)<sup>12-18</sup>. 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<sup>19</sup>. The daylight, D, is recommended for shade selection in dentistry<sup>20</sup>. CIE D illuminants are used to mimic various daylight conditions<sup>9</sup>. 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)<sup>21</sup>. 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<sup>22</sup>. 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<sup>23</sup>. Color corrected lights, such as D55, ensure consistent and appropriate conditions for tooth color matching<sup>2</sup>.

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

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<sup>29</sup>. 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<sup>9-11</sup>:

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

where  $\Delta E^*$  is difference in lightness-darkness, while  $\Delta a^*$ , and  $\Delta b^*$  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<sup>30</sup>.

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 2<sup>nd</sup> best match was selected, they obtained 9 points, the 3<sup>rd</sup> best match corresponded to 8 points, and so on up to 1 point if the 10<sup>th</sup> best match was selected. Any color match worse than the 10<sup>th</sup> 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  $\Delta E^*$  values was as follows:  $\Delta E' = 0.63 \times \Delta E^* + 0.14$ , while the equation for estimating  $\Delta E^*$  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 ( $\Delta E^*$ ) and CIEDE2000 ( $\Delta E'$ ) for the exact match task tabs (3D) and the closest match task tabs (VC)

| Points | $\Delta E^*$ , 3D | $\Delta E'$ , 3D | $\Delta E^*$ , 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<sup>31-34</sup>. It was reported that that gender played an important role in shade matching, and females achieved significantly better results than males<sup>4</sup>. On the other hand, numerous studies showed that no gender-dependent difference in shade matching ability between genders<sup>2,5,6,19,28,35-37</sup>.

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<sup>19</sup>. 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<sup>6</sup>.

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<sup>7</sup>.

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<sup>24</sup>. 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<sup>38</sup>.

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<sup>39</sup>. 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<sup>41</sup>. 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 ( $\Delta E^*$ ) 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<sup>17</sup>. 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 5<sup>th</sup> best match (in average, there were four better matches than the selected one). The mean color differences between the task tabs and the 5<sup>th</sup> 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<sup>42,43</sup>. Furthermore, significant education and training-dependent improvements were reported in two recent publications<sup>28,44</sup>.

## 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 5<sup>th</sup> best match, underlined the need for implementation of color education and training programs in dental schools and continuing education for dental professionals.

**Note:** The results of this paper were presented as a part of an invited lecture at the 21<sup>st</sup> BaSS Congress.

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