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**ORIGINAL ARTICLE**

# Evaluation of two different approaches to learning shade matching in dentistry

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**Abstract**

***Statement of the problem.*** An important aspect of dental education is teaching and learning shade matching. ***Objective.*** To assess the success of two different strategies for learning shade matching. ***Materials and methods.*** Seventy-one pre-clinical students (mean age 23; 33.3% men) were divided into two groups. One group (TTB) formed teams of two and they matched three pre-determined teeth on each other using the 3D-Master shade guide. After this exercise, they learned shade matching using a standardized device (Tooth Guide Training Box, TTB) by matching shade tabs in an artificial environment. The other group (GL) matched tooth color in a pre-defined clinical setting in groups of four students. After this, they matched the same teeth as before training, again in groups of two, similarly to group TTB. The reference tooth color was determined by two experienced prosthodontic clinicians. The L*a*b* values for the tabs were provided by the manufacturer and the color difference ($\Delta E_{ab}$) between the chosen tab and the reference was calculated. Linear general estimation equation models were used for statistical evaluation ($p = 0.05$). ***Results.*** In the TTB group, the difference between $\Delta E_{ab}$ values before and after training was 0.03, which was not significant ($p = 0.927$; 95% CI: −0.70/0.77). In the GL group, $\Delta E_{ab}$ was 0.98 smaller after training, which was significant ($p < 0.001$; 95% CI: 0.50/1.50). ***Conclusion.*** The ability to match tooth color could be improved by using a group-learning approach in a clinical setting and implementation of such a training session should be considered in undergraduate and postgraduate dental education.

**Key Words:** *tooth shade, color learning, color teaching*

## Introduction

The optimum color of restorations is of a great importance to patient satisfaction with dental restorations. Shade matching should, therefore, be an important aspect of undergraduate and postgraduate dental education. However, little information is yet available on this topic. This may be because the shades in most guides, for example the widespread VITA Classical shade guide (VITA Zahnfabrik, Bad Säckingen, Germany), are not grouped systematically and shade matching is a matter of choosing the best fitting sample out of a relatively large group of samples.

With the development of the 3D-Master shade guide (3D, VITA Zahnfabrik) a more systematic approach toward shade matching was established in dentistry. This more systematic approach improves patients' satisfaction with the esthetic outcome of restorations [1]. Completely uniform matching may not be achieved, however [2]. The 3D-Master divides the shade-matching process into three steps—matching of lightness, chroma and hue [3]. This is in agreement with the three-dimensional CIE (Commission internationale de l'éclairage) color space in which L* describes lightness and a* and b* describe the red/green and yellow/blue axes or, in cylindrical projection, C*, the chroma, and $h^o$, the hue, respectively [4]. Color differences are expressed in terms of $\Delta E$ [5–8].

A curriculum has been established by Professor H. Jakstat, University of Leipzig, in conjunction with VITA Zahnfabrik, for learning shade matching using a systematic process. The first step is working with Toothguide Trainingssoftware (TT; Figure 1A; www.toothguide.com). TT is a computer-based tool in which a shade tab from the 3D-Master is presented

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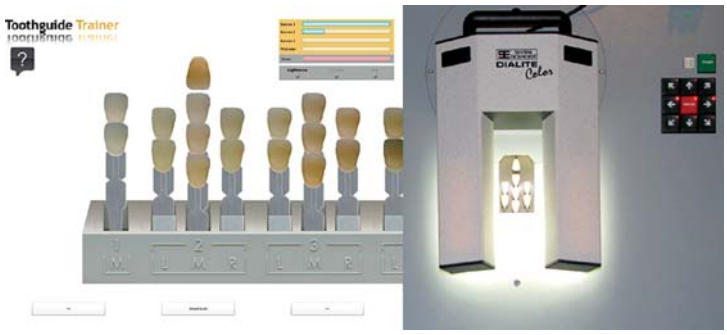


Figure 1. (A) TT and (B) TTB.

on a computer monitor. The learner has to choose lightness first, then chroma and hue, and the computer then tells the learner whether or not the selection was correct. This is repeated until the learner reaches a specific level of performance. In the second step, the Tooth Guide Training Box (TTB) presents a real shade tab under artificial daylight conditions. Opposite the unknown tab, the box presents the tabs of the 3D-Master from which the user could choose (Figure 1B). The box tells the learner whether or not his/her selection was correct. Again the learner has to match colors until a specific level of performance is reached [9,10]. Previous studies have shown that this standardized approach improves the ability of students to match the shade tabs of the TTB [11,12]. It remains unclear, however, whether this approach really improves ability to match tooth color clinically. For example, shade tabs are more homogenous in color and structure than natural teeth.

The objective of this study was to assess, in a clinical setting, the success of two strategies for learning shade matching in dentistry. We investigated whether training with TT and then the TTB or a group learning approach in a clinical setting affects shade-matching ability in comparison with a 'gold standard'. The research hypothesis stated that an improvement of natural tooth shade matching ability would not be possible for both strategies.

## Materials and methods

All participants in the pre-clinical course in 2009 at the University of Heidelberg participated in the study and signed an informed consent. Before investigation, color blindness was monitored by use of the Ishihara test. This test shows, in several forms, a red number mapped on a green background. A person with red–green color blindness or debility would not be able to detect the number. No participant had to be excluded because of color blindness.

To achieve comparable knowledge in shade matching in dentistry and in use of the shade guide system to be used, the 3D-Master, a 45-min lecture was given, including the basics of color and shade matching in dentistry; the TT software was then completed by every participant. The software indicates whether or not participants fulfilled the requirements for successful training.

After the lecture and use of the computer program two groups were randomly formed. Group 1 learned tooth-color matching using a standardized device (TTB group), whereas group 2 used a group-learning approach in a clinical setting (GL group). The TTB group comprised 34 students (38.2% men) with a mean age of 22.3 years (SD = 2.7). The GL group contained 35 students (28.6% men) with a mean age of 23.9 years (SD = 3.5). The next step was to create groups of two persons within both the TTB and GL groups (one group with three participants in the GL group). The participants then matched three pre-determined teeth on each other using the 3D-Master shade guide. They matched the maxillary right central incisor, the maxillary right canine and the mandibular right first bicuspid. These teeth were matched if they were unrestored, but the teeth on the opposite side were used if the respective tooth had a filling or a veneer. Matching took place in a special room which was painted a neutral grey (~ 20%) and illuminated with daylight lamps (D55) (Figure 2). The person being matched wore a grey cape. Women had to remove make-up. For shade matching a daylight lamp was used (Dialite Color, System Eickhorst, Hamburg, Germany; daylight lamp with diffuse light from two angled 5-Watt lamps, 5700 K, 1500 Lux, distance ~ 25 cm). After matching the three shades ($n$ = 102 matched teeth), the TTB group completed a standardized training program with the TTB. In the GL group, after matching the three above-mentioned teeth ($n$ = 105 matched teeth), groups of four persons were established. Three persons then clinically matched the color of three other teeth on the fourth person in the color-matching room (all possible combinations). All three shade matchers had to be in agreement on each tooth color. When the training was finished, two persons again matched the shade of the maxillary upper central incisor, the

Figure 2. Clinical setting for tooth-color matching.

maxillary right canine and the mandibular right first bicuspid, as at the start of the procedure.

To evaluate if the shade selected before or after training was more correct a 'gold standard' had to be defined. Therefore, the tooth shades were also matched using the 3D-Master guide by two prosthodontic clinicians who also had to agree on the best match (N.C. and A.J.H, one female and one male). All tooth-color matching was performed within 1.5 h.

Statistical evaluation – Differences between the shades selected by the participants and the 'gold standard' were determined as $\Delta E_{ab}$, which describes the Euclidian distance between two colors (L*a*b* coordinates) in CIE-LAB color space by use of the formula:

$$\Delta E_{ab} = \sqrt{(L^*_1 - L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1 - b^*_2)^2}$$

L*a*b* for the shade tabs was provided by the manufacturer. Homogeneity of the experimental groups was tested with regard to gender (chi$^2$ test), age (*t*-test) and $\Delta E_{ab}$ between participant and standard before training (*t*-test). To account for multiple observations of one participant (three matches per participant) linear general estimation equation models (GEE) were used for each group. Dependent variables were the differences between the 'gold standard' and $\Delta E_{ab}$ before and after training for each participant and for each tooth. The participant ID was introduced as a subject factor and the tooth number as an inner-subject factor. Finally, multifactorial analysis taking possible confounders into account was performed, again using linear GEE. Age, gender and group (GL/TTB group) were also introduced as independent variables. All statistical analysis was performed using SPSS (Version 16.0.1). The level for significance was set to alpha = 0.05.

## Results

Homogeneity of the groups; the groups did not differ significantly with regard to gender ($p = 0.395$) or $\Delta E_{ab}$ from the standard before training ($p = 0.782$). For age the mean difference was 1.6 years ($p = 0.042$; 95% CI: 3.1/0.06).

The distribution of $\Delta E_{ab}$ before and after training for both groups is shown in Figures 3 and 4 (matched tooth as single unit). In the TTB group, the mean $\Delta E_{ab}$ from the standard before training was 4.60 (SD = 2.8); it was 4.56 (SD = 1.8) afterwards. When adjusted for multiple observations, the difference between $\Delta E_{ab}$ values before and after training was 0.03 (95% Wald CI: −0.70/0.77) at a non-significant level of $p = 0.927$. In the GL group the mean $\Delta E_{ab}$ from the standard before training was 4.70 (SD = 2.7); it was 3.73 (SD = 1.6) afterwards. When adjusted for multiple observations the difference between $\Delta E_{ab}$ values before and after training was 0.98 (95% Wald CI: 0.5/1.5) at a significance level of $p < 0.001$.

Multifactorial analysis revealed a significant association of group (TTB/GL) with difference between $\Delta E_{ab}$ values before and after training when adjusted for age, gender and multiple observations. The difference between $\Delta E_{ab}$ values was 0.96 units greater (smaller $\Delta E_{ab}$ after training between participant and 'gold standard') in the GL group at a significance level of $p = 0.025$ (Table I).

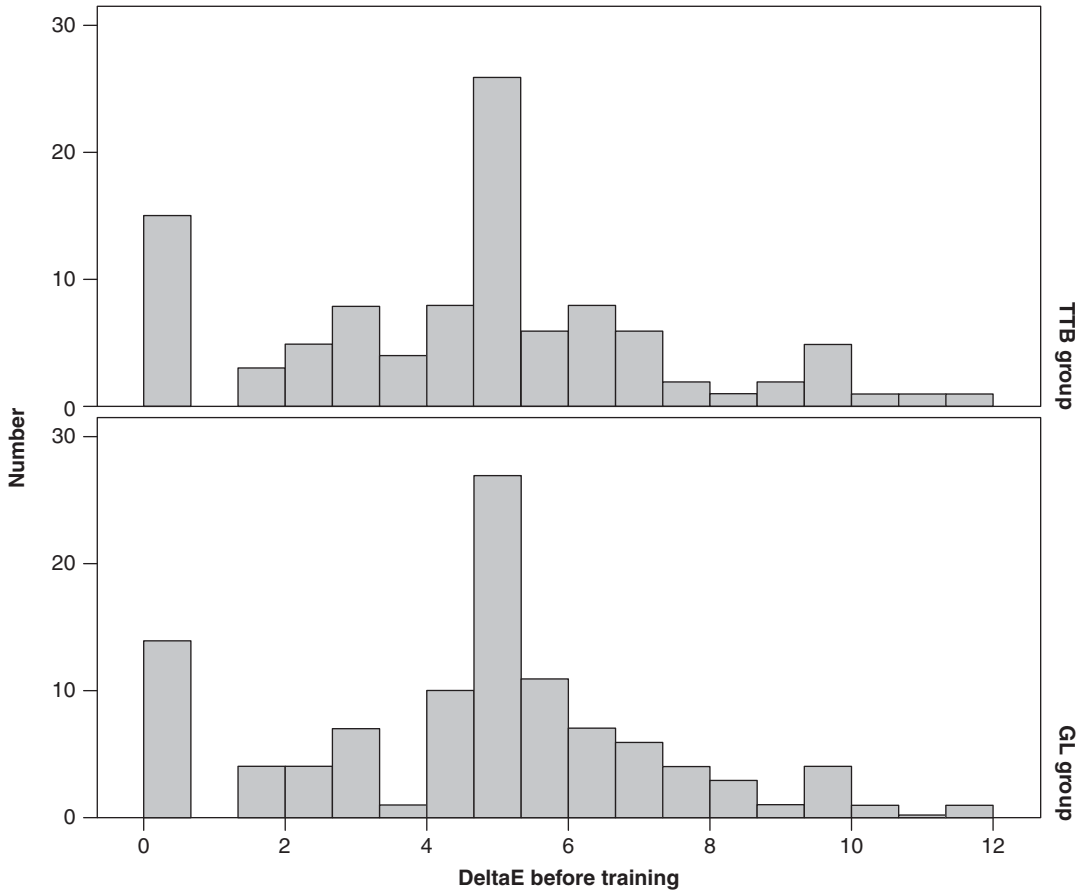


Figure 3. Distribution of $\Delta E_{ab}$ before training, by group.

## Discussion

The research hypothesis had to be rejected for the GL group and had to be accepted for the TTB group. The results revealed there was no improvement in clinical shade matching after training with the TTB [11,12]. This result was unexpected, because studies have shown an improvement in shade-matching ability after training, although these studies examined shade-matching ability not in a clinical setting but with the test mode of the TTB, which presents shade tabs to be matched and records the correctness of the results without indicating correctness of the choices during matching. A study in which the TTB curriculum was performed three times reported a significant improvement in the test mode and a decrease of the time needed for matching was achieved. The result was, however, non-significant when using the shade guides and not the test mode [11]. Another study found a reduction of $\Delta E$ of 33% between an initial test on the TTB and a second test after training with the TTB [12]. Comparison with our results reveals a difference between matching tabs and matching real tooth color. A curriculum for matching tooth color clinically should therefore implement a more clinical setting. In contrast with the findings for the TTB group, the GL group with the more clinical and team-based approach achieved a significant improvement in shade-matching ability of 1 $\Delta E_{ab}$ unit. This could be regarded as a meaningful improvement: $\Delta E_{ab}$ = 1 is the 50:50% detectable point for experienced examiners, 2.7 was found to be the 50:50% replacement point for esthetic dental materials by Ragain and Johnston [7] and $\Delta E_{ab}$ =3.7 was the largest color difference with no mismatches observed as described by Johnston and Kao [8]. The mean $\Delta E_{ab}$ of 3.7 between the 'gold standard' and the participants after training could be interpreted as being at the limit of what could be regarded as acceptable [8]. Although this improvement could be because of the clinical training setting, which is close to the real clinical situation, it may have been achieved because of the team approach. The students learned in groups of three color matchers. A student could therefore see what others would have chosen as the correct color and there may be a learning effect relative to the color most persons would choose.

The results of this study, however, are limited by the shortcomings of the research design. With a neutral colored shade-matching room as the setting an attempt was made to establish comparable and ideal conditions for the shade-matching process. However, there is no real 'gold standard' when determining tooth color. Another approach would have

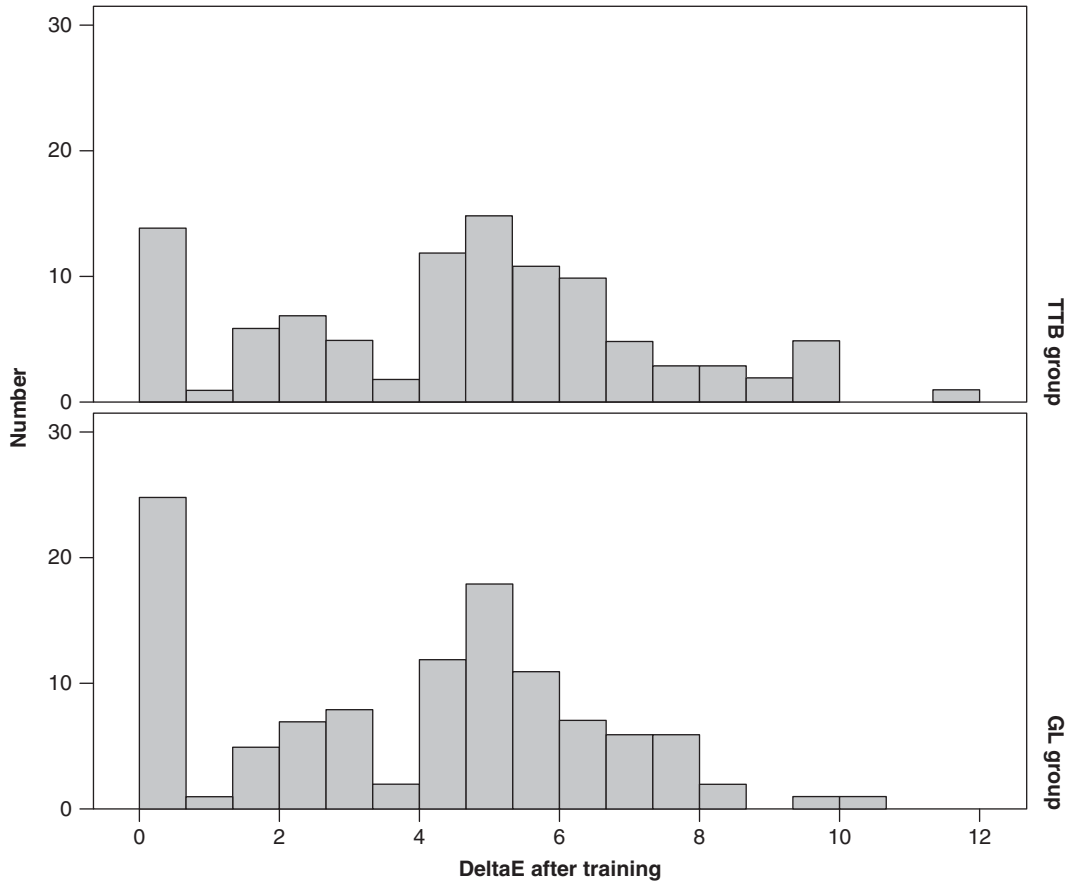


Figure 4. Distribution of $\Delta E_{ab}$ after training, by group.

been to use a result from an electronic device as a reference. Different devices do not consistently agree with each other and with human observers, however [13]. The two experienced color matchers defined as the 'gold standard' also had to agree on the best shade match. This could not be regarded as 'real' tooth color, however. The uncertainty of the reference color limits the conclusions but will, currently, limit every study because perception and matching of tooth color are liable to subjective effects.

Table I. Multifactorial analysis of differences between $\Delta E_{ab}$ values before and after training as a dependent variable ($n$ = 207 teeth).

| | | 95% Wald confidence interval | | |
|---|---|---|---|---|
| | B | Lower bound | Upper bound | Significance |
| Constant | 1.71 | −1.36 | 4.78 | 0.275 |
| Group | | | | |
| TTB group | −0.96 | −1.80 | −0.12 | 0.025 |
| GL group | 0 | — | — | — |
| Gender | | | | |
| Men | −0.27 | −1.28 | 0.74 | 0.602 |
| Women | 0 | — | — | — |
| Age | −0.03 | −0.16 | 0.11 | 0.694 |

## Conclusion

The ability to match tooth color clinically could be improved by use of a group learning approach in a clinical setting. Implementation of such a training session is recommended for undergraduate and post-graduate dental education. The approach tested, using only shade tabs in a non-clinical setting, did not improve clinical shade-matching ability.

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