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Interrater Repeatability of Shade Matching

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Abstract. The objectives of this study were to evaluate the interrater repeatability in shade matching procedure, and to determine if differences exist in selection of particular common shades. Five groups (10 each) of participants were selected: prosthodontists, dentists, dental interns, dental technicians and dental patients. Shade selection was carried out using Vitapan classical shade guides to mach seven shade tabs (A1, A3, B2, B3, C2, C4 and D3) of the same shade guide. Shade tabs label were masked and the shade selection was carried out through two rounds with an interval of one week time. Spectrophotometer was used as control.

Shade repeatability results showed variation between the studied groups. A statistically significant difference ($p<0.05$) were found between dental interns (48.6%) and both dental patients (24.3%) and dental technicians (21.4%). The Spectrophotometer provided a 100% match of the two rounds. Among the seven shade tabs C4 showed the highest incidence of being matched correctly; 56% in the 1st round and 62% in the 2nd round.

Dental interns were the most reliable group in providing correct matching, whereas the reliability of dental patients and dental technicians in reproducing shade selection is questionable.

Introduction

The use of dental shade guide is a common practice in matching of natural teeth color in order to obtain aesthetic and naturally looking dental restorations. There are various shade guides made from different materials available for the clinicians depending on the kind of restoration intended to be delivered. The shade matching carried out by comparing of a patient's tooth to the shade guide tabs. To facilitate color selection most of tabs in the shade guide are arranged in decreasing value (from lightest to darkest) and grouped by hue (Miller, 1988).

Shade selection could be done by two methods, namely the visual and the instrumental methods. Visual method is the determination of shade by the perception of the wavelength of light entering the brain through the retina. The perception of the object's color is the result of a physiological response to a physical stimulus. The nature of color engrosses several physical, physiological and psychological factors (Glick, 1998).

Shade tabs have been demonstrated to be more easier design for shade evaluation and improves the proficiency of individuals on repetitive matching tasks (Barret *et al.*, 2002). In visual shade selection, the light from the test tab enters the eye, received by the rods and cones in the retina, creating impulses that are carried to the brain where interpretation is made at the optical center. Different people interpret the same stimulus differently, making it very subjective (Land, 1977). Lack of consistency among and within individual dentist in matching color evoked the question of need for special training for the maneuver (Donahue *et al.*, 1991).

The current study was designed to assess the capacity of individuals to repeat the shade matching. The various parameters affecting accurate shade selection include illumination, background color, method of shade selection, and shade guide design

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used. Hence, efforts were taken to standardize these factors in order to estimate the acumen of persons with variable dental experience in matching and repeating color selection.

Instruments such as spectrophotometer and colorimeter can be used to evaluate and specify the shade of an object. The device measures the reflectance or transmittance of the wavelength of light from the object. These devices are complex and have been used in industrial and research setups but lately their application in dental field have been tested for feasibility, and reliability (Meireles *et al.*, 2008; Kanawati and Richards, 2009; Kuzmanovic and Lyons, 2009). Technological advancements have not only reduced the size of these devices for intraoral use but also digitized them to produce the immediate location of the shade within the 3-dimentional CIE-LAB (Commission Internationale de l'Eclairage L* a* b* color system which when analyzed mathematically, can compare the color parameters of different objects) color space (Meireles *et al.*, 2008). In CIE-LAB system, L* characterized the lightness of a color, a* defines a color on red-green axis, and b* defines a color along yellow-blue axis. A clear-cut supremacy of the objective instrumental method over the subjective visual method could not be definitely proved because of the polychromaticity of structure and difficulty in accurately re-establishing the same position on the tooth to acquire the same shade again (Judeh and Al-Wahadni, 2009). Although the visual method seems to suffer a high intra-examiner and inter-examiner variability, still it frequently demonstrates acceptable shade selection, provided the color vision is not compromised. Instrumental method is reserved for individuals suffering from error in their color vision and specifically for those who find it difficult to match shades.

There are about 10 millions of shades that could be identified using the modern technology but as the human brain could only perceive approximately one million of them, the practicality of providing so many materials and shade tabs for fabrication of restorations is impractical and costly. Hence, it was essential to assess the permissibility limit of shade variance.

$$\Delta E = [(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2]^{\frac{1}{2}}$$

L_1 = L color parameter of the standard
L_2 = L color parameter of the selected shade
a_1 = a color parameter of the standard
a_2 = a color parameter of the selected shade
b_1 = b color parameter of the standard
b_2 = b color parameter of the selected shade

The minimum shade difference perceptible by the human eye was estimated to be $\Delta E = 2.6$ units (Meireles *et al.*, 2008). Fortunately, the acceptability threshold of ΔE is as high as 5.5 units (Douglas *et al.*, 2007). Even though equipments offer a great hope for the future, visual shade selection still remains the most predictable method available.

Duplicating natural teeth is getting more exacting than ever before due to rising levels of patients' expectations. Thus the challenge doesn't end with just a convincing shade selection, but continues into the replication of the correct shade before delivering the prosthesis. The subjectivity of shade matching goes on with reproducing also. The dental technician is the one who is concerned with the imitation of shade at the laboratory.

Lagouvardos *et al.* (2009) questioned the reliability of two intraoral colorimeters for shade reliability. The point of concern is that which one to rely upon for an acceptable reproduction of shade during insertion. This problem still remains unresolved. Therefore, the main objectives of this study is to evaluate the interrater repeatability of different groups of individuals who are either directly or indirectly involved in shade matching procedure and to determine if differences exist in the selection of any particular shade among the common shades.

Materials and Methods

The study was being conducted in King Saud College of Dentistry for males. Fifty male participants within the age range of 24 to 70 years were divided into five groups of ten each. Forty participants were chosen according to their levels of education and experience in dental profession and 10 participants were chosen from dental patients visiting dental clinic of the College of Dentistry, King Saud University. The groups comprised of prosthodontists (PD) with an average experience of 10 years, dentists (GP) with over 5 years of experience, dental interns (DI) 4 years of learning experience, dental technicians (DT) with over 5 years of experience and dental patients (DP).

All groups of participants were given a questionnaire to fill out their names, age, gender and years of experience. Before starting the shade matching procedures, each participant was tested for color acuity using Ishihara plates (Tokyo, Kanehara and Co.) To standardize the environment, the shade selection was carried out on a neutral grey background and under a 6500ºK color fluorescent lamp (Demetron Shade Light, Kerr, USA), which simulates the natural light.

Two identical Vitapan classical shade guides were taken (Vita ZahnFabrik, H.R auter, G mb H and Co. KG, Germany). Seven shade tabs (A1, A3, B2, B3, C2, C4 and D3), representing the whole spectrum of values investigated, were selected from the first shade guide to work as reference. The second shade guide was left as complete set to be used for shade matching. The shade tabs labels were masked using opaque adhesive tape and were randomized in position so that differences in shade gradation could not be evident.

Given 30 seconds per shade tab, each participant was asked to match each of the seven shade tabs from the randomized shade guide to a corresponding shade tab of the other shade guide (used as reference). To avoid retinal fatigue they were instructed to look into a blue card after every ten seconds of gazing (Marcucci, 2003). Three separate readings were taken by every participant who was blinded from his earlier result and the mode of the three readings was taken as the selected shade. Immediately after each shade matching the results were recorded as either a match or a mismatch by unmasking the tabs.

Percentage of correct shade matching = (Number of correct selections/ Total number of shade selections) x 100

After one week the same experiment was repeated and the results were recorded. The results of both rounds of shade matching were compared to evaluate examiner repeatability. The percentage of repeatability was calculated using the following formula (Hammad, 2003):

Percent repeatability = (Number of repeated shade selections/Total number of shade selections) x 100

In addition the incidence of correct selection for each shade tab was calculated from both the first and second rounds.

A similar shade matching was conducted using an intraoral spectrophotometer Vita Easyshade system (VES) (Vident, USA) under the same conditions of illumination and background. The probe of the VES was held at 90º and in contact with the middle third of each shade tab. This result was used as the control. The percentages of the correct shade matching in the first and second rounds were compared using paired t-test.

Results

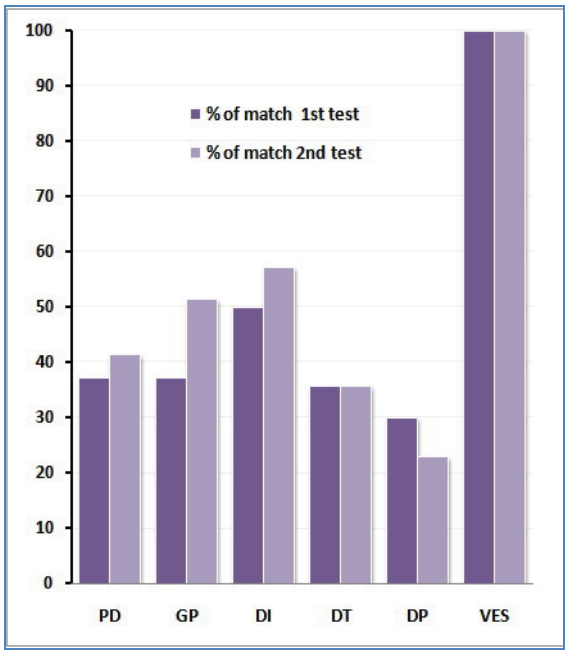
On conducting the test for color acuity using Ishihara plates, none of the selected participants were detected to have color blindness and hence no elimination was required.

The percentages of the correct shade matching in the first and second round are presented in Table 1 and Fig. 1. There was statistically significant improvement in tab shade matching for the PD, GP and DI groups when comparing 1st to 2nd round, while for the DT remained unchanged. The DP exhibited a lower percentage of matching in the second round as compared to the first. The DP group gave the least percentage. Paired t-test showed statistically significant ($p<0.05$) difference between DI and DP in both the rounds.

Table 1. Percentage of the correct shade matching for each group in the 1st and 2nd rounds

Group	% of match 1st round	% of match2nd round
PD	37.1	41.4
GP	37.1	51.4
DI	50.0	57.1
DT	35.7	35.7
DP	30.0	22.9
VES	100	100

PD - Prosthodontists; GP - Dentists; DI - Dental Interns; DT - Dental Technicians; DP - Dental Patient; VES - Vita Easyshade system (intraoral spectrophotometer)



PD - Prosthodontists; GP - Dentists; DI - Dental Interns; DT- Dental Technicians; DP - Dental Patient; VES - Vita Easyshade system (intraoral spectrophotometer)

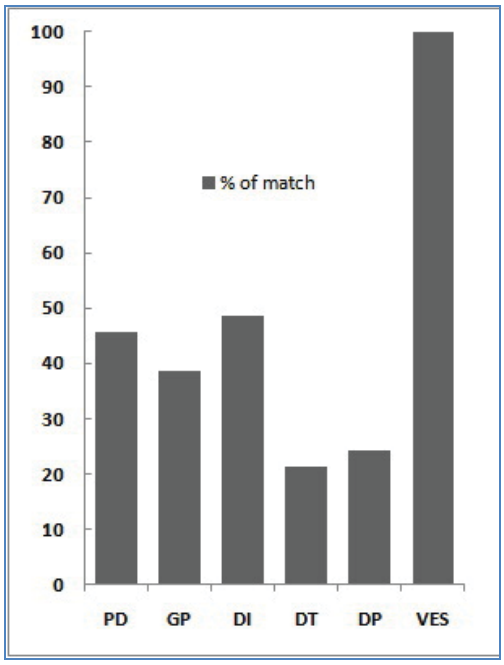
Fig. 2. Percentage of participant repeatability and the reliability.

The percentage of participant repeatability is presented in Table 2. Statistical significant difference ($p<0.05$) was observed between DI (48.6%) and both DP (24.3%) and DT (21.4%). The VES provided a 100% match in both rounds for all the seven shade tabs.

Table 2. Percentage of participant repeatability and reliability

Groups	% of match
PD	45.7
GP	38.6
DI	48.6
DT	21.4
DP	24.3
VES	100

PD - Prosthodontists; GP - Dentists; DI - Dental Interns; DT - Dental Technicians; DP - Dental Patient; VES - Vita Easyshade system (intraoral spectrophotometer)



PD - Prosthodontists; GP - Dentists; DI - Dental Interns; DT-Dental Technicians; DP- Dental Patient; VES - Vita Easyshade system (intraoral spectrophotometer)

Fig. 2. Percentage of participant repeatability and the reliability.

Among the seven shade tabs C4 showed the highest incidence of being matched correctly; 56% of the participants readings in the 1st round and 62% in the 2nd round was matched correctly (Table 3).

Table 3. Percentage of correct shade matching for the seven shade tabs in the 1st and 2nd rounds

Shade tab	% of match 1st round	% of match 2nd round
A1	42	44
A3	36	42
B2	46	44
B3	42	46
C2	22	30
C4	56	62
D3	22	24

Discussion

Polychromaticity, translucency and curvature of the tooth structure make it difficult to accurately match the shades of natural teeth even for the electronic devices (Seghi *et al.*, 1989). Moreover, the perceptible ΔE value for human eye (2.6 units) is much lesser than the acceptable threshold (up to 5.5 units) (Douglas *et al.*, 2007). Yet, visual shade matching is still the more convenient and reliable method (Kuzmanovic and Lyons, 2009). However, instrumental shade matching of homogenized shade tabs has been positively shown to exhibit higher reliability than visual method (Tung *et al.*, 2002).

The current results are in consensus with the findings of an earlier study which demonstrated a clear edge of Vita Easyshade systems over the Shade Eye NCC (Natural Color Concept) in terms of the inter-device reliability and repeatability (Lagouvardos *et al.*, 2009). The human color memory is very low as the same dentist could not repeat a shade selection in just two days (Culpepper, 1970). Hence, in the present, study one week interval was set between the two rounds of shade matching. The participants are less likely to have any memory of the selected shades after a week especially when they were randomized to eliminate the risk of chance.

The current agrees with Della Bona *et al.* (2009) in demonstrating that scientific knowledge as well as professional training plays a significant role in shade selection, whereas previous studies show that there was no difference in shade matching ability among dental students, general practitioners and prosthodontists (Davison and Myslinski, 1990; Sim *et al.*, 2001). The interns have demonstrated the maximum repeatability shade matching as compared to the dental patients. This can be explained by unfamiliarity of the patients with strategies of color selection. This is comparable with the observations of Mcmaugh (1977) who showed that prosthodontists gave better shade matching than first year dental students who can be compared with the patients in the present study. The high repeatability

demonstrated by the interns could be attributed to their concentration and systematic implementation of their knowledge. This attitude and attention to detail might decrease overtime, explaining the relative lower incidence of correct matches by the prosthodontists and general dentists. Moreover, the dental interns were the youngest group of examiners in this study, which might also have an influence on the acquired result as the perception of shade decreases with aging.

The range of shades available in shade guides is inadequate, as they do not cover the complete color space of natural tooth color (Schwabacher and Goodkind, 1990). Also, the shades are not systematic in their color space (Sproull, 1973) for that reason, seven shades (A1, A4, B2, B3, C2, C4 and D3) were selected in this study that are represent the common tooth shade gradients (Yap *et al.*, 1999). Among these, the darker shade, C4, was the easiest shade to match at both the 1st and the 2nd rounds by all examiners. This is in contrast with the findings of Yap *et al.* who claimed that discrepancies occurred with the L* and B* coordinates of C4. Significant differences in the shade perception was evidenced by similar groups of examiners who demonstrated a higher incidence of shade matching for B3 shades (Sim *et al.*, 2001) as compared to the C4. This could possibly be due to variability in both cultural factors and individual preferences (Watts and Addy, 2001) or to differences in the in the methods or environment of shade matching.

In the present study, difficulty was confronted by all groups for matching D3 shade. Particularly the prosthodontists matched zero out of ten in round 1 and one out of ten in round 2. The shade guide used could also influence the repeatability of shade selection, as suggested by Hammad (2003), who perceived that the intra-rater repeatability of prosthodontists was significantly higher than that of general practitioners when the Vita Lumin Vacuum shade guide was used ,while the use of Vitapan 3D-shade guide significantly improved the intra-rater repeatability of general practitioners. A similar pattern has been reported in the current study also in regard with the prosthodontists and the general practitioners.

All groups showed improvement in the reliability test except for the dental technicians, who had the same results for the 2 rounds, and the patients who had lower results in the 2nd round. This shows the lack of experience and training as agreed upon by Della Bona *et al.* (2009). This reinforces the need for establishing professional training of shade matching in the curriculum of dental technicians programs (Sim *et al.*, 2001).

Conclusion

Within the limitations of this study it can be concluded that:

1. Repeatability of shade matching is 100% only with spectrophotometer.
2. Dental interns were more reliable in providing correct shade matching and were able to improve the results in the second round.
3. The reliability of dental patients and dental technicians in reproducing shade matching is questionable.
4. High incidence of correct match occurred with shade C4, and low incidence were observed with shade D3.

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تقييم إمكانية إعادة مطابقة اللون

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الكلمات المفتاحية: لون السن، إعادة تكرار اللون، أطباء الامتياز، أخصائي تعويض الأسنان، أطباء الأسنان.

ملخص البحث. من أهداف هذه الدراسة إمكانية إعادة تقييم إجراءات مطابقة اللون وتحديد وجود اختلاف في اختيار الألوان. خمس مجموعات (كل مجموعة تتألف من عشرة مشاركين) تم اختيارهم كالتالي: أخصائي تعويض الأسنان، وأطباء أسنان، وأطباء امتياز، وفنيو أسنان، ومرضى أسنان. تم اختيار اللون باستخدام دليل الألوان الكلاسيكي (فيتابان) ليطابق سبعة ألوان من دليل الألوان وهي A1 و A3 و B2 و B3 و C2 و C4 و D4 لنفس دليل الألوان. تم تغطية علامة دليل الألوان وأجري اختيار اللون من خلال محاولتين الفاصل الزمني بينهما أسبوع واحد، وتم استخدام المقياس اللوني الضوئي (Spectrophotometer) كمقياس.

أظهرت نتائج تكرار إعادة تقييم اللون تباين ما بين مجموعات الدراسة، ووجد اختلاف إحصائي ملحوظ ($P<0.05$) بين أطباء الامتياز (٤٨,٦٪)، ومرضى الأسنان (٢٤,٣٪)، وفنيي الأسنان (٢١,٤٪)، بينما أعطى المقياس اللوني الضوئي تطابقاً نسبته ١٠٠٪ خلال المحاولتين. من بين ألوان الدليل السبعة اللون أظهر C4 أعلى حدوث في التطابق اللوني الصحيح، ٥٦٪ في المحاولة الأولى، و ٦٢ ٪ في المحاولة الثانية. أطباء الامتياز كانوا المجموعة الأكثر ثقة في اختيار اللون المطابق الصحيح في حين كانت الثقة في مرضى الأسنان المعالجين وفنيي الأسنان في إعادة تكرار اختيار اللون مثار الجدل.