

RELIABILITY OF TOOTH SHADE PERCEPTION BY DENTAL PROFESSIONALS AND PATIENTS

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ABSTRACT

The objective of this study was to evaluate the reliability of dental personnel and patients in ascertaining the shade of natural teeth compared to the electronic shade matching devices. Five groups (10 each) of participants were selected: prosthodontists, general practitioners, dental interns, dental technicians and dental patients. Shade selection was carried out using Vitapan classical shade guides to match seven shade tabs (A1, A3, B2, B3, C2, C4 and D3) of the same shade guide. The electronic shade matching consistently gave lower ΔE for all teeth. Comparing the different groups of observers; prosthodontists (PD), dental patients (DP), dental interns (DI) showed comparable ΔE value. The general practitioners (GP) and dental technicians (DT) showed the least values. Additionally, DI showed the highest correct matches while DT showed the lowest. It could be concluded that when visual method is chosen for shade selection, it appears to be preferable to rely upon the dental interns, prosthodontists and general dental practitioners, especially when the tooth is homogenous in appearance.

Key words: Esthetics, Color matching, Tooth, Shade guide

INTRODUCTION

Patients' satisfaction with shade match is important when constructing or replacing a restoration, and the level of satisfaction of patients might be different from that of the clinician.¹ Esthetic expectations have exponentially increased over the last few years. Color and shade determination have traditionally been one of the greatest challenges in dental field.² Esthetics of any restoration depends not only upon the outline form, surface finish and translucency but also the color. The importance of appearance can be understood by the fact that the dental materials used for restorative purposes have been broadly classified as esthetic and non-esthetic materials.³ With the technological advancements, several esthetic restorative materials are being produced and made available for use. But the real challenge is faced when an accurate shade matching has to be done. Increasing patient awareness has raised the level of demand for accurate shade matching. Color perception is a complex and subjective phenomenon which could vary based on illumination, color-vision and the background.⁴

Visual color determination is the method by which the color of the natural tooth is compared with a color standard. Color perception depends upon the light source, the object and the observer.⁵ Shade selection

through the use of shade guides is inadequate due to lack of standardization.⁶ Both intra and inter-operator errors are common in shade selection.^{7,8} Several methods for shade selection have been investigated to find a justifiable one.⁹⁻¹¹ Choice of any particular method is based upon the practicality, convenience, reliability and repeatability.¹² In the past, adjunctive aids such as slides, pictures and written descriptions have been used to make the color perception process acceptable.¹³ Visual color selection is the most widely and conventionally used method.¹⁴

Mechanical means of controlling the color of dental restorations has overcome the difficulties of visual method, ruling out the subjectivity.¹⁴ Electronic devices like spectrophotometers and colorimeters have been used as an attempt for precise shade matching with significant success. But at times the extreme accuracy of colorimeter may complicate the situations for the clinician when there is a difference between the original shade and the shade of the fabricated restoration.¹⁵ Although, studies have demonstrated that the change in brightness from tab to tab varies greatly, visual color matching remains the primary method for selecting and evaluating the color of teeth and restorations from a clinical stance.^{3,5,16,17} A review of several clinical trials has demonstrated that Vita Classical

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shade guide data are consistent with data gathered using electronic color measurements.¹⁸

A shade matching method depends on the clinician's color perception, ambient light conditions and the background against which the tooth is compared; all of these factors may vary.¹⁹ Inconsistencies may result from uncontrolled factors such as fatigue, aging, emotions, previous eye exposure, differences in understanding, color perception and the experience of the observer.^{14,20} Additionally, the inability of the human eye to perceive color in a clear, concise and consistent manner is another important factor and color perception varies from person to person.¹⁰ Color matching with shade tabs is extremely difficult to perform at chair-side because of variable viewer interpretation and environmental influences, resulting in unreliable and inconsistent color perception.¹⁴

Visual methods are mostly based on conditions existing in dental operatory at the moment of tooth shade selection. The dental shade selection should be carried out in natural light, ideally in the morning (10 am) or in the early afternoon (2 pm), close to a window on a clear day.²¹ The light varies with seasonal changes and also with the geographical parameters affected by the position of the sun at that particular time and on the human eye perception. The color of the patient's dress, make-up, shade of gingiva as well as the color of the walls and dental unit in surgery are all important elements of the background which influence the color selection.

The reliability of shade selection by individuals without prior training and awareness of strategies of shade matching needs to be assessed, to achieve consistency in result. The objective of this study was to test the reliability of shade selection among different groups by visual means as compared to the results of Vita Easy Shade intraoral spectrophotometer.

METHODOLOGY

Visual Method

The present study was conducted in the College of Dentistry, King Saud University, to determine the difference in color perception among dental personnel with variable experience and the patients who are involved in the shade selection process. Ten extracted teeth (four premolars, two canines, two lateral incisors and two central incisors) were collected, polished using rubber cup and pumice to remove any extrinsic stain and stored in saline to keep them hydrated. The tooth number to the corresponding tooth type is recorded in Table 1a. Only sound teeth, without any restoration, caries and/or root canal treatment were included.

Four groups with ten participants each were selected according to different levels of education and

experience in dentistry. A fifth group consisted of 10 dental patients. A total of 50 male participants in the age range of 24 to 70 years were selected. Based on their dental experience, observers were grouped as follows: prosthodontists (PD) with experience over 10 years, dentists (GP) over 5 years, dental interns (DI) 4 years, dental technicians (DT) over 5 years and dental patients (DP) with no experience in color selection. Prosthodontists and general dentists were considered to have an additional 4 years of undergraduate experience. Members of various groups were selected randomly.

All groups of participants were given a questionnaire to fill out their name, age, gender and years of experience. First, each participant was tested for color acuity using Ishihara plates (Tokyo, Kanehara and Co.) before shade selection. Each tooth was removed from the saline solution and placed on a neutral grey background under a color fluorescent lamp (6500°K) (Demetron Shade Light, Kerr, USA), which simulates the natural light, to standardize the environment.

The participants were shown the 10 teeth randomly and asked to select the matching shade using the Vitapan classical shade guide. (Vita Zahnfabrik, H. Rauter GmbH & Co. KG, Bad Säckingen, Germany). The color tabs were randomly arranged and their markings were masked using an opaque adhesive tape. The shade of the middle third of the labial surface was chosen by placing each tooth at the level of the observer's retina, where most of the color sensitive cells are situated. The observer was informed not to focus at the teeth for a longer period of time to avoid fatigue to the eyes. Examiners were given sixty seconds for shade selection and after every ten seconds of gazing they were asked to rest the eye by looking into a neutral blue card.

Electronic Matching

A spectrophotometry was conducted with integrating sphere using the Vita Easy Shade (VES) intraoral dental spectrophotometer (Vita Easyshade; Vident; Brea, CA, USA). It is a portable device for dental shade matching. The probe of the VES was placed at 90° and in contact with the middle third of the labial surface of each tooth and the shade tab. The shades selected by the participants for the corresponding teeth were recorded. The shade tabs were converted to L*a*b* values using the VES under the same conditions (illumination and background).

All the measurements were established in mathematic coordinates referred to the international color space CIE-L*a*b* (Commission International de l'Eclairage L*a*b*). CIE-L*a*b* is system in which L* coordinate, represents color luminosity, varying from

white to black; and a^* and b^* coordinates, represent the chromaticity of the color, a^* denoting the green-red axis and b^* for the blue-yellow axis. This color space is represented by a sphere, where the Y axis represents the L^* coordinate, the X axis represents the b^* coordinate and the Z axis represents the a^* coordinate. The match of these coordinates results in a spatial position that mathematically expresses a color. The results when analyzed mathematically can compare the color parameters of different objects. Three separate measurements of the $L^*a^*b^*$ values were taken for each tooth and the average of the measurements were recorded. Then, ΔE which is the color difference between the natural tooth and its corresponding shade tab was calculated using the following equation:

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{\frac{1}{2}}$$

where ΔE = total color difference and ΔL , Δa , and Δb = differences in lightness, green-red coordinate, and blue-yellow coordinate respectively between the extracted teeth and its corresponding Vitapan classical shade tab, and the $L^*a^*b^*$ values of the corresponding shade tabs were measured using the (VES) under the same conditions used for the natural teeth. The teeth were then assigned a numbers randomly from 1 to 10 for the feasibility of computation. The mean color difference between the natural tooth and its matched vita tab ΔE for each tooth for every group was calculated. Two way ANOVA test and Tukey HSD test were used to analyze the data.

Dunett t-test was used to compare the average ΔE of each group with the average ΔE of the control group (VES).

RESULTS

The CIE-Lab values of the 10 teeth and their corresponding tabs from the Classical Vita Lumen Shade Guide (A1, A2, A3... etc) were measured using VES. The CIE-Lab values of the Classical Vita Lumen Shade Guide were used as the control. Then the ΔE for each tooth was calculated for both the visual and electronic measurements (Table I).

On comparison of the average ΔE of each group with the average ΔE of the control group (VES) using the Dunett t-test, the standard error was 2.13. Both Univariant Analysis of Variance and Tukey HSD tests showed no statistically significant difference between the five groups (Table I). Profile Plots were used to illustrate the average ΔE for each group with respect to the control group (VES) [Table 2].

The electronic shade matching consistently gave lower ΔE for all teeth. On comparing the different groups of observers, PD, DP, DI showed comparable ΔE

TABLE 1a: TOOTH NUMBER AND THE CORRESPONDING TOOTH TYPE USED IN THE STUDY

Tooth Number	Tooth Type
1	Maxillary Left Central Incisor
2	Maxillary Right Central Incisor
3	Maxillary Left Lateral Incisor
4	Maxillary Right Lateral Incisor
5	Maxillary Right Canine
6	Maxillary Left Canine
7	Maxillary Left First Premolar
8	Maxillary Right First Premolar
9	Mandible Left First Premolar
10	Mandible Right First Premolar

TABLE 1b: THE ABBREVIATIONS USED FOR EACH GROUP IN THIS STUDY, THEIR AGE RANGE AND YEARS OF EXPERIENCE

Examiner Category	Age Range (yrs)	Years of experience
Prosthodontist (PD)	32-70	10-48
General Practitioner (GP)	26-48	5-23
Dental Intern (DI)	24-26	4
Dental Technician (DT)	24-57	5-37
Dental Patient (DP)	25-47	0

TABLE 2: AVERAGE ΔE FOR EACH GROUP FOR THE TEN TEETH USING TWO-WAY ANOVA AND TUKEY HSD STATISTICAL TEST

Examiner Category	Mean ΔE
Prosthodontist (PD)	11.36
General Practitioner (GP)	11.34
Dental Intern (DI)	11.25
Dental Technician (DT)	12.74
Dental Patient (DP)	12.24
Control (VES)	9.35

values. The GP and DT offered the least values. Additionally, DI showed the highest incidence of correct matches while DT was the lowest. ΔE of PD and GP exhibited close approximation.

Most of the examiners agreed on the shades of Maxillary Left First Premolar comparable with the VES selection. However, there was a wide variation between examiner readings observed with regard to tooth Mandible Left First Premolar.

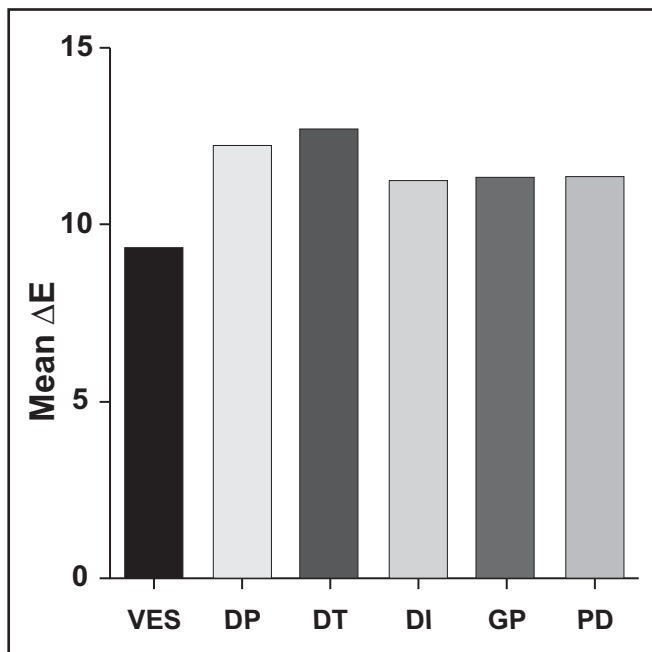


Fig 1: Average ΔE for each group for the ten teeth (Prosthodontist (PD), General Practitioner (GP), Dental Intern (DI), Dental Technician (DT), Dental Patient (DP))

DISCUSSION

The purpose of this study was to evaluate the reliability of different dental personnel and patients to ascertain the shade of natural tooth when compared to the efficacy of a electronic shade matching device. Determining an accurate shade match is one of the most critical steps for cosmetic procedures. Shade selection of dental restorations is usually done visually by matching a shade guide.⁵ Light from the shade sample enters the eye and acts on receptor (rods and cones) in the retina. Impulses are then passed to optical center of the brain, where the interpretation is made. Different persons will make different interpretations of the same stimulus, and thus shade selection depends on subjective assessment.

In this study visual shade matching was done by the different groups independently following a standard protocol under controlled viewing conditions. Efforts were made to standardize the conditions for optimal shade matching. The illumination was matched to the recommended temperature of light (over 6000°K) and intensity (over 5000 lumens), as the bulbs usually used in dental units have much lower temperature (4000 °K) and it may result in misleading yellow shade. Moreover, an artificial light is preferred over the natural light due to the constant intensity.²² Hence a color fluorescent lamp (65000K) was used and the background was maintained in neutral gray. Viewing blue or grey color at frequent intervals during shade selec-

tion would activate blue-sensitive zone in the retina and relax the other zones so that the eye again becomes more sensitive to perceive the yellow-red colors of the teeth.¹⁶ The selection of tooth shade in artificial light is more difficult.²³ These measures were taken to re-sensitize color vision and reduce the possibility of errors resulting from eye fatigue, contrast and afterimage formation (positive nor negative). Unfortunately, the arrangement of the color tabs in the classical shade guides is erroneous and difficult to match. DI utilized the full time allowed to match the tabs in comparison to other groups.

It is evident from the results of the present study that electronic shade matching consistently provided better shade selection. On comparing the different groups of observers, it is evident that all dental clinicians including dental interns were capable of making a good choice of shade. This is in accordance with the previous findings of. It was reported that the dental technicians were able to identify darker shades more accurately than clinicians²⁴, however, our results showed that the patients and dental technicians offered the poorest matching in color selection.

Dental interns showed the highest incidence of correct matches with a small edge over the experienced clinicians. The finding could be attributed to their patience in utilizing all the time allowed for color selection, concentration at work, enthusiasm and sincerity in young professionals of any field. Besides, this variation could also be attributed to their age and hence the ability for accurate color perception as substantiated previously by many researchers. Although, a study which compared the ability of first year dental students and experienced clinicians in shade selection, found that prosthodontists demonstrated better color matching skills²⁵, another study²⁴ where final year dental students were utilized, the results were in agreement with the present study. Aging is associated with yellowing of cornea that effects the blue and purple color discrimination and chronic diseases, certain medications and environmental exposure to cigarette smoke, sun and lasers affect the color perception.²³ These could also be the factors for the dental interns, being the youngest group in this study for demonstrating the highest ability for accurate shade matching.

Human eye can distinguish only three parameters of color dependent on dominant wavelength, luminous reflectance and excitation purity. It means that color can be characterized by three parameters: hue, value and chroma. Hue describes the dominant color of an object, value (lightness) describes an overall intensity of the color (how light or dark the color is) and chroma (saturation) may be defined as the strength or dominance of the hue. Color is three dimensional and

requires a three dimensional space. In a previous study, dental students achieved a high identification rate for chroma, but not for hue, especially when determining the correct hue group for unmarked shade tabs. Incorrect responses tended to remain in the same value and chroma range but were selected in a different hue group.²⁶

Unlike the results of Sim et al.,²⁴ the current findings questions the reliability of dental technicians for clinical shade selection. However Sim et al.,²⁴ also agree upon the large

disparity in L* values between clinicians and DT which might explain the significant difference in ΔE values. The observations of the current study are in agreement with previous reports that the color perception of general population is relatively inferior to that of dental professionals especially compared to the prosthodontists⁵, though there are observations that place the general population at a level comparable with the general dentists.¹⁰

Qualitative descriptions of subjective shade measurement of a natural tooth and of its replication in the dental laboratory are often less satisfactory. But digital tooth shade matching provides exact color codes of the color chart, and colorimetric values, objectively. The reliability of visual shade matching of natural teeth among different groups is difficult to establish without comparison to an accurate and reliable source such as spectrophotometers. Many previous studies have tested spectrophotometers with positive results.²⁷⁻²⁹ This study also proves that spectrophotometers are more reliable than human color perceptions.

Systematic approaches are suggested as an aid for attaining accurate shade selection in order to enable the dentist to place more esthetic restorations.³⁰ It is interesting to find that the clinical acceptability of patients is much broader compared with that of the prosthodontists in assessing the color match of the fabricated porcelain shade tabs. Also the use of certain porcelain visual shade-matching systems may result in a clinically acceptable color match of the final restoration more readily than the use of other systems.⁵ Capa et al⁴ showed that dental care professionals who routinely performed restorative procedures matched the shades better than other participants indicating that professional experience was associated positively with the outcome, while sex, eye color and use of eyeglasses or contact lenses did not have any effect on shade-matching results.

Color difference (ΔE) was obtained to compare results of the groups with the control group (VES) for each tooth independently. Under controlled conditions, one ΔE unit of color difference is visually perceptible.³¹ However, the average color difference of 3.7 is

still rated as a good match in the oral environment. In this study all groups showed ΔE values larger than 3.7.^{24,32,33} In the current study all the ΔE values were much higher than the clinically acceptable value (3.7). This could be addressed from two aspects: firstly there have been reports which show that the shade guides are inadequate in providing extended shades throughout the volume of the color space^{34,35} and secondly, males might display a lesser tendency for color perception unlike females who inherently possess a better acuity explaining the lower ΔE values in a similar study conducted using females dental students as participants.³⁶

Moreover, evidence exists that the electronic systems do not solve all problems involved in the determination of a tooth shade. Vita Easyshade spectrophotometer was more likely to match the shade compared to visual method. Nevertheless, this system needs further refinement, as well as software upgrades. Shade-matching devices could help clinicians and technicians achieve a better shade choice. The combination of visual shade analysis and digital shade measurement together lies in the precise predictability of the shades.³⁷ DT showed the lowest shade matching capability among the five tested groups. This could be due to the reason that clinical shade matching is not a part of their curriculum in the dental schools.

Typically, dentists require fifteen minutes to properly take a shade of a central incisor, while some require 3 to 10 appointments to achieve a correct esthetic match.³⁸ In our study each participant was given just 1 minute for each tooth or tab which might have affected the results. It is agreeable to reinforce that the color-match evaluation of final restorations should be accomplished through a consensus between prosthodontists and patients. The shortcomings of this study included the lack of age specification for the observers and also the need for a relatively longer time allocation for shade selection.

CONCLUSIONS

Under the given circumstances, it may be concluded that:

- Academic training plays a significant role in the development of color selection skills.
- In the selection of shade, patience may be the essential factor for good shade matching rather than the experience.
- Although, it might be preferable to consider the patient's choice in shade selection on ethical grounds, yet the final decision could be made by the dental intern, prosthodontist or the dentist, rather than just relying on the patient or dental technician, especially when teeth are more homogenous.

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