Evaluation of visual and instrumental tooth shade determination techniques

Doctoral Theses

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1. INTRODUCTION

Correct tooth shade selection and communication are essential to success of a restoration. There are two methods of shade determination: comparison with shade tabs and shade measurement with electronic devices. These two methods have gone under great improvement during last decades and their combination increases esthetic success. By taking advantage of combination of visual methods and technology-based instrumentation the subjectivity of visual color assessment can be minimized and accurate color analysis for restoration's shade is more easily communicated and predictable esthetic outcome can be achieved.

Routine clinical shade match, the method of comparing the tooth with shade tabs is subjective with not always quite controlled conditions and methods. Color matching is complicated by individual differences in color perception of even those dentists with normal color vision. The frequency of red-green color vision deficiency is reported 6-14% among dentists and dental students.

Training leads to improvement in tooth shade selection. Toothguide Trainer (TT) computer program *(Figure 1.)* and Toothguide Training Box (TTB) electromechanical device are part of an educational program and used as teaching-learning aid for tooth shade selection.

Figure 1. : Toothguide Trainer (TT) /www.Toothguidetrainer.com/

With the TTB an aid is available that allows to do an international testing at different universities to exactly the same and defined conditions *(Figure 2.).*

TT and TTB were used to evaluate how gender, experience, red and green color vision deficiency (CVD) and training influences color matching results.

Figure 2. : Toothguide Training Box

Shade-matching protocol outlines those recommendations for reliable shade match, that gives predictable esthetic results.

2. AIM

2.1. DOES GENDER AND EXPERIENCE INFLUENCE SHADE MATCHING QUALITY?

The aim of this study was to compare shade matching results by gender (female vs. male), and by experience (dental students vs. dental professionals).

2.2. THE ISHIHARA TEST AS A DATA-PROJECTION – STILL A VALID SCREENING TOOL TO TEST RED-GREEN COLOR VISION DEFICIENCY

The aim of this study was to test whether group test of projected Ishihara slides was a valid screening tool for red-green CVD of dental students.

2.3. THE EFFECT OF RED-GREEN COLOR VISION DEFICIENCY ON TOOTH SHADE DETERMINATION, A PRELIMINARY STUDY

The aim of the investigation was to clarify whether red- green CVD influences tooth color differentiation.

2.4. TOOTHGUIDE TRAINER TESTS WITH COLOR VISION DEFICIENCY SIMULATION MONITOR

The aim of this study was to evaluate whether simulated severe red and green CVD influences color matching results while training and testing with TT computer program and to investigate whether training with TT enabled better color matching results.

2.5. SHADE-MATCHING PROTOCOL

The aim of the protocol is to outline the recommendations for a more objective and predictable approach to shade matching for dentists with normal color vision and color vision deficiency as well.

3. MATERIAL AND METHODS

3.1. DOES GENDER AND EXPERIENCE INFLUENCE SHADE MATCHING QUALITY?

Study was simultaneously performed at 15 universities located in 9 countries (Austria, Czech Republic, France, Germany, Hungary, Lebanon, Slovenia, Spain and USA). A total of 614 color normal participants (age 18-47) completed all phases of the experiment. Among them, there were 305 females and 309 males, 319 dental students and 295 dental professionals. Color vision was tested by Ishihara test. A lecture on color matching in dentistry was given to all participants. Initial training was performed using Toothguide Trainer software, while Toothguide Training Box was used for both training and testing of participants' shade matching results *(Figure 3.)*. The test task was to successively match 15 shade guide tabs with the corresponding shade guide. The shade matching result for each participant was computed as a sum of color differences ($\sum \Delta E^*ab$) between target tabs and selected tabs. Means and standard deviations were calculated. Mann-Whitney U test was used for statistical analysis of the data ($\alpha 0,05$). All tests were performed using SPSS 10.0 for Windows (SPSS, Chicago, IL).

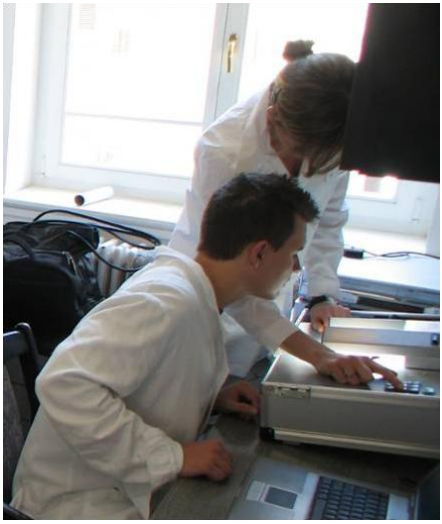

Figure 3. : Training with the TTB at Semmelweis University.

3.2. THE ISHIHARA TEST AS A DATA-PROJECTION – STILL A VALID SCREENING TOOL TO TEST RED-GREEN COLOR VISION DEFICIENCY

The Universities of Budapest, Siena and Leipzig participated in the study. Ishihara Tables were presented to 272 dental students (Leipzig 97, Budapest 125, Siena 50), 125 (46 %) male and 147 (54 %) female. After evaluation of test-results, those participants who missed more than 2 Ishihara plates were tested by Farnsworth D15 Test and Nagel Anomaloscope.

3.3. THE EFFECT OF RED-GREEN COLOR VISION DEFICIENCY ON TOOTH SHADE DETERMINATION, A PRELIMINARY STUDY

As Hungarian sample site of the international investigation at the Department of Prosthodontics, Semmelweis University 125 students, postgraduate students and dentists (60 males, 65 females, age 19-38) consented to the participation in the study. To the screening on red-green CVD, participants took part in a group testing with the Ishihara Test. In order to secure a possible red-green CVD and to determine its type and severity those participants who missed the Ishihara Test were submitted to test by printed version of Ishihara book, Farnsworth D15 test and Nagel anomaloscopy at the Department of Ophthalmology Semmelweis University.

All participants received a lecture to give an introduction to tooth color differentiation based on value, chroma and hue. Afterwards all had to accomplish a preliminary training with TT computer program. Last stage of the investigation was the training and testing with TTB to measure the individual ability of tooth color differentiation. Data of participants after performing all stages anonymized was sent to the central evaluation center at the University of Leipzig. The shade matching result for each participant was computed as a sum of color differences ($\sum \Delta E^*ab$). Means and standard deviations were calculated.

3.4. TOOTHGUIDE TRAINER TESTS WITH COLOR VISION DEFICIENCY SIMULATION MONITOR

A total of 31 color normal dental students participated in the study (13 males, 18 females, age 20-33). Every participant had to pass the Ishihara Test. Participants with a red-green color vision deficiency were excluded. A lecture on tooth color matching was given, and individual training with TT was performed. To measure the individual tooth color matching results in normal and color deficient display modes, the TT final exam was displayed on a calibrated monitor that served as a hardware-based method of simulating protanopy and deuteranopy. Data from the TT final exams were collected in normal and in severe red and green CVD-simulating monitor display modes. Color difference values for each participant in each display mode were computed ($\sum \Delta E^*ab$), and the respective means and standard deviations were calculated. The Student's t-test was used in statistical evaluation. All tests were performed using SPSS 10.0 for Windows (SPSS, Chicago, IL).

4. RESULTS

4.1. DOES GENDER AND EXPERIENCE INFLUENCE SHADE MATCHING QUALITY?

The mean ΔE *ab of males was higher than corresponding values of females. Women performed better in the final test and the difference between females and males was statistically significant.

The mean ΔE *ab of group students was higher than corresponding values of dental professionals. However, the difference between the two groups was not statistically significant.

4.2. THE ISHIHARA TEST AS A DATA-PROJECTION – STILL A VALID SCREENING TOOL TO TEST RED-GREEN COLOR VISION DEFICIENCY

Ishihara-Test showed 14 (11,2 %) of the male participants to have red-green CVD.

Ishihara test specificity showed to be 99,6 %. The positive predictive value appreciation turned out to be 93.3% and negative predictive value appreciation 100%.

Farnsworth D15 sensitivity compared to the Nagel anomaloscope was only 21,4 %, it means that 80 % of the participants with red-green CVD passed the Farnsworth D15 test.

4.3. THE EFFECT OF RED-GREEN COLOR VISION DEFICIENCY ON TOOTH SHADE DETERMINATION, A PRELIMINARY STUDY

Screening 125 participants 10 person (9 male, 1 female) missed more than two of the Ishihara Plates. Nagel anomaloscopy showed deuteranomaly in case of 6 males, protanopy in case of 3 males and 1 female proved to have normal color vision. TTB test showed a difference in the ability for tooth color differentiation as the mean ΔE *ab of color vision deficient participants was higher than thoses with normal color vision (65,5 to 43, 8 respectively).

4.4. TOOTHGUIDE TRAINER TESTS WITH COLOR VISION DEFICIENCY SIMULATION MONITOR

Participants made larger ΔE*ab errors in severe color vision deficient display modes than in the normal monitor mode. TT tests showed significant ($p<0.05$) difference in the tooth color matching results of severe green color vision deficiency simulation mode compared to normal vision mode. The color differences in both protanope and deuteranope mode were significantly higher ($p<0,001$) than ΔE*ab of the normal display mode after training.

Training with TT improved students' shade match results, as shown by the significant decrease in the mean ΔE*ab ($p=0,009$) when TT tests were done for the second time in the normal display mode of the monitor.

5. CONCLUSIONS

5.1. DOES GENDER AND EXPERIENCE INFLUENCE SHADE MATCHING QUALITY?

Females achieved significantly better shade matching results than males, indicating that gender plays an important role in shade matching. The experience was not found to be significant factor in shade matching.

5.2. THE ISHIHARA TEST AS A DATA-PROJECTION – STILL A VALID SCREENING TOOL TO TEST RED-GREEN COLOR VISION DEFICIENCY

Using projected slides of Ishihara plates in a group test is an effective and timesaving method for detecting colorvision deficiency among dental students.

5.3. THE EFFECT OF RED-GREEN COLOR VISION DEFICIENCY ON TOOTH SHADE DETERMINATION, A PRELIMINARY STUDY

Within limitations of our preliminary study red-green color vision deficiency seams to impair the determination of tooth colors.

Screening of dental students for red-green CVD should be used on a routine basis in dental schools. If color vision deficiency is detected,

more complete CVD testing (anomaloscopy) is recommended for further quantification of the severity of the deficiency.

5.4. TOOTHGUIDE TRAINER TESTS WITH COLOR VISION DEFICIENCY SIMULATION MONITOR

Computer-simulated severe color vision deficiency mode resulted in significantly worse color matching quality compared to normal color vision mode.

The ability to simulate protanopy and deuteranopy for the color matching process, coupled with the computer's inherent capacity to automate data collection in an efficient and highly repeatable way, may offer a new methodology to collect data for statistical evaluation of severe CVD effects on color matching abilities.

Experience improves shade matching quality as training with TT leads to statistical significant improvement in students' shade matching results.

5.5. SHADE-MATCHING PROTOCOL

Steps to a successful shade match are: Preoperative patient evaluation, Analysis, Communication, Interpretation and fabrication in the laboratory, Verification.

Best way to take a shade is to combine visual and instrumental methods: use comparison method of shade tabs with subjective measurements of digital devices and reference photography together.

Color vision deficient dentists should use also visual help from assistants and dental technicians together with patients agreement to ensure correct shade matching.

6. CANDIDATE'S OWN PUBLICATIONS LIST

6.1. PUBLICATIONS LIST RELATED TO THE THESES:

INTERNATIONAL ACADEMIC PUBLICATIONS, JOURNAL PAPERS:

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