ZONGULDAK BÜLENT ECEVİT UNIVERSITY
GRADUATE SCHOOL OF HEALTH SCIENCES
FACULTY OF DENTISTRY DEPARTMENT OF PROSTHODONTICS

THE EFFECT OF EXPERIENCE AND GENDER ON THE COMPARISON OF DIRECT AND INDIRECT VISUAL TOOTH SHADE MATCHING

MOATAZ MAKHLOOTA

DOCTOR OF PHILOSOPHY THESIS

ADVISOR
Assoc. Prof. Dr. Ayşegül KÖROĞLU
Prof. Dr. Bilge TURHAN BAL

ZONGULDAK
2021

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ABSTRACT

Moataz MAKHLOOTA, The Effect of Experience and Gender on The Comparison of Direct and Indirect Visual Tooth Shade Matching. Zonguldak Bülent Ecevit University, Graduate School of Health Sciences, Faculty of Dentistry Department of Prosthodontics, Doctor of Philosophy Thesis, Zonguldak, 2021.

Visual tooth shade matching is the most common method applied in dental practice. Several factors such as the method used, clinical experience, and gender can affect the success of shade matching. The aim of this study was to evaluate the effect of experience and gender on the comparison of direct and indirect visual tooth shade matching. The present study included the teeth of 3 volunteers with different tooth colors. The colors of three teeth were evaluated by 87 examiners (42 males and 45 females) who were divided into 3 groups according to clinical experience; Undergraduate Preclinical Dental Students (UPDS), Undergraduate Clinical Dental Students (UCDS), and Postgraduate Dental Students from the Department of Prosthodontics (PDS). The shade matching observations were divided into two subgroups according to the method; direct shade matching (DSM) and indirect shade matching (ISM) groups. For ISM, photos were taken from three different volunteers by the digital camera under the special conditions of lightness and camera settings. Statistical analyzes of the data were performed by using Kruskal-Wallis, Mann-Whitney U, and Chi-Square tests. A statistically significant difference was observed between the PDS group and the other two groups in terms of clinical experience. There was no significant difference between gender groups. No significant difference was observed between indirect and direct methods according to success frequencies. However, there was a significant difference according to Shade Matching Deviation Score (SMDS) values between the two methods. It is concluded that clinical experience is an effective factor while gender is not an influential factor in the shade matching process. Digital images taken under standard lighting conditions may be a reliable alternative shade matching method.

Keywords: Visual shade matching, Instrumental shade matching, Digital photography, Gender, Clinical experience.

ÖZET

Moataz MAKHLOOTA, Direkt ve Indirekt Görsel Diş Renk Seçiminin Karşılaştırılmasında Deneyimin ve Cinsiyetin Etkisi. Zonguldak Bülent Ecevit Üniversitesi, Sağlık Bilimleri Enstitüsü, Protetik Diş Tedavisi Anabilim Dalı, Doktora Tezi, Zonguldak, 2021.

Görsel diş renk seçimi, diş hekimliğinde uygulanan en yaygın yöntemdir. Klinik deneyim ve cinsiyet gibi çeşitli faktörler renk seçiminin başarısını etkileyebilir. Bu çalışmanın amacı, direkt ve indirekt diş renk seçiminin karşılaştırılmasında deneyim ve cinsiyetin etkisini değerlendirmektir. Bu çalışma, farklı diş renklerine sahip 3 gönüllünün dişlerini içeriyordu. Bu üç diş rengi, klinik deneyime göre 3 gruba ayrılan 87 gözlemci (42 erkek ve 45 kadın) tarafından değerlendirildi; Diş Hekimliği Preklinik Öğrencileri (UPDS), Diş Hekimliği Klinik Öğrencileri (UCDS) ve Protez Bölümü Doktora /Uzmanlık Öğrencileri (PDS). Renk seçimi, yönteme göre iki alt gruba ayrıldı; direkt renk seçimi (DSM) ve indirekt renk seçimi (ISM). ISM için dijital kamera ile üç gönüllüden, özel ışık ve kamera ayarı şartları altında fotoğraflar çekildi. Verilerin istatistiksel analizleri Kruskal-Wallis, Mann-Whitney U ve Chi-Square testleri kullanılarak yapıldı. Klinik deneyim açısından, PDS grubu ile diğer iki grup arasında istatistik olarak anlamlı fark gözlendi. Cinsiyet grupları arasında istatistiksel olarak anlamlı bir farklılık bulunmadı. Başarı sıklıklarına göre indirekt ve direkt yöntemler arasında anlamlı bir farklılık gözlenmedi. Ancak iki yöntem arasında Renk Seçimi Sapma Puanı (SMDS) değerlerine göre anlamlı bir farklılık bulundu. Renk seçim sürecinde klinik deneyimin etkili bir faktör olduğu, cinsiyetin ise etkili bir faktör olmadığı sonucuna varıldı. Standart aydınlatma koşulları altında çekilen dijital görüntüler, güvenilir bir alternatif renk seçim yöntemi olabilir.

Anahtar Sözcükler: Görsel renk seçimi, Enstrümantal renk seçimi, Dijital fotoğrafçılık, Cinsiyet, Klinik deneyim.

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LIST OF SYMBOLS AND ABBREVIATIONS

CIE	The International Commission on Illumination
ISO	International Standards Organization
JPEG	Joint Photographic Expert Group
CVD	Color Vision Deficiency or Color Blindness
FDI	World Dental Federation Notation
UPDS	Undergraduate Preclinical Dental Students
UCDS	Undergraduate Clinical Dental Students
PDS	Postgraduate Dental Students
DSM	Conventional Visual (Direct) Shade Matching Method
ISM	Visual Shade Matching on Image (Indirect) Method
SMDS	Shade Matching Deviation Score
NBS	National Bureau of Standards

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1. INTRODUCTION

A big challenge in esthetic dentistry is producing a prosthesis that matches a patient's teeth. The esthetics of any prosthesis relies on good shade matching, designing outline shape, surface texture, and translucency. Selecting the most proper shade of prosthesis is based on applying science and art at the same time, however, if the methodologies of shade matching and the color systems are not well understood, that would create a problem for patients and dentists. Selecting the shade for a restoration can be done in two techniques: conventional and instrumental (1).

Conventional shade matching is a comparison between multiple standards (shade guide tabs) and sample (tooth). Conventional evaluation can be affected by many elements related to the practitioner (age, fatigue, gender, problems in color vision, the ability of shade perception, and experience in shade matching) or unrelated to the practitioner (sample type, surface, light source, and background) that's why it is considered as a subjective method. The practitioner's clinical experience significance is questionable. Another element which influences color perception is the nature of light produced by a light source, which can vary in intensity, angle of incidence, and type. The dental office has a combination of lights which are daylight, dental unit light, and light generated by overhead lamps. Therefore, these different types of lighting are variable, which recommends the use of light correcting sources in dental color matching (2). Understanding color principles are essential for accurate color matching (3). The Vita 3D and the Vita Classical Shade Guides are the most commonly used shade guide among available products (4). The empirically-based Vita Classical (VC) chart was considered the "gold standard," thus it has a large extent (5).

Instrumental shade matching is performed by using colorimeters, spectrophotometers, spectral and digital photography. When properly matched and applied, instrumental methods are objective and more robust, therefore being a valuable complement to dental visual shade matching (6). An important advantage of a digital color selection system is the inclusion of accuracy and objective readings. The spectrophotometer can always be used to accurately measure the natural tooth color using several shade-matching systems. It assesses the color characteristics of the teeth by measuring the different light intensities in several parts of the tooth/color distribution (7). According to Paul SJ, the most delicate, flexible, and handy shade matching tools for the dental practice are the Spectrophotometers (8).

To have a successful shade matching, a professional level of communication is requested between the dentist and the lab staff. If a dentist does not have enough knowledge to explain hue, chroma, and value to the lab staff, he/she will not be able to deliver the needed information in order to create an esthetic restoration that matches the patient’s teeth color. An important part of the shade matching depends on the dental technician's understanding of the color information that was provided by the dentist (9).

Imaging systems and digital cameras are alternatives to contact-type instruments for color measurement. In dentistry, digital photography has been widely adopted. Digital images improve the communication between dentists and lab technicians about the color difference over teeth surfaces, dental morphology, and intra-oral situations. It is recommended that color communication gives the best results using an image with reference shade tabs. One of the main problems with imaging shade analysis is unstable illumination (10). Since the critical component of shade matching is lighting conditions, therefore production companies created lights that purport to simulate ideal lighting conditions. The ideal light was suggested to be the natural light which occurs between the middle of the day and 3 PM and north sky daylight (3).

It has been widely thought that females are better shade selectors than males. It was considered as ‘‘scientific fiction’’ by people who oppose this thought (11). As far as color normal individuals of males and females are involved, vision science literature mentioned that differences between color normal males and females in red-green color discrimination were not significant (12). When color diagnosis and evaluation test was applied by one hundred fifty color normal men and one hundred fifty color normal women, no noticeable gender-related differences were documented (13). Color confusion or color vision deficiency can be classified as acquired or hereditary. Hereditary color vision deficiency, often known as color blindness, can be assessed by Ishihara’s test which provides accurate and rapid information on the hereditary color defect. (3).

The aim of this study was to compare the results of shade matching by conventional visual method (direct) and visual shade matching on image method (indirect) and to evaluate the influence of experience and gender on the result of shade matching for both methods.

The first null hypothesis is that the clinical experience has an effect on the shade matching results. The second null hypothesis is that gender has an effect on shade matching and females show better results than males. The third null hypothesis is that there is no difference in the shade matching success between visual shade matching on image method (indirect) and conventional visual method (direct).

2. LITERATURE REVIEW

2.1. Dental Esthetics Conception

Esthetics is a branch of philosophy that deals with beauty. The term esthetics is derived from the Greek word “aisthetike”. In 1735, the philosopher Alexander Gottlieb Baumgarten has expressed the term esthetics as “the science of how things are known through the senses. A common saying is "Beauty is in the eye of the observer”, so this concept suggests that there may not be a worldwide agreement on what constitutes beauty or art (14). The sense of beauty differs from one to another. Individual experiences, comments, and expressions make it unique (15).

Esthetic dentistry is defined as " techniques and skills used to improve the art and symmetry of teeth and face to enhance the appearance as well as the function of the teeth, oral cavity and face" (16). Esthetic dentistry provides benefits beyond dental health, towards total well-being throughout life, and not only treats the patient's problems, but it also takes the patient’s desires into account. Considering that the mouth is the most prominent structure of the face, it should be remembered that the teeth are the most striking part of this structure (15). Esthetics nowadays has been noticed to be as important as structure, function, and biology in dental practice. In this context, the dental treatment priority of the patient has changed with esthetic preferences (17). Esthetic restorations require superior clinical skills, creative ability, and knowledge of all facial relationships. However, imagination and logic are important for analyzing existing elements and creating the treatment plan. This makes it inevitable to give the necessary importance and value to esthetic oral rehabilitation (18).

Dental esthetics is influenced by cultural and sociodemographic factors, as well as individual preferences, and is associated with numerous factors such as the shape and color of the teeth as well as the dental arch shape(19). Shade matching, which is one of the most important steps in obtaining esthetic restorations, is still difficult and a dilemma for many clinicians (20).

2.2. The Importance of Shade Matching

In modern dentistry, restorations and ceramics are expected to mimic not only the color of natural teeth but also color distribution, translucency, and opacity (21). Only minimal results can be expected in esthetics without knowing about the structure of natural teeth and without understanding the technical properties of ceramic materials. Often, the reason for the unsatisfactory esthetics of a ceramic restoration is based on limited information about the appropriate shade selection and the shade pattern given to the technician. Ideally, the person who chooses the shade should make the restorations, but unfortunately, this is not always possible. In order to prevent misunderstandings between the dentist and the laboratory technician in transmitting shade data, a system covering every step, from determining the tooth shade to producing the prosthesis, should be designed. The problem is simplified if both the dentist and the lab technician are familiar with the general shade theory and the fundamentals of physical-optic and materials science. (22).

The knowledge of shade matching includes physics, psychology, psychophysics, and even philosophy. The color scientists' world comprises so many confusing matters like the color vision theories, nature of light, spectrophotometric studies, color order systems, and color dimensions. These concepts are not required for equating and understanding shades, but they are essential if one does understand what is occurring in color matching and perception (23).

Shade matching comprises more than choosing a tab from a shade guide and creating a prosthesis of the same shade processed. It is important to develop the ability to choose a color that will cause a restoration that matches adjacent natural teeth. The limitations and benefits of existing materials and guides should also be realized (23). The dentist should consider the basics of color and the artistic aspects of color matching to create an esthetic restoration (24).

2.3. Basics of Color

Color is defined as a psychophysical response perceived by the observer based on his subjective personal observation as a result of the physical interaction of light energy with an object. An interaction between the three elements is needed to perceive the color. These are light, object, and observer (23, 25).

2.3.1. Three elements of color: light, object, and observer

A. Light Source

Light, a form of energy, is part of the electromagnetic radiation spectrum, which can affect the retina of the eye. The main factor in the perception of color is light and if there is no light, the color will not exist. Radio waves, x-rays, ultraviolet, and infrared rays are all part of the family of electromagnetic radiation and have different wavelength properties. However, the human visual system is only sensitive to a very narrow wavelength range of 360-780 nm. This area is called the visible light spectrum (Figure 1) (25-28).

The used light sources have a definite effect on color perception. There are natural and artificial light sources in dental clinics. Homogeneous spectrum lights are a feature especially in light sources to be used in color matching and the sunlight, which is a natural light source, has a homogeneous spectrum covering all colors. However, in different parts of the world and at different times of the day, the sun rays do not contain homogeneous energy distribution. In that context, the ideal light that was suggested to be the natural light is the one that occurs between the middle of the day and 3 PM. Artificial light sources also do not have a uniform color distribution. For example, incandescent light is predominantly red-yellow, while the cool-white fluorescent light source is predominantly blue. In this regard, color corrected lights are a special tool that emits light with a more uniform color distribution. The first shade matching should be done using color corrected lights, but any shade must be matched under multiple lights to overcome the problem of metamerism (3, 24, 25).

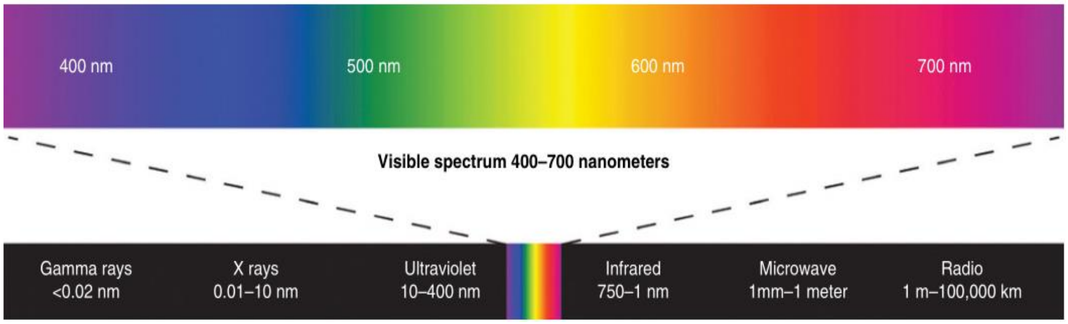

Figure 1. The relative wavelengths and frequencies of the electromagnetic spectrum (23).

B. Object

The color appears because the light source is absorbed by the object and their own color is reflected. If the object is red, it absorbs all wavelengths except red and is detected as red by reflecting only the light in the red wavelength. The object changes the light falling on it by absorbing, transmitting, reflecting, or breaking some or all of the light energy, thereby creating the color quality (Figure 2). A transparent medium will allow visible light to pass through almost unaltered. Translucent object scatters, absorb and transmit portions of wavelengths of visible light, while opaque materials do not transmit, but absorb and reflect various wavelengths of visible light. The teeth shade matching is highly related to the reflection rate of light (23-25, 29).

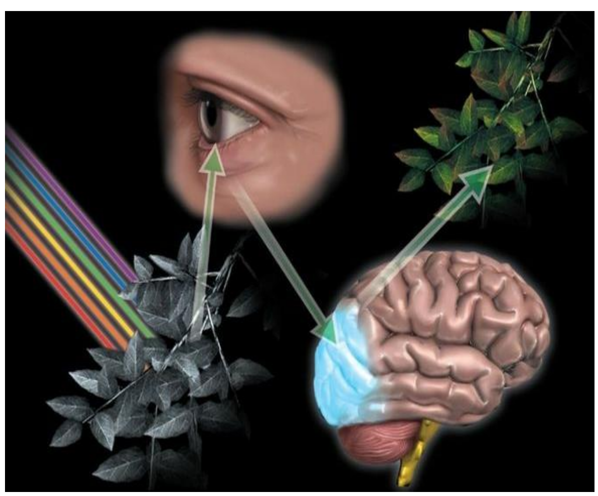

Figure 2. Color perception occurs in the brain (26).

C. Observer

Visible light enters the eye through the transparent area of the cornea and is focused on the crystalline lens on the retina. The retina is the receptor system for vision and is composed of two types of specialized photosensitive cells called the cones and rods cells and these cells contain photosensitive pigments (Figure 2) (29). The cones cells perceive the hue of the color, while the rods cells perceive the lightness. The cone cells then send signals to the brain, which translates the signals into colors (26).

2.3.2. Color systems

From the beginning of the 20th century to the present, there are many different systems developed to measure colors mathematically. Some of these are only theoretical, some are based on sample placement and some are based on physical measurements and calculations (25, 27). An accurate shade matching and specification become possible in art, industry, and science because of the color system that defines a coordinate system for all possible color perceptions (30). Color theories assist the designer and artist in finding a logical and reliable method of dealing with color. These theories also were developed to help in color communications between artists, designers, and manufacturers. Moreover, they aided to answer the most basic questions about color how it could be used and how it was formed. Understanding of science and the development of technology led to the changing of the theories. Aristotle can be considered the grandfather of color theory as he wrote the first known book on the subject, DeColoribus. Leonardo da Vinci proposed a basic set of six hues which is white related to light, green for water, yellow stood for the earth, red for fire, blue for air, and black for night or darkness. Newton surely must be considered the founding father of color theory who endeavored to know a basic truth behind the science and nature of color. He was also the first person who place hues in a circular arrangement, a format that is still used today. In 1703, J. C. Le Blon developed the theory of the primary color system. His theory was that three hues (yellow, blue, and red) were the primary or basic hues since they could not be reduced or broken down any further. He also stated that these hues can be blended or mixed in variable combinations to make up all of the other colors. More than fifty years later in 1766, Moses Harris, in his book "The Natural System of Color" developed one of the first full-color circles, which spaced the primaries at equal distances from one another. In 1905 Albert H. Munsell might be considered the father of modern color classification. A numerical notation system has been assigned by Munsell to these elements so that hues and their variations could be classified and organized. He developed a three-dimensional color wheel. The Commission International D'Eclairage, or CIE, formed in 1931 to standardize color internationally and introduced its standardized color table (31). Visually descriptive Munsell and the more quantitive CIE color systems are the most emphasized in terms of development principles, experiential technique, and qualifications (Table 1) (25, 32).

Table 1. Color theory timeline (31).

350 BCE	Aristotle	DeColoribus (the first book on color theory)
1500	daVinci	Treatise on Painting (published posthumously in 1651)
1701	Newton	Opticks published
1703	LeBlon	Develops concept of primary hues
1766	Harris	Natural System of Color published
1810	Goethe	Theory of Colors published
	Chevreul	Develops concept of color harmonies or color schemes
1879	Rood	Modern Chromatics published
1905	Munsell	Color Notation published. Three-dimensional color wheel developed.
1920	Itten	The Art of Color—ltten develops color star
1931	CIE	CIE develops chromaticity chart based on wavelengths, not actual color.
	Ostwald	Color Science published
1960	Albers	Homage to the Square Series begun
2001	Batchelor	Chromophobia published
2003	Nadin	Anticipation published

2.3.2.1. Munsell color system

In 1915, an orderly numeric system of color description was created by Albert Henry Munsell which is still accepted as a standard system (33). This system was used in the past to quantify color and is widely used in the dental literature. Today it is still a famous system of visual color description (32). In the Munsell color system, three features of the color determine the principle of placing the samples in three dimensions. The first system that separates hue, chroma, and value into independent dimensions, perceptually uniform, and systematically illustrates colors in three-dimensional space is called the Munsell color system. (Figure 3) (34).

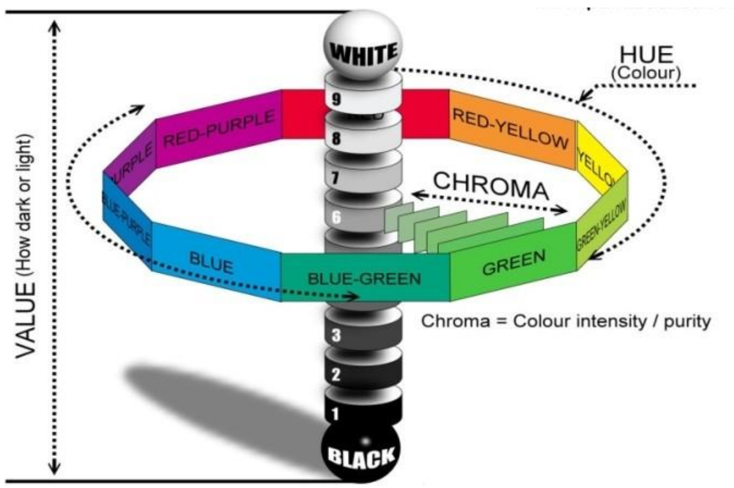

Figure 3. Munsell color system (35).

A. Hue

It is defined as the special type (name) of the color that is the quality that distinguishes one color from the color family. Munsell color system defines five basic colors groups: Yellow, Red, Green, Purple, and Blue, In addition, 5 combination colors are consisting of a combination of these basic colors; green-yellow, yellow-red, red-purple blue-green, and purple-blue. (Figure 3) (34). Hue is a psychological and physiologic interpretation of a sum of wavelengths. In dental terminology, the hue is classified as A, B, C, or D on the commonly used Vita Classic shade guide (35).

B. Chroma

Chroma is described as hue concentration. Dental literature uses the terms chroma and saturation interchangeably; both mean the concentration of pigment or the intensity of a given hue (32). Therefore, hue differences mean different colors, while chroma differences mean the same color with different strengths (23). In the Munsell color system, the Chroma intensity of a particular hue is less intense near the hub of the weel than on the outer rim (Figure 4) (32).

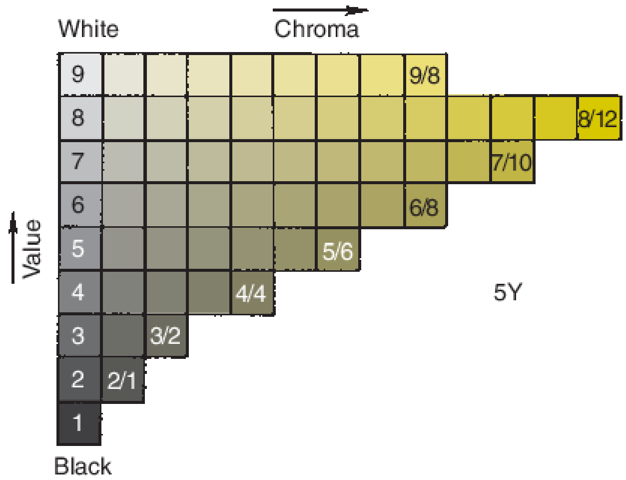

Figure 4. The Munsell system arrangement of Value and Chroma (32).

C. Value

The brightness of an object or the relative darkness or lightness of a color is described as Value. The object brightness is a direct reaction to the amount of light energy that the object transmits or reflects. (Figure 4) (32). Munsell defined the Value as a white to black gray-scale and it was rated from 0 to 10, and there is black at the bottom and white at the top. Pure white is determined as 10 and pure black is 0 and is evaluated as inaccessible. Dark objects have higher amounts of gray, while high-value objects have lower amounts of gray which makes them look brighter (25, 36). As Value is increased, the Chroma is decreased on account of Value and Chroma are inversely related (37). For color selection, Value is considered the most important color characteristic. In a restoration where the value is correctly determined, the aesthetic errors that may arise as a result of incorrect detection of hue and chroma values can be relatively less noticeable (24, 25).

2.3.2.2. CIELAB color system

In 1931, the International Commission on Illumination or the Commission International de I'Eclairage (CIE) defined the concept of the tristimulus values X, Y, and Z. The concept for the XYZ tristimulus values is based on the three-component theory of color vision, which states that the eye possesses receptors for three primary colors (blue, red, and green) and that all colors are seen as mixtures of these three primary colors. The

XYZ tristimulus values are calculated using these Standard Observer color matching functions (38). In 1976, CIE defined one of the most popular spaces for measuring object color which is the CIELAB space (also referred to as The L*a*b* color space) to reduce one of the major problems of the original YXZ space (39). The L* value is a measure of the lightness of an object and is quantified on a scale such that a perfect black has an L* value of 100 * (synonym for Munsell Value). The a* value is a measure of greenness (negative a*) or redness (Positive a*) (−a* green, +a* red). The b* value is a measure of blueness (negative b*) or yellowness (positive b*) (−b* blue, +b yellow). The a* and b* coordinates approach zero for natural colors and increase in magnitude for more saturated or intense colors. The CIE color space represents a uniform color space, with equal distances corresponding to equal perceived color differences. (Figure 5) (32).

Presently, in the dental color study, colors and color differences are quantified respectively using the CIELAB space and the associated ΔE*ab as shown below (40):

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

The color difference in the CIELAB formula is denoted ΔE* it represents the difference in sensation (the symbol delta, Δ, means the difference, while E is the first letter of the German word Empfindung, which means sensation), and represents the interaction of L*a*b* which means ΔL*, Δa*, and Δb* are the differences between the CIE L*a*b* color parameter of two samples. Clinical shade matching between teeth and restorations may be rated according to ΔE* values (32, 41).

Moreover, the ΔE* values were converted into National Bureau of Standards (NBS) units by the followed equation these values are shown in (Table 2) (42, 43):

NBS units = ΔE* × 0.92

Table 2. National Bureau of Standards (NBS) ratings (44).

Unit of (NBS)	Color differences	Critical remarks
0.0-0.5	Trace	Extremely slight-change
0.5-1.5	Slight	Slight-change
1.5-3.0	Noticeable	Perceivable
3.0-6.0	Appreciable	Marked-change
6.0–12.0	Much	Extremely marked-change
12.0 or more	Very much	Change to other colors

A more advanced and recent CIE formula, CIEDE2000, has been subsequently introduced and it is increasingly used in dental color research (32).

The CIEDE2000 color-difference formula is given as follows:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L} \right)^2 + \left(\frac{\Delta C'}{K_C S_C} \right)^2 + \left(\frac{\Delta H'}{K_H S_H} \right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C} \right) \left(\frac{\Delta H'}{K_H S_H} \right) \right]^{1/2}$$

Where $\Delta L'$, $\Delta H'$, and $\Delta C'$ are the differences in lightness, hue, and chroma for a pair of samples in CIEDE2000, and RT is a function (the so-called rotation term) that accounts for the interaction between hue and chroma differences in the blue region (45).

The CIE Lab system advantage is that color differences have a clinical significance because they can be expressed in units that can be related to visual perception (35). The CIELAB color system is exclusively used for dental color research worldwide (32).

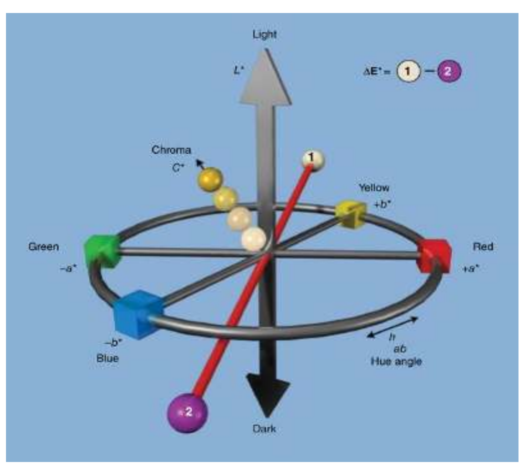

Figure 5. Value, chroma, and hue, and color difference ΔE* (23).

2.4. Shade-Matching Measurements

The shade matching process for any dental prosthesis consists of the shade matching phase in the dental clinic and the shade duplication phase which is processed by the lab technician (32). Dental shade matching has two methods that assist the technician to create an esthetically compatible prosthesis in the distance (21). Accurate shade matching is important but the objectives of the patient have to be considered, this process should be agreed on before starting any esthetic treatment. For ideal color analysis, the color-corrected lights in addition to natural light conditions should be used. Also, the restorative material that will be used has a direct effect on the color choices (46). Shade matching could be achieved by either conventional visual shade matching or by instrumental analysis (32).

2.4.1. Visual shade matching

Color selection tools are called shade guides. There are many types of color standards for dentistry, depending on their purpose and the tissue for which they are intended. These can be listed as follows; Tooth shade guides, gingival, and facial shade guides (29).

In 1931, Bruce Clark introduced a custom shade guide based on a visual matching of human teeth, recorded in Munsell value, chroma, and hue (Figure 6). Because of the deficiencies of the commonly used guides in the 70s, Robert C. Sproull proposed that an ideal shade guide is preferably based on the Munsell color system that should contain shade tabs that are logically arranged and well distributed in color space. The shade guides' limitations are the factors that led to the dissatisfaction of patients, dentists, and technicians and compromise shade matching processes in dentistry (29, 47). The main requirements for dental shade guides for a long-time are adequate color distribution and logical order (23). There are three main groups of shade guide which fulfill these criteria to different extents as following:

A. VITA classical shade guides A1–D4.
B. VITA 3D-Master System shade guides.
C. Others: classical-proprietary shade guides (23).

Figure 6. The Clark shade guide (23).

A. VITA Classical A1–D4 Shade Guide

The VITA classical shade guide (VITA classical, VITA Zahnfabrik, Bad Säckingen, Germany) which for a long time was a gold standard for shade matching in dentistry, and significantly it still is. VITA classical contains sixteen shade tabs. The (A to D) is the original tab arrangement (Figure 7-A). The four groups are created based on hue: A is reddish-brown (A1, A2, A3, A3.5, A4), B is reddish- yellow (B1, B2, B3, B4), C is gray (C1, C2, C3, C4), and D is reddish-gray (D2, D3, D4). Within the groups, tab arrangement is based on decreasing value and increasing chroma, the lower the number, the higher value, and the lower chroma. The “value scale” is an alternative tab arrangement that has been established according to the (brightness degree), with no group division (Figure 7-B). The “value scale” tab order is B1, A1, B2, D2, A2, C1, C2, D4, A3, D3, B3, A3.5, B4, C3, A4, and C4. For monitoring the teeth whitening, the value scale is considered as a gold standard that is expressed in shade guide units (sgu). For dental shade matching the “value scale” is more logical and preferred by many over the (A to D) arrangement (23). VITA Classic shade guide has some limitations like a limited color range compared to human tooth and the organization of the shade guide: (A- to- D arrangement and “value scale”) (48). Yılmaz, et al (49) studied the influence of the hue arrangements and value arrangements of the VITA Classical shade guide on the accuracy and repeatability of visual shade matching. They found that no significant differences in the repeatability or accuracy of the shade matching outcomes are achieved by the two arrangements.

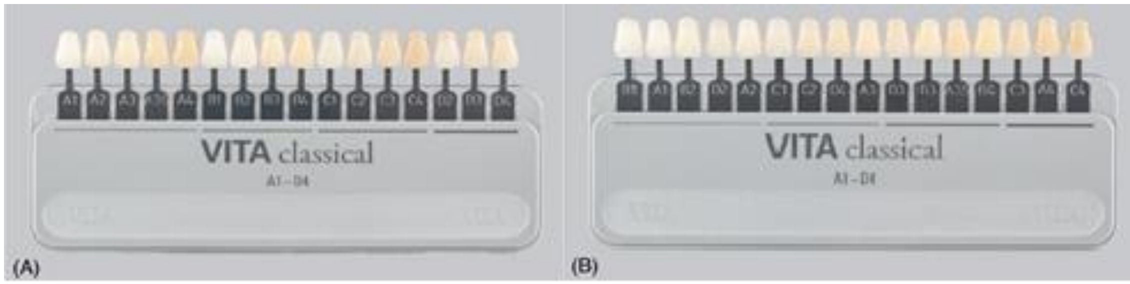

Figure 7. VITA classical shade guide: (A) hue-arrangement (B) value-arrangement (23).

B. VITA System 3D-Master Shade Guide

VITA 3D-Master system shade guides have been developed based on research on the color of the natural tooth. There are three 3D-Master shade guides: Toothguide, Bleachedguide, and Linearguide. The 3D-Master tabs are using (letter-number) combination. The first number defines the group and represents value, from 0 (the brightest) to 5 (the darkest). Hue is represented by letters L, M, and R: (L) corresponds to yellowish (or less red), (M) refers to (medium), and (R) refers to (reddish). The number after the letter represents chroma, which increases from 1 to 3, with designations 1, 1.5, 2, 2.5, 3 (23).

1. <u>The VITA Toothguide 3D-Master Shade Guide</u> (Figure 8) consists of 29 tabs divided into six groups according to lightness. Within the groups, tabs are arranged horizontally according to hue and vertically to chroma. Groups 0 and 5 have three tabs each; group 1 has two tabs, while groups 2, 3, and 4 have seven tabs each. The Toothguide is a three-step shade matching procedure. The first step is to determine the value (group 0-5) by using the entire shade guide therefore the number of possible shades is reduced. The next step is to determine chroma, while the third step is to determine hue. Given that, the variations of hue are present only in groups 2, 3, and 4, there are only two steps for groups 0, 1, and 5. This method can be challenging for those with limited knowledge about the system and less experience in teeth shade matching (23).

Figure 8. VITA Toothguide 3D-Master shade guide (23).

2. The VITA Linearguide 3D-Master Shade Guide (Figure 9) also has the same shade tabs such as the Toothguide. The differences are in its design and process of shade matching. In the same way to the Toothguide, in step one the group matching occurs, but using only a single linear scale which contains the middle tabs from each of these groups (0 M2 to 5 M2, dark gray tab holder). The initial matching is simplified by a small number of tabs with huge color differences and the familiar linear tab arrangement. The second step is “fine-tuning” by choosing the best selection within the group matched in step one. The tabs from groups 0–1, 2, 3, 4, or 5 are placed into five separate light gray holders (23).

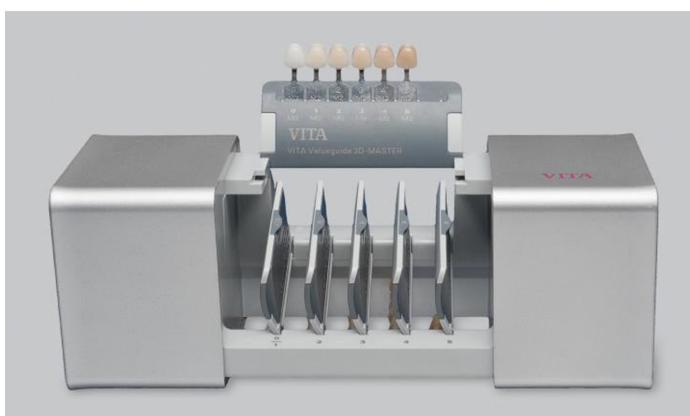

Figure 9. VITA Linearguide 3D-Master shade guide (23).

3. The VITA Bleachedguide 3D-Master Shade Guide (Figure 10) has been developed specifically for tooth whitening observation. It has 15 shade tabs, marked as the Toothguide and Linearguide tabs in the letter-number-letter style. Tooth whitening

causes an increase in the lightness and a decrease in chroma and hue of natural teeth. The most pronounced changes are in chroma, followed by changes in value and hue. The Bleachedguide is a color scale (not a hue, chroma, or value scale), lighter tabs being less red and less chromatic than the darker tabs. The Bleachedguide exhibits a more consistent color distribution and a wider color range than the classical "value scale" and some other products (23).

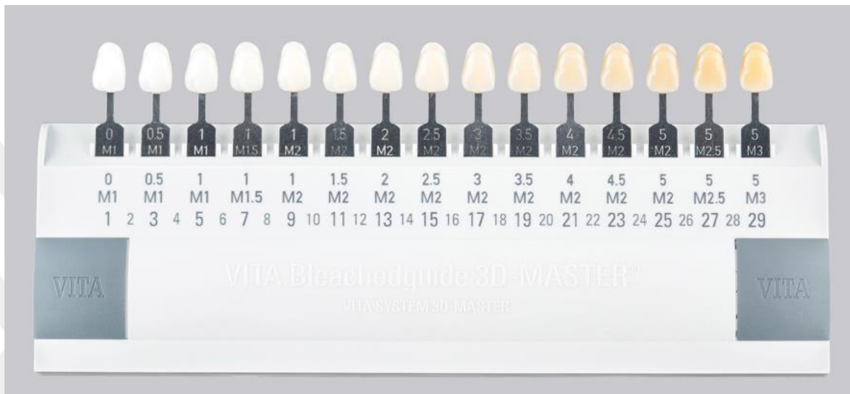

Figure 10. VITA Bleachedguide 3D-Master shade guide (23).

C. Others: proprietary or classical-proprietary shade guides.

1. The Chromascop is a shade determination system that depends on Ivoclar dentin shades and is arranged into five divided shades or hue: (white-color, group-100), (yellow-color, group-200), (light-brown-color, group-300), (gray-color, group-400), and (dark-brown-color, group-500) (Figure 11-A). The four shade intensities in each group are chromatically arranged. Using this guide, shade matching starts with determining the base shade of the patient, then picking up the matching shade group, lastly determining the intensity of the shade within that group (46).
2. Trubyte Bioform Shade Guide (Dentsply International) is a classical/proprietary resin/ceramics shade guide arranged according to hue and as the VITA classical "value scale" (Figure 11-B). The former includes (A to D) classical arrangement and eight proprietary shades, while the latter represents a light to dark order of 24 tabs marked with two-digit numbers (order: 59, 51, 91, 62, 66, 52, 53, 92, 63, 54, 65, 93, 55, 69, 94, 95, 67, 56, 77, 81, 96, 83, 84, 85). The bleached tabs are also available as in many other shade guides (23).

Figure 11. Classical proprietary shade guides: (A) Ivoclar Chromascop; (B) Trubyte Bioform (23).

2.4.1.1. The advantage and the disadvantage of visual shade matching with dental shade guides

The dental shade guides have advantages such as being used anywhere and being less expensive than other tools. On the other hand, visual shade matching also has some disadvantages, the first and most obvious problem related to perceiving the color of the tooth with the naked eye is the environment. The environment affects the results of the color-matching procedure. The perception of tooth color can be affected by many parameters such as the dental chairs, equipment's color, the clothing color of the patient, the wall decorations, and sunlight. The sunlight has a different wavelength and qualities at different times of the day. Therefore, the same color looks different when observed from different angles or reflected from different surfaces, which can cause the true color to be perceived incorrectly, which is called metamerism. Furthermore, Eye fatigue of the person at the end of an exhausting day or some medicaments used may affect color perception (21). Moreover, the colors of the guides do not cover all the color of natural teeth. Also, even in a particular manufacturer, the colors of shade guides can vary from guide to guide. Guides do not duplicate how porcelain restorations should be done (opaque thickness, body thickness, and incisal porcelain, metal bonding, etc.). Standard shade tabs are made of synthetic resin and have a thickness of 3-4.5 mm. Therefore, it is often inevitable that a finished restoration with a thickness of 1-1.5mm, will not have the same color as in the guide (32, 50).

2.4.1.2. Shade matching procedure

There are a few simple guidelines in shade matching that help to eliminate many sources of mistake and to standardize the process (24). The most important points are:

A. Shade matching must be done under suitable lighting and in a gray or pastel-colored environment (32).
B. The clinician should be located between the light source and the patient (51).
C. The clinician should ask the patient to remove anything that could affect the shade matching such as lipstick and brightly colored clothing (32).
D. The teeth should be free of stains and cleaned before starting the process of shade matching (52).
E. As the teeth are dehydrated and result in higher values, preparation must be done after shade matching (52).
F. In order to provide unhindered shade matching intraoral area, cheek retractors should be used.
G. The patient should sit at eye level and the observing distance should be approximately 10 inches (25 cm) so that the most sensitive part of the clinician's retina is used.
H. Wetting the surface of the shade tab and the tooth helps eliminate the surface characteristics differences (32).
İ. The dental clinician should select the tooth color at the beginning of the day to avoid eye fatigue (52).
J. Shade matching must be done quickly (within 5 seconds), by placing the shade tab next to the tooth that will be selected. This assures that the background of the shade sample and the tooth are the same.
K. The clinician should rest his eyes by focusing on a gray surface between choices to balance the color sensors of the retina.
L. The canine teeth are suggested for comparison in order to select the appropriate hue since canines have the highest chroma of the dominant hue.
M. When the clinician compares shade tabs he/she should narrow the options into about three tabs as fast as possible. After that, one or two of the selected shade tabs that match the best should be reselected.

N. Shade matching must be completed at one or two further visits and, if possible, confirmed with an auxiliary staff member. Shade matching is advisable to be done under different lighting sources (32).

O. A shadow / chromatic map should be created that is divided into different sections to ensure that different effects, shades, and characterizations are placed correctly (52).

P. The shade tab with the highest value and lower chroma is preferred to be chosen when an exact match cannot be achieved because, in order to reduce the value and increase chroma, an extrinsic characterization can be used (32).

Q. Before putting the shade guide away, it must be disinfected (51).

R. The clinicians should map the polychromatic nature of the teeth being selected its special characteristics (e.g., hypocalcification, cracks, and translucency of the incisal enamel of the teeth) with one of the following:

    1. Chart of the color distribution,
    2. Staining of the closest matching shade tab.
    3. A digital photo that includes the tooth next to the closest shade tab (32).

2.4.2. Instrumental shade matching technique

There are many factors such as gender, age, and observers' experience that affect obtaining the exact shade in the visual shade matching procedure. However, the instrumental color matching technique provides an easily communicable, objective, and readily reproducible data system which gives a predictable outcome (21).

Dental shade matching devices and systems have an advantage over conventional shade matching caused by their ability and objectivity to compute differences in color and its dimensions compared to the nearest match from different shade guides. (23). Anand, et al (53) reported that electronic shade matching ensures accuracy, complete shade matching, and the elimination of variables that tend to confuse and clutter the shade-taking process.

Clinicians need to be familiar with the features and restrictions of the devices in terms of shade matching communication, verification, and reproduction processes. Since instrumental and conventional shade matching methods are complementary, using them together will lead to better esthetic results (23). Anand, et al (53) concluded that the best achievable in color construction and communication is through the combination of conventional techniques with the science of colorimetry.

Technology-based shade selection devices can be listed as follows:

- Colorimeters
- Spectrophotometers.
- Digital cameras
- Computerized shade matching system (23, 53).

2.4.2.1. Colorimeters

Colorimeters process reflected light from the surface of an object, and calculate the data into color parameters, and be used to determine the shade and to calculate color differences (38). Colorimeters measurements allow communication to be more precise. Moreover, colorimetric measurement allows the quantification of color using CIELab coordinates (38, 54). Tristimulus colorimeter is a color measurement instrument that is equipped with three or four special filters. Filters obtain RGB (red, green, and blue) values and have features such as compact size, comparatively low price, simple operation, excellent repeatability, and superior mobility (55, 56). A relatively new colorimeter ShadeEye NCC (Shofu, Menlo Park, CA) has been presented to the market as an appropriate device for intra-oral color measurements (57). Shofu ShadeEye NCC (Natural Color Concept) consists of two components - the main unit that includes an integrated printer and a mobile measuring unit that is the size of a cell phone (Figure 12) (53). However, a colorimeter is not suitable for complex color measurements such as colorant strength and metamerism (56).

Figure 12. ShadeEye NCC (21).

2.4.2.2. Spectrophotometers

One of the most accurate, handy, and flexible device for dental shade matching are spectrophotometers (8). They measure the amount of light energy reflected from an object at 1–25 nm intervals along the visible spectrum (58). The spectrophotometer consists of a detector, a means of converting light obtained to a signal that can be analyzed, a means of dispersing light, a source of optical radiation, and an optical system for measuring. The instrument measurements are converted to the shade tab equivalent and keyed to the dental shade guides (59). It was found that spectrophotometers results are more objective and increase the accuracy, compared with the conventional method (60, 61), Other studies revealed that spectrophotometers provide a closer shade match of the prosthesis to the adjacent natural teeth compared to the visual shade matching method (48). There are various high quality and reliable spectrophotometers. VITA Easyshade, VITA Easyshade Compact, Shade-X (X-Rite, Grandville, MI), and Crystaleye are available in the market (39, 58).

The Easyshade Compact (Vident) is a spectrophotometer shade matching device that helps the dentist to evaluate the shade of restorations either indirect or direct, effectively, and very quickly. It can also verify the shade of lab-produced work before the patient is brought in for cementation. VITA Easyshade Compact is wireless, lightweight, and portable (Figure 13). Color readings are based on the VITAPAN 3D-Master and VITAPAN Classical shades. VITA Easyshade Compact illuminates the target area spontaneously and makes the results independent of situations such as lighting conditions, working colors, clothes, etc. The unit has a storage capacity of twenty-five shades at a time, and the shade can easily be transferred to the technician (21). VITA Easyshade Compact has four different measurement settings: tooth single-mode, tooth areas mode (incisal, middle, and cervical shades), restoration color verification (includes hue, chroma, and lightness comparison), and shade tab mode (practice mode) (62).

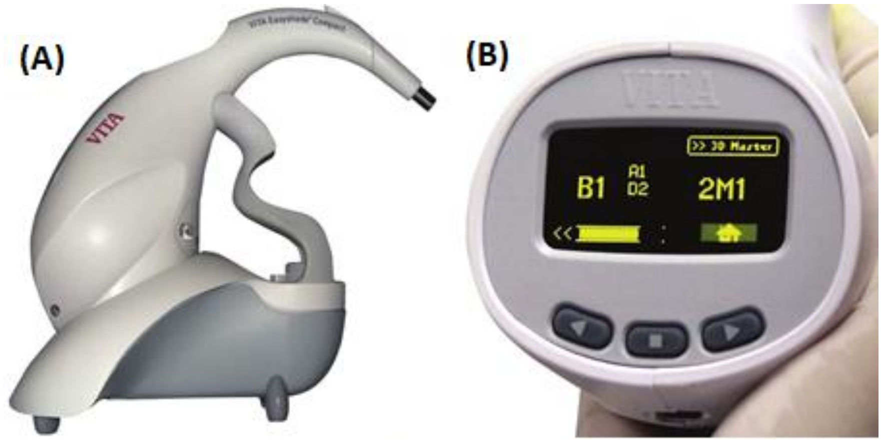

Figure 13. VITA Easyshade Compact. A) Handpiece and base. B) The interface screen is found on the handpiece end (21).

2.4.2.3. Computerized shade matching system

In addition to dental colorimeters and spectrophotometers, scanners and digital cameras can be used to record color data and provide a useful color mapping and a detailed image of the teeth surface (23). With these devices, digital color imaging is combined with very precise colorimetric evaluations to improve dental color management. This innovative technology improves the quality and predictability of treatment and saves time. Cynovad ShadeScan (digital color analysis with colorimetric analysis), X-Rite ShadeVision System (digital color analysis with colorimetric analysis), MHT SpectroShade Micro (uses double digital cameras connected to a fully functional spectrophotometer) (Figure 14), METALOR Ikam Shade Analysis System, and ClearMatch System (is a software that uses digital high-resolution images) are the examples of existing devices in this scope (21, 29, 50, 53, 58, 62).

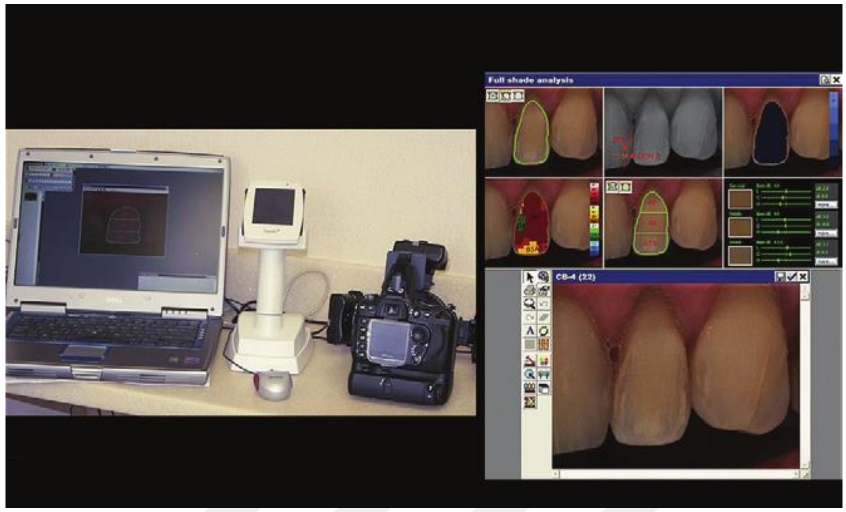

Figure 14. MHT SpectroShade system (21).

2.4.2.4. Digital cameras

Digital photography is defined as the photos that can be saved in an electronic file format which is called a digital image file. It implies a file format that is composed of a graphical image instead of program data or text. The photos could be saved in a bitmapped image form (GIF, BMP, TIFF, JPEG, and PNG) and vector-based photos used in illustration programs or paint (63).

Digital technology has changed dentists' perspectives on data collection and treatment by allowing dentists to capture photographs of teeth or other lesions in the oral cavity in seconds using intraoral cameras (63). Like many other developed modern technologies, digital photography provides significant benefits to the field of dentistry. A digital camera captures photos using charged coupled devices that contain millions of microscopically small light-sensitive components. This method has the advantage that the digital camera is easy to use and highly efficient (29). Also, the digital image can offer other accurate options as well as a cost-efficient method of teeth shade matching by improving connection with the lab staff (64).

Nowadays, using megapixel digital cameras has been broadly adopted in dentistry. Digital shade matching using photos could decrease the gap of shade communication between clinicians and dental technicians. Through communication with lab technicians, dentists can provide not only the colors and morphology of teeth but also the color distribution, surface texture, and other data about the intraoral conditions. Intraoral photos with the shade tabs placed correctly beside the tooth as a reference are useful methods in shade matching. However, during shade analysis, unstable illumination in the photos poses a big problem in the normalization of intensity. Another problem relates to the image color description, it should be capable to present the color distribution of the tooth surface in detail. It is claimed that color alternates along the vertical axis of the teeth surface. The gradation starts from the cervical, which is the most saturated, to the incisal area. The gingival and the proximal contact area are subjective to change due to the effect of shadow and cannot reveal naturally teeth color. The middle third chosen for selection records the color gradation complexity on the natural tooth and can be used as a valuable content of color comparison (65). Digital Imaging could be a perfect adjunctive instrument for the clinician and dental technician to quantify color (66). Pandey, et al (64) expressed that, the use of both instrumental and visual methods complement each other and provide predictable esthetic results.

Basics of Photography:

A. Exposure

To get the best photo result, the photographer needs to take the photo at the correct exposure (67). Exposure is the measurement and stabilization of light. When the photo is taken with a lot of light, the photo is washed and bright areas lose their detail (overexposed photo). If there is not enough light, the picture may not be clearly visible and it will be too dark(underexposed) (68). Therefore, the settings listed below must be made to obtain the correct exposure of a photograph;

1. Increasing aperture (wider f-point)
2. Extending the time (longer shutter speed)
3. Increasing the sensor precisely and a higher number of ISO (International Standards Organization).
4. Increasing the lighting (brighter lighting) (69).

B. Shutter speed

The term “Shutter speed” can be called also “exposure time”. It is measured by the amount of time that the sensor is exposed to the light while the shutter remains open. When the shutter speed is slow, that means long exposure time, while a fast shutter speed means a short exposure time. However, the important criterion here is the amount of camera movement and object. Photographing a moving object using slow shutter speed may cause a blurred photo while increasing the shutter speed makes the object sharper, with less blurring and better definition. The shutter speed and the aperture are inversely related (70).

C. Aperture

Aperture is defined as the width of the shutter opening in a camera when a photo is taken (70). The aperture controls the size of the opening that light passes through the sensor and is calculated by f-stop numbers. Typical ranges are from f- 1.4 to f-32. A larger f value means a smaller aperture. Aperture is a significant component for dental photography as it is the determining factor of "depth of field". The depth of field is essential in intraoral photographs because the teeth and surrounding structures exist in different planes therefore they should be in focus (68). Aperture and shutter speed are inversely related. The wide aperture allows more light to reach the sensor, and faster shutter speed allows less light to escape through it by reducing the time that the sensors are exposed to light (70). In order to get the best results for intraoral photography, the aperture can be set at 32 to have the maximum depth of field in the taken photograph (68).

D. ISO sensitivity

The third component next to aperture and shutter speed which determines the exposure of an image is the electronic light sensitivity, which intervenes with the exposure of an image. In most digital cameras the electronic light sensitivity is adjustable under the name of “ISO” sensitivity. Increasing the ISO sensitivity will reduce the amount of needed light to get the right exposure. Cameras that have a greater ability of ISO sensitivity can produce a higher quality photograph at a narrower aperture and fast shutter speed. This feature is useful when taking a photo in dim light and when the blurred motion effect of a narrow depth of field or the slow shutter speed that results from a wide aperture is not desired (70).

E. Depth of field

The depth of field is the responsible factor for determining the amount of area which have a sharp focus in an image. The human eye can see everything in focus, unfortunately, cameras can’t see and capture it in the same way. The depth of field and the aperture opening differ inversely. When the aperture is set to f4, the depth of field will be narrow and cover a small area, while setting the aperture at f22 will make everything mostly in focus (69). The area of the sharpest focus on the subject (front or back) depends on which the lens is focused. Depth of field relies on:

1. Aperture (f-number)
2. Focal length of the lens. (12-400mm)
3. Distance from the lens to the subject.

A smaller aperture which is denoted by a larger f-number like 20 or above means shorter focal length, and furthest focused distance increasing the depth of field which is desirable for the intraoral photo (68). Therefore, setting the aperture to smaller than f22 will seriously diminish image clarity without a substantial gain in depth of field, that’s why most macro lenses are designed with a diaphragm which does not close lesser than f22 (69).

F. White balance (Color temperature)

When a white card is viewed outdoor in the light of day it looks white and if the same card is viewed under tungsten lights, it still appears white. This is due to the fact, even though the color temperature of the ambient light has changed, the card still appears white due to a phenomenon termed “color adaptation” (69). The brain can adapt to color temperatures. A digital camera records the color temperature of the illumination as it is. For example, daylight appears neutral, halogen bulbs give greenish lighting and tungsten lighting has a less or more strong tendency to yellow-red. One of the digital cameras' biggest advantages is that they can be adapted to lighting in terms of color temperature. The cameras usually have the option of determining the white balance automatically. Dental photography is generally worked with electronic flash lighting. To achieve repeatable outcomes, the white balance should be set using a flash icon to "flash photography" (71).

G. Lens

Dental images are mostly close-up images, which requires the use of macro lenses (Figure 15). The macro lenses have another advantage which is their ability to compensate for image problems inherent in close-up images (71). A lens chosen for dental uses must be able to capture accurate and diagnostic views of the gingiva, teeth, and surrounding structures. For dental photographing, macro lenses with a fixed focal length designation of (85 to 105 mm) present the ideal combination of working distance convenience and magnification ability. The lens's quality has a significant influence on the ultimate quality, sharpness, and clarity of the photo (68).

Figure 15. Nikon macro lenses (70).

H. Data file format

There are different file formats to store image date files by the camera that should be pre-selected. The most important types of digital photo file format are:

1- JPEG: (Joint Photographic Expert Group; file extension .jpg)
2- RAW: extensions are named differently: NEF = Nikon, CRW/CR2 = Canon, ORF = Olympus, MRW = Minolta, RAF = Fuji.

Some cameras store two different formats at the same time. If the image will be converted manually later, and the aim is to achieve the highest possible quality, the RAW format should be chosen. However, the JPEG format considers the highest quality format which is recommended for routine processes. For special purposes, two formats can be selected at once (70).

I. Image editing programs

There are many programs for image editing on the market which are regularly updated. Therefore, a complete overview of all programs and their features is not possible to present. Adobe Photoshop® is the industry standard of professional image editing software program that allows editing and improvement process (71). To have an alternative to spectrophotometric or colorimetric methods, imaging shade matching has been suggested. The software (Adobe Photoshop) is being used for digital image analysis on a computer screen. By using this way, there is an improvement in the shade matching achievement over visual methods (48, 72-74).

2.5. Transmission of the Color to the Laboratory

Color is an exclusive language spoken by the dentist and the technician in restorative dentistry (75). Shade matching and reproduction are complex processes that the clinician and technician need to work together in harmony to communicating effectively (23). The importance of good technician-clinician communication has been stated in many studies and is the key to cosmetic success. Appropriate communication among technicians and dentists, will save effort, time and, enhance the final restoration's quality (76, 77). Effective communication occurs when the technician meets with both the patient and the clinician to discuss the case. Such a meeting allows the technician to directly assess and collect the patient's character, mouth structure and movements, and the patient's esthetic demand (78). However, most of the dental clinics and technician lab are located in different places. Therefore it is believed that proper communication with the technician is a serious challenge for the success of the procedure, especially in esthetically important situations (76).

In the past, traditional photography and slide films were considered valuable methods to convey shade and form in dental procedures. Today, these applications are being replaced by digital photography (23). Communication that does not require the use of paper and printing is extremely recommended. The selection of the right web content management systems, taking into account individual requirements and program design, will guarantee long-term successful relationships between technicians and dentists (76).

2.6. Problems with Tooth Shade Matching

Many variables affect color perception. Light conditions, environment, and viewer are all playing critical roles in affecting color perception and evaluation (79). In the shade matching process, the clinician may face the following difficulties (21).

2.6.1. Hue sensitivity

Staring at a shade guide or tooth for more than five seconds, the eye accommodates and becomes biased. If a person stares at any color for more than five seconds and then closes his or her eyes or stares at a white surface, the image appears in the complementary hue. This phenomenon, known as hue sensitivity, affects shade matching adversely. After five-seconds, by staring briefly at a blue-surface or looking away, the vision will re-adapt to the orange-yellow portion of the spectrum (33).

2.6.2. Clinical lighting challenges

The dentist has long relied on color-corrected lighting to determine the shade of the teeth, but using these specially named lights may not always provide the correct shade match. There are two reasons for this which are lighting conflicts and metamerism (80).

A. Lighting conflicts

The dental operatory is not free from conflicts in lighting. The light coming from a window with the fluorescent light coming from the hallway in addition to the color-corrected lighting in the dental operatory mixes all together and affects the shade matching process. It is the clinician's challenge to determine the correct shade. The following tips will help this process:

1. Having a natural light source helps the clinician or the lab technician to perform the shade matching, the best time for shade matching is from 10 am to 2 pm while having a clear, bright day and the ideal color temperature of 5,500 K is present.
2. When only artificial lighting is available and there is no natural light, color corrected lighting tubes that burn at about 5,500 K (D 50 illuminants) have to be installed.
3. In order to ensure that a color temperature of 5,500 K is attained in the shade matching zone, a color temperature meter should be used regularly.

4. Dirt and dust must be cleaned routinely from diffuser and lighting tubes because the presence of dust may change the quality and quantity of produced light (80).

B. Metamerism

Is a phenomenon when two objects look to be identical colors under a certain kind of light but look totally different under another light condition (Figure 16) (81). For example, shade tabs will look different when viewed under various lighting, which creating difficulties in shade matching (80). However, this issue can be avoided by doing the shade matching in different lighting conditions, such as fluorescent light and natural daylight (82). The observer metamerism occurs when the light condition remains the same and the observer changes, caused by either instrumental or human visual stimulus. It is recommended that a third observer evaluate the shade matching before cementation (29).

Figure 16. Illustration of the effect on perceived color if the proper lighting is not used. (a) Incandescent lighting (2,856K). (b) Fluorescent lighting (4,000 K). (c) Color-corrected lighting (5,500 K) (83).

2.6.3. Fluorescence

Fluorescent is the light absorption by the subject and its spontaneous emission at a longer wavelength. In the natural teeth, it usually occurs in the dentin because of the high amount of organic material (Figure 17) (35). With the fluorescence feature, restorations look brighter and more alive. If the fluorescent of the dentin increases, the chroma decreases (83). In order to increase the amount of light returning to the observer, block out discoloration, and reduce chroma, fluorescent powders are added to restorative materials (35).

2.6.4. Translucency

The teeth of humans have different degrees of translucency. Translucency is defined as the gradient between opaque and transparent. In general, translucency and value are inversely related, as translucency increases value decreases. Increasing the translucency allows the light to go by the surface and scatter in the body of porcelain. The enamel translucencies vary with the surface luster and texture, angle of incidence, wavelength, and level of dehydration (Figure 17) (35).

2.6.5. Opalescence

Is a phenomenon when the subject looks to be color when you observe light transmitted through it while appears to be another color when you see light reflected from it (84). The light coming to an object that has an opalescent feature is reflected and scattered in all directions when encountering a wavelength shorter than its own wavelength. In this case, the object appears red-orange in transmitted light and blue in reflected light. The effect of opalescent depends on the translucency behavior of natural teeth (Figure 17) (25, 80). Opalescence is highly wavelength dependent and mimics enamel. Hydroxyapatite which is opalescent materials act as a prism and tend to refract short wavelengths (violet) more than long wavelengths (yellow and red). As a result, the enamel scatters violet and blue light but transilluminate red and yellow light in its body. That effect is the reason for the incisal enamel to appear translucent (and bluish) as well as producing optical depth. (33).

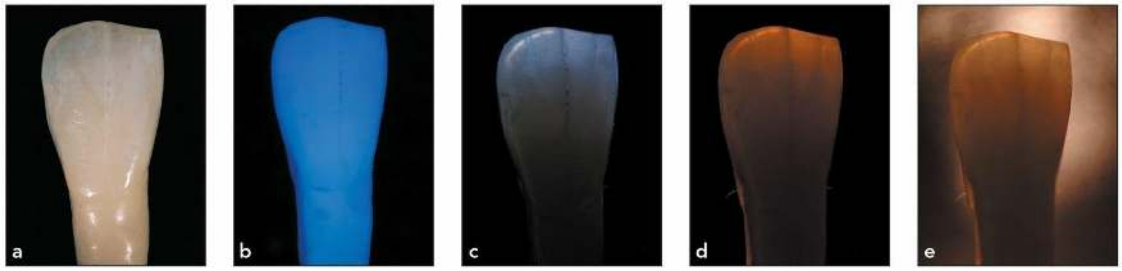

Figure 17. Light effects exhibited by a natural tooth. Natural light effects (a), fluorescence (b), opalescence (blue [c] and orange [d]), and translucency (e) (80).

2.6.6. Teeth whitening

Teeth whitening dehydrates enamel and sometimes dentin, and sometimes removes pigmented organic material from between the hydroxyapatite crystals. Teeth whitening changes the value, chroma, and hue of the teeth, resulting in a lighter appearance. Whitening resulting from dehydration is temporary and reverses upon teeth rehydration (33). A newly bleached tooth is not color stable. That is why the shade matching process must be postponed for at least a month after teeth bleaching. Since the whitened tooth is dehydrated faster than other teeth so shade matching must be completed before other treatment (83).

2.6.7. Surface texture

The texture of the surface influences esthetics by changing the direction and amount of light reflected from the surface (52). To harmonize with the natural dentition, the surface texture of a prosthesis have to be designed to simulate the reflectance pattern of the adjacent natural teeth. Typically, teeth of the young exhibit a great deal of surface characterization, including striations, ridges, stippling, and evidence of developmental lobes. These surface features are gradually worn away with daily functions, leaving older teeth with a much smoother, highly polished surface. Communicating the quality and the amount of surface texture is very difficult. Some authors suggest the use of sterilized extracted teeth or custom shade tabs as a guide (51).

2.6.8. Contrast and glare

Contrast is caused by a difference between the background and the brightness of an object. The object which has high contrast is easier to select than objects with low contrast. Some contrast is useful to our visualization system, on the other hand, excessive contrast causes glare. An object with high brightness against a dark background or significantly differently colored objects causes discomfort and can interfere with our perception. This interference is generally known as glare, which reduces our capability to perceive visual data (83). Preston et al (85) mentioned that the illumination of the teeth cannot be significantly lighter than the ambient environment.

2.6.9. Environmental influences

The surroundings and background of the environment can affect the hues and the saturation perceived. The patient's skin color, make-up, and even reflection from the walls and operatory equipment can alter the color of the oral environment and the shade guide, which can influence the shade matching. Therefore, it is preferred to remove the patient's make-up and utilize a neutral gray background in the operatory, in order to reduce the effects of surrounding colors and to prevent an inaccurate shade matching (29).

2.6.10. Observer associated effects

A. Age

Getting older is detrimental to shade matching abilities since the lens and cornea of the eye become yellowed with aging, imparting a yellow-brown bias. This progress starts at the age of thirty and becomes more noticeable at the age of fifty and has clinical significance after sixty years old. After sixty years of age, a lot of individuals have significant problems in observing blues and purples (80).

B. Fatigue

Fatigue is one of the most common reasons for matching the wrong color (80). The high intensity and brightness of the dental unit light can cause eye fatigue. Color matching should be completed before turning on the light of the unit (86). Misperception may develop due to mental, local, or systemic fatigue (29). Lack of accurately determining color and tone is extremely obvious during times of fatigue; the color may also be perceived as blurry or faded. Consecutive shade matching, for example treating many patients who require shade matching during a single working day, could be one of the main causes of fatigue (80).

C. Emotions

Shade could be understood and analyzed as a language. For example, in many places in the world, the yellow color represents enjoyment, while the red color exemplifies anger, and the blue color is related to sadness. It is commonly believed that feeling can have an impact on papillary diameter, causing constriction or dilation and this has a direct effect on the color judgment (29).

D. Medications

The abuse of caffeine, alcohol, and drugs will influence not just judgment but also a perception of color (29). Furthermore, many prescription and non-prescription medications are related to visual adverse effects. Medications can affect any part of the optical system from the visual cortex to the retina. Like all medications' side effects, they differ from one to another (80). For example, long use of oral contraceptives will cause a reduction in color perception of yellows and blues (29).

E. Binocular difference

The binocular difference is defining as the difference in perception between the left and right eyes (29). Two items are placed next to each other under homogeneous lighting to control the binocular color difference. They may look different, e.g., the one on the right may seem slightly lighter than the one on the left. If the item on the right still looks lighter when the position changes, the binocular color difference may exist (80). Placing shade tabs under or above (not next to) the tooth that will be matched, will reduce the error caused by the binocular difference (29).

F. Gender

Color deficiency is more common in males (8%) than females (0.5%) (23). Although it is thought that males and females differ in their ability to distinguish shades and traditionally females are superior to males in shade matching, most studies have given little or no attention to the gender of the observer in color matching (87). Some authors concluded that females significantly improved outcomes compared to males, whereas others found that gender had no effect on shade matching skills (88). Thus, the gender effect on shade matching abilities is a controversial issue among academics (89).

G. Training and experience of the person

Color training and education have long been used in many fields of art and science, including dentistry. In dentistry, this type of education has to provide information about the color notation systems, basics of color, shade matching methods, proper shade matching guides and conditions, and communication with lab technicians (88, 90). The argument of whether the accuracy of shade matching is a hereditary or acquired skill is still unresolved. Many studies disagree with the idea that experience is important in shade matching (91). While on the other hand other studies stating that experience positively affects shade matching (88).

H. Color vision problem/Colorblindness

Color vision deficiency (CVD), also known as color blindness, is the decreased ability or inability to perceive color variances under normal lighting conditions (92). The most complicated and misunderstood parts of color perception are the detection of radiant energy in the human eye by the receptors and the interpretation of this visual stimulation by the human brain. Color vision deficiency is caused by the absence or lack of one or more types of the three photosensitive pigments able to recognize blue, red, and green (29). Color vision deficiencies can be classified as congenital or acquired. People with acquired type reflects a problem which occurred anywhere along with the visual system from the photoreceptors to the cortex due to diseases, drugs, and chemicals (93, 94). Color vision deficiency is commonly congenital and is fairly prevalent. Red/green deficiency is the most common and could differ from very mild, when color discrimination does not differ significantly from that of color normal and is virtually unnoticeable in daily life, to very severe, when visual performance is significantly damaged. Congenital color vision deficiency does not affect other features of vision such as contrast sensitivity or acuity. The variety and severity of deficiency that an individual inherits remain stable throughout life, even though chromatic sensitivity could decline with age gradually (95).

There are different types of color vision confusion:

1. Complete lack of hue sensitivity which is called "Achromatism".
2. Sensitivity to only two primary hues usually either green or red is not perceived that called "Dichromatism".
3. Sensitivity to all three hues with abnormality or deficiency of one of them in the retinal cones which is "Trichromatism".

Clinicians have to get tested for color perception. If a deficiency is detected, clinicians have to seek help with shade matching (32). Ishihara Color Vision Test is an important tool for identifying Color Vision Deficiency (CVD) (96).

2.7. Color Deficiency Test (Ishihara's Test)

The Ishihara test is a color perception test for congenital and acquired color vision defects (97). In 1906, the Ishihara test was first published and was the first Picture (PIC) test commercially produced. It is the most widely used color vision test and has been reprinted in several editions over time (98). The test contains a number of colored plates named "Ishihara plates", every plate has a circle of dots looking randomized in size and color (Figure 18). Within the pattern, the dots form a shape or number which is clearly visible to those with normal color vision, and difficult to see, or invisible, to those with a color vision deficiency. Specific plates are purposely designed to display numbers only to those with a red-green color vision defect and invisible to normal color vision. The complete test contains thirty-eight plates, but the presence of a severe deficiency is usually apparent after only a few plates (99). There is also a version for children which employs letters rather than numbers (98).

The various studies of the effectiveness of Ishihara's test may be summarized as it is still the 'gold standard' for the quick detection of inherited red-green defects. The individual plates of Ishihara's test have specificities and sensitivities typically between

0.85 and 0.95 and the test as a whole performs very close to 1 in both specificity and sensitivity (98). The Ishihara test plates have been suggested to be loaded onto handheld computers to guarantee quick and reliable testing (100). The computer-based color defect test software on the LCD screen can be used for screening of color vision defects with nearly similar specificity and sensitivity to the Ishihara test (97).

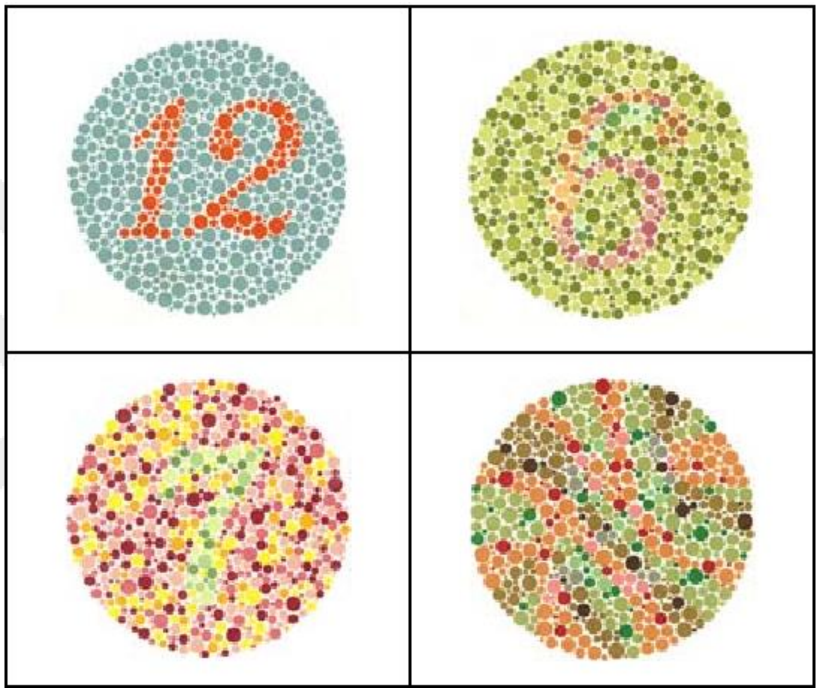

Figure 18. "Ishihara test" tests for color blindness (101).

3. MATERIALS AND METHODS

This study was carried out in Zonguldak Bülent Ecevit University, Faculty of Dentistry. Ethical approval of the study received from Zonguldak Bülent Ecevit University Human Research Ethics Committee, at the meeting dated 19.12.2018, the register protocol number was 2018-245-19/12.

3.1. Selecting Volunteers and Teeth Measured

Three maxillary central incisor teeth (number 8 according to Universal System and number 11 according to FDI system) (102), that each one was in separate volunteers and have different tooth colors, and also photos of the relevant teeth were included in the study. The participation of three volunteers was based on voluntariness in the study.

The volunteer selection criteria were the following:

A. Non-smoker, non-alcoholic with good oral hygiene.
B. The tooth vital, non-colored, without any caries, restorations, crowns, or veneers.
C. Absence of any change in the teeth colors for any reasons (caries, water, medicines, job, genetic…).
D. Absence of enamel or dentinal defects for any reason.
E. No previous whitening procedures, nor the use of whitening toothpaste.
F. No orthodontic appliance presence at the time of the shade determination.

A standardized verbal questionnaire, clinical examination, and spectrophotometer color test was performed in order to select the appropriate volunteers with the desired tooth color.

3.1.1. Verbal questionnaire

Each volunteer had to answer a verbal standardized questionnaire. The questionnaire includes the following questions:

A. Do you smoke cigarettes or drink alcoholic drinks?
B. Do you brush your teeth and visit the dentist regularly?
C. Has any dental treatment been applied to the chosen tooth?
D. Is there any discoloration or dental defect in the upper anterior tooth?

E. Have you undergone any whitening procedures or used whitening tooth-paste?
F. Do you have any orthodontic appliance either for treatment or fixation?

3.1.2. Clinical examination

The clinical examination was aimed to make sure that the selection criteria is matched with the volunteers. Another aim was to primarily determine the tooth color by using VITA classical shade guide.

3.1 3. Shade selection using a spectrophotometer

After the first and second stages, three volunteers with three different tooth colors were selected by using a spectrophotometer (VITA Easy shade, Vita Zahnfabrik, Bad Säckingen, Germany). The spectrophotometer device results were considered as reference. The results were displayed in accordance with Vitapan Classical A1-D4 the shade guide of choice for comparison. Since no device gives an accuracy of 100%, to decide the real color of the tested teeth, the measurement of the teeth was repeated 10 times with intervals in different places (Figure 19). The most frequent results were considered as the real color. Before each measurement, the spectrophotometer was calibrated according to the manufacturer's recommendations. In this way, different tooth shades (B1, A1, and B2) belonging to three different volunteers were selected.

Figure 19. Using VITA Easy shade Spectrophotometer ten times for each volunteer.

3.2. Selection of Examiners

The present study included eighty-seven examiners ranging in age from 19 to 40 years and the examiners were divided into three groups. There were at least twenty examiners in each group, half of them male and half female. In the study, attention was paid to select the examiners who did not have any color deficiency or a disease or injuries in the eyes at the time of examination. The preclinical students had never been participated in a similar study or took a course for shade matching before, while the clinical students had previous experience with shade matching. The groups were as the following:

A. **Undergraduate Preclinical Dental Students (UPDS).** This group consisted of thirty-one second-year dental students who didn't have any clinical experience. Fifteen of them were males and sixteen were females whose ages were ranging between nineteen and twenty-four years old.

B. **Undergraduate Clinical Dental Students (UCDS).** A total of thirty-four students from fourth and fifth-year dental education, who had some clinical experience, were involved in the second group. In addition, sixteen of them were males and eighteen were females, while their ages were between twenty-one and twenty-eight years old.

C. **Postgraduate Dental Students (PDS).** The third group included twenty-two postgraduate students from the department of prosthodontics. Eleven examiners of this group were males and eleven were females, aged between twenty-four and forty.

3.2.1. Verbal standardized questionnaire

Participation in the study was completely voluntary. Each examiner has gone through a verbal standardized questionnaire. The questionnaire includes the following questions:

A. I am working on research and I need your help. Participation in the study is completely voluntary, would you like to take part in the study?

B. Are you a preclinical student? If yes, have you ever been involved in a similar study or taken a course for shade matching before?

C. Are you a clinical student? If yes, do you have previous experience with shade matching with real patients?

D. Do you have any disease, symptoms, or injuries in your eyes?

E. Do you have any color vision deficiencies?

F. Would you mind if you go through Ishihara's test to examine color vision deficiency?

For the first and sixth questions, if the answer was no, and also for the fourth and fifth questions if their answer was yes the person was not included in the study.

3.2.2. Test of color vision deficiency

Ishihara's test may be summarized as the 'gold standard' for the quick identification of inherited red-green defect (98). Marey et al. (2015) founded that, the computer-based color defect test on LCD screen could be used for testing color vision deficiency with nearly the same specificity and sensitivity as the Ishihara test (97). Each examiner was screened for color vision defect using the "pseudoisochromatic color test". Ishihara color blindness test (38 plate version (Figure 20)) was used to assess red-green color defect among the examiners participating in the study. Examiners who presented color vision deficiency were excluded from the study. In the present study, only two of the eighty-nine examiners tested had a red-green color deficiency and were excluded from the study.

Figure 20. Ishihara color blindness test (38 plate version).

3.3. Shade Matching Methods

In the present study, shade matchings were applied by eighty-seven examiners. Each examiner filled out the Google form and provided the information of their gender, age, and profession before starting the shade matching. Each examiner was asked to match the shade of the upper right central incisor (number 11) at the middle third. Each tooth was matched in two different ways; Conventional Visual (Direct) Shade Matching Method (DSM) and Visual Shade Matching on Image (Indirect) Method (ISM).

3.3.1. Conventional Visual (Direct) Shade Matching (DSM) Method

The conventional visual shade matching method was carried out in an experiment room with a light, which is the combination of daylight and fluorescent or incandescent light as shown in (Figure 21) (80).

Figure 21. Experiment room.

Before shade matching, the existing colorations on the teeth were removed with a paste application. In order to eliminate dehydration effects on the tooth surface, volunteers were asked to close their mouths and rewet their teeth. Shade matching was done in a controlled experimental environment of natural daylight and incandescent light at certain times of the day (sunny days between 10:00 and 15:00). Three volunteers were placed in an upright position, every examiner determined the shade of the chosen tooth (in the mouth of the volunteers), and choose the correspondent shade from the shade guide that contains 16 tabs arranged in four groups according to hue (Figure 22) (VITA Classical shade guide, Vita Zahnfabrik, Bad. Sackingen, Germany) (23, 34).

Figure 22. Vita Classical shade guide (Vita Zahnfabrik, Bad. Sackingen, Germany).

The selected shade was entered in the Google form in the space that was specified for it. Google form was created in order to collect personal information of the examiners and all their responses about the study and it was used in the later analysis (Figure 23).

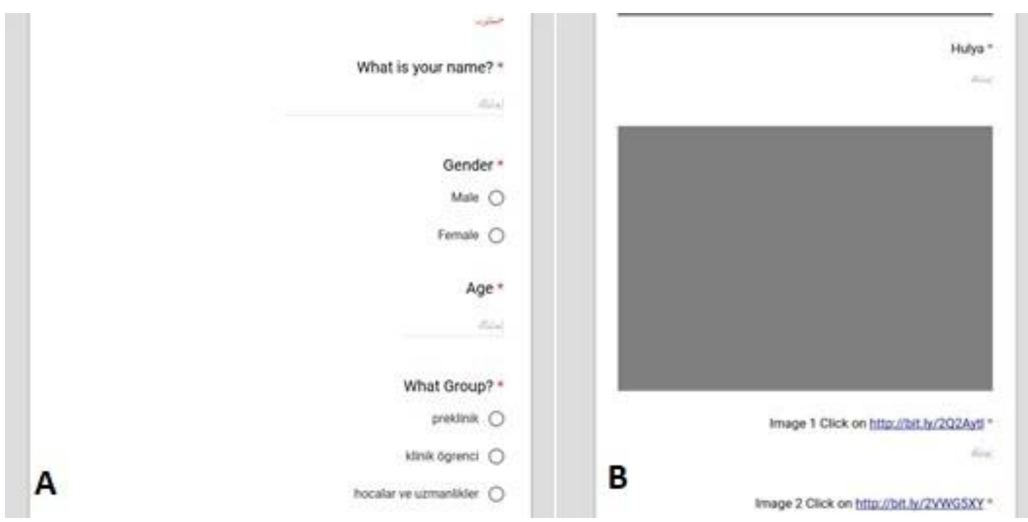

Figure 23. Google form A) personal information B) the essential information for the survey.

Between each volunteer, the examiners were asked to take a break and to look at a blank gray picture to prevent "eye fatigue". The shade guide has been disinfected again before each match (Figure 24).

Figure 24. Conventional visual shade matching (DSM) Method.

3.3.2. Visual Shade Matching on Image (Indirect) Method (ISM)

In the current study, three photos have been taken from three different volunteers by the digital camera that was uploaded to Google drive. The digital camera (Canon EOS 7D Mark II, Tokyo, Japan) was used to capture photos of the desired teeth and the shade guide (Figure 25-A). The aim of capturing photos was to implement the indirect method of visual shade matching. The digital camera's specifications were 20.2 Megapixel CMOS sensor with Dual DIGIC 6 Image Processors for high-quality imagery. It shoots up to 10 frames per second. The range of ISO is from 100–16000. The camera has a 65-point all cross-type autofocus system (103).

Because dental photography is mostly associated with the close-up photography method, that's why macro lenses were required. For dental purposes, a macro lens with a focal length of 100 mm was found to be most useful (104). For this reason, in the present study macro lens (Canon 100 mm macro lens, Tokyo, Japan) was chosen for shooting the photos (Figure 25-B). The lens has high-quality optics, includes hybrid image stabilization system technology that effectively compensates for both angular and shift camera shake during close-up shooting (105).

Figure 25. A) Camera Canon EOS 7D Mark II, B) Canon 100 mm macro lens.

In order to create the best environment for photo shooting for the ISM method, the photo was taken in a completely dark room with the support of a twin flashlight (Macro Twin Lite Flash MT-24EX, Tokyo, Japan) with a capacity of 5200 K (Figure 26). This way, it was possible to get the ideal lighting condition by eliminating any other sources of light that might affect the shooting environment. The two flash heads can be controlled separately in order to achieve the best results (106).

Figure 26. Twin Flash.

The cheek retractors (DynaFlex, Missouri, United States) were used during photo shooting in order to retract the lips and cheeks to have the best view of the teeth (Figure 27).

Figure 27. Cheek Retractors.

In dental photography, it is important to have a sufficient depth of field that forces the photographer to have a small aperture opening and to ensure that the shutter speed is fast enough to make the photograph as sharp as possible, due to the movement of the patient and camera (69). In this regard, in our study, the shutter was set at 50 frames per second and the lens was opened at the aperture F10. The white balance was set to 5200 K, and the ISO value was set to 1000 (Figure 28).

Figure 28. The photo has taken in the darkroom using the twin flashlights and white balance (5200 K).

In the present study, the editing and interference with pictures were limited to just measure the value of L*, a*, and b*. In order to apply the least amount of editing, the following steps were applied:

1. Taking the first photo of a white paper in the same environment in accordance with the rules of the study.
2. Inserting the first photo in Photoshop.
3. Measuring the correct white balance, using the raw filter panel and eyedropper tool.
4. Retaking the photo after editing the white balance in the camera.
5. Inserting the second photo to Photoshop and maintaining the correct white balance.
6. After checking the white balance in Photoshop for the second time, repeating the procedure until getting the desired result.

After repeating the process several times, the correct white balance in the darkroom with the twin flashlights and reflected surfaces was detected as 5200K. At this value, there was no need to edit the photos. The digital photos have been imported to Adobe Photoshop CS6 (Adobe Inc., San Jose, California, United States) for preparation of the digital color guide and digital color measurement. SD card (SanDisk, Milpitas, California, United States) was used to transfer the photos to the computer environment (Figure 29).

Figure 29. The memory card has been used to transfer the photo to the laptop.

In the current study, the laptop (Lenovo, Hong Kong, China) was used to display the volunteers' photos for each examiner to select the best match with the photos of the shade guide (Figure 30). The reason for using the laptop was to have the best colors with good resolution and to avoid changes in printed photos or projector (107).

Figure 30. Lenovo Laptop G510 Core İ7 was used to display the volunteers' photos.

Adobe Photoshop CS6 (Adobe Inc., San Jose, California, United States) was used to identify the L*a*b* values and compare them with the L*a*b* values given by the spectrophotometer for the same tooth at the same area to check whether there was a match in the result or not (Figure 31).

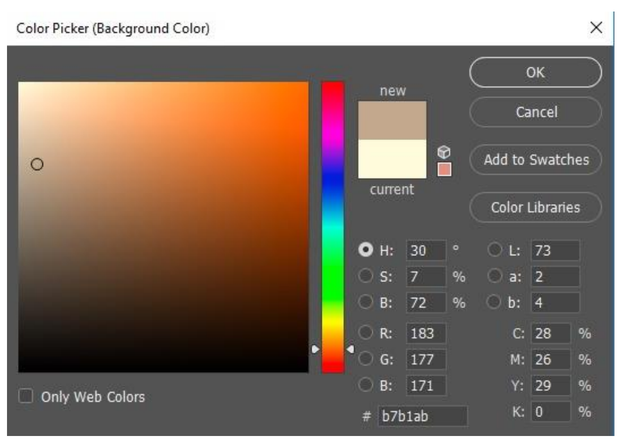

Figure 31. Identifying the L*a*b* values using Photoshop.

In order to make the photographs compatible with the ISM method, a removable shade guide image was added. The photograph was cropped by using Photoshop tools to show only the patient's teeth (Figure 32).

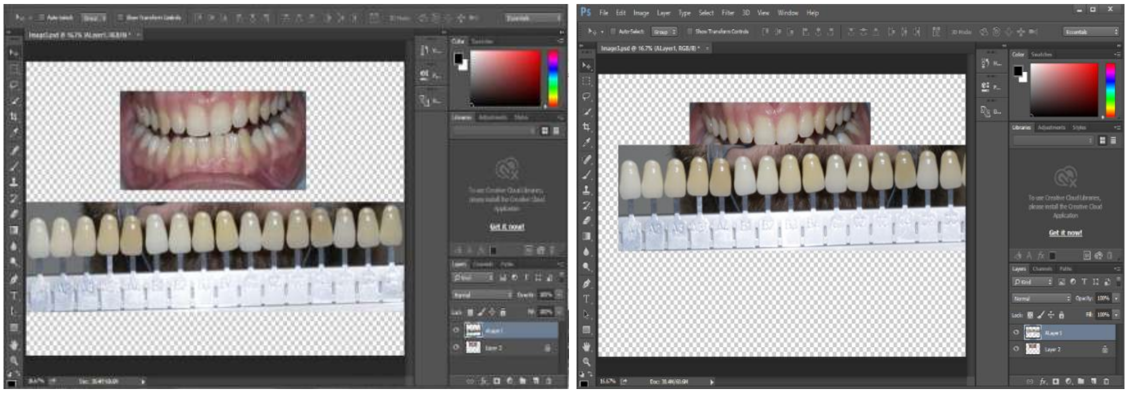

Figure 32. Photos adjusted by Photoshop.

For standardization, digital photos of the shade guide and volunteers' teeth were taken on the same day and under the same conditions. The images have converted to an Adobe image file (PSD format file) by Photoshop program and the followings were applied:

1. Cropping and splitting procedures were applied to the taken image which included the volunteers' teeth and the shade guide at the same photo in order to have the same light condition. Photos were cropped and split into two parts. The first part was the volunteers' teeth, while the second part was the shade guide (Figure 33 (A-B), Figure 34 (A-B)).

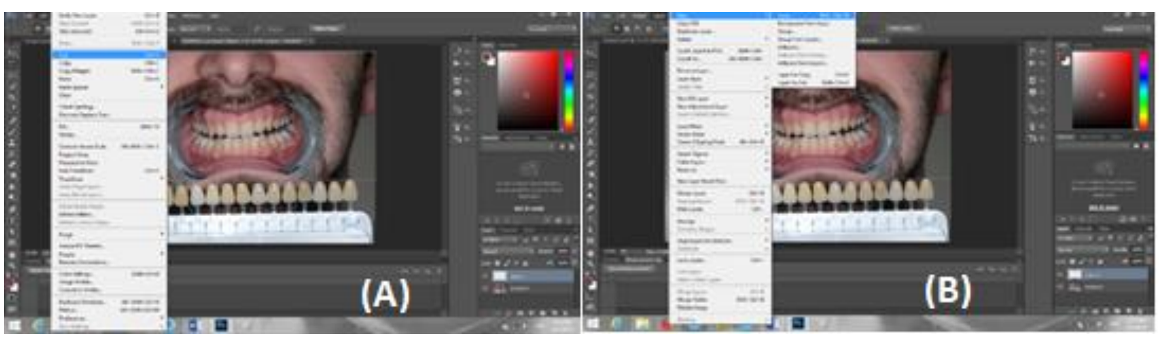

Figure 33. A) cutting the shade guide part, B) creating a new layer.

Figure 34. A) The first part is the patient's teeth, B) The shade guide part.

2. Unnecessary parts from the photo were removed and the volunteers' photo and digital shade guide part were pasted into the new layer (Figure 35).

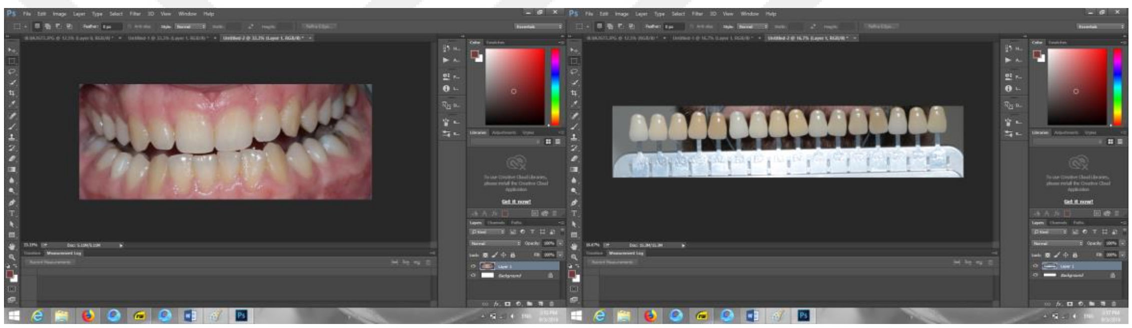

Figure 35. Removing unnecessary parts from the photo.

3. The last step was allowing the digital shade-guide image to move in front of the patient teeth's image (Figure 36).

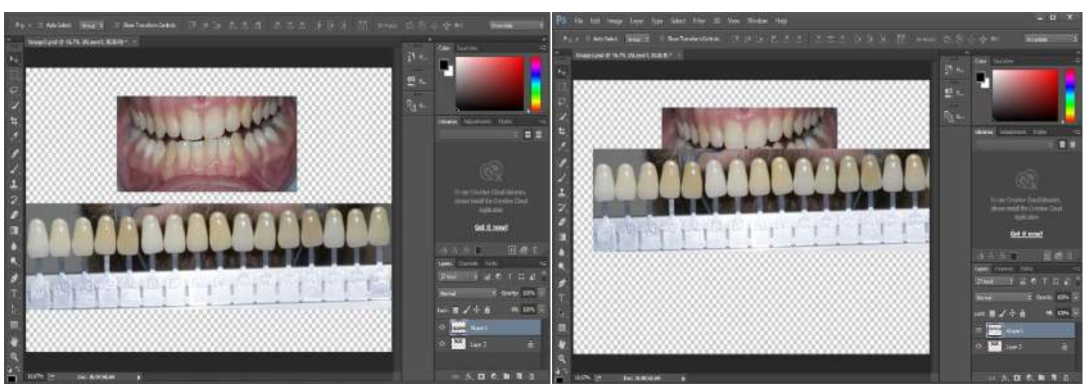

Figure 36. The photo after adjusted by Photoshop and made it removable.

After the transfer and editing procedures of the digital images, every examiner examined the colors of teeth which were displayed on the screen of the laptop by comparing the image of teeth and the shade guide (Figure 37).

Figure 37. Shade matching on the photo using Photoshop.

The matching results were recorded in Google-form at the specified space for each volunteer (Figure 38 (A-B)). Once more, examiners were reminded to take a short break and focus on the blank gray picture to rest his/her eyes before looking to the next photo. After filling out all the required spaces, each examiner clicked on the submit button at the end of the survey page to save the matching in the driver. At the end of the shade matching process for all the examiners, the matching has been saved as an Excel sheet and sent to the statistical analysis.

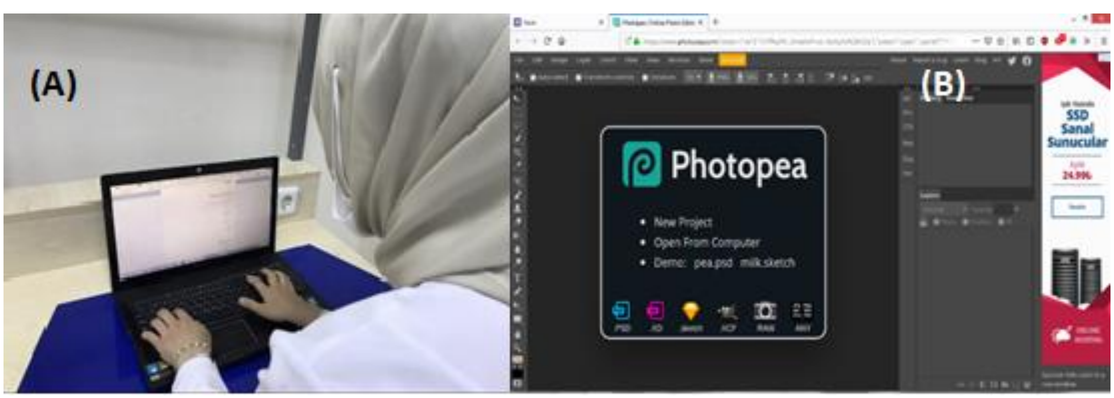

Figure 38. A) Images uploaded to Google drive and added as links, B) photos opened using online Photoshop.

3.4. Statistical Analysis

Statistical analysis of the study was done using SPSS 13.0 (SPSS Inc., Chicago, IL, USA). Kruskal-Wallis test is a non-parametric method which was used for comparing the result between the examiner's groups (UPDS, UCDS, and PDS) with different sample sizes and if there was a significant difference between the results, Mann Whitney U test was used to compare the result between every two groups (for example; UPDS, UCDS, and UCDS, PDS). The Chi-Square Test is a parametric method that was used to determine if there is a statistically significant difference between the results frequencies.

Turkey's HSD test was used to assess the differences between the groups and the result was evaluated at a 95% confidence interval and $p < .05$ significance level.

4. RESULTS

In the current study, 522 shade matching observations were performed on 3 different volunteers who have three different tooth colors (B1 color, A1 color, and B2 color). The study was carried out by 87 examiners in ages ranging between 19 and 40. Examiners were divided into 3 groups according to clinical experience; Undergraduate Preclinical Dental Students (UPDS), Undergraduate Clinical Dental Students (UCDS), and Postgraduate Dental Students from the Department of Prosthodontics (PDS). Shade matching observations were divided into two subgroups according to the method; direct shade matching (DSM) and indirect shade matching (ISM) groups.

4.1. Descriptive Statistics of Examiner-Groups and Samples

4.1.1. Examiner groups distribution according to clinical experience

The number and percentage of examiner groups according to the clinical experience are shown in (Table 3). The UPDS Group consisted of 31 examiners, the UCDS Group 34, and the PDS Group 22 examiners, respectively.

Table 3. Examiner number and percentage according to clinical experience.

Examiner Group	Number	Percent (%)
UPDS Group	31	35.6
UCDS Group	34	39.1
PDS Group	22	25.3
Total	87	100

4.1.2. Examiner groups distribution according to gender

Each examiner group included male and female examiners. The UPDS Group consisted of 31 examiners 15 male, and 16 female. The UCDS Group has included 34 examiners 16 male, and 18 female. Finally, the PDS Group consisted of 22 examiners, half of whom were female.

Table 4. Examiner groups distribution according to gender.

Examiner Group	Number			Percent (%)		
	Male	Female	Total	Male	Female	Total
UPDS Group	15	16	31	48.4	51.6	100
UCDS Group	16	18	34	47.1	52.9	100
PDS Group	11	11	22	50.0	50.0	100
All Subjects	42	45	87	48.3	51.7	100

4.1.3. Shade matching assessment numbers according to examiners groups

31 examiners in the UPDS group, 34 examiners in the UCDS group, and 22 examiners in the PDS group made a total of 186, 204, and 132 assessments, respectively. The percentages of assessments were shown in (Table 5).

4.1.4. Shade matching assessment numbers according to gender and examiner groups

Shade matching assessment numbers and percentages of the examiner groups according to gender are shown in (Table 5). The number and percentage of the assessments for female examiners were higher than that of the male examiners.

Table 5. Shade matching assessment numbers and percentages of examiner groups according to gender.

Examiner Group	Number			Percent (%)		
	Male	Female	Total	Male	Female	Total
UPDS Group	90	96	186	48.4	51.6	100
UCDS Group	96	108	204	47.1	52.9	100
PDS Group	66	66	132	50.0	50.0	100
Total Assessments	252	270	522	48.3	51.7	100

4.1.5. Assessment number and percentage distributions of the examiner groups according to the shade matching method

According to the used shade matching method (DSM or ISM), the number and percentage distributions of the examiner groups are shown in (Table 6).

Table 6. Assessment distributions of examiner groups according to the shade matching method.

Examiner Group	Number			Percent (%)		
	DSM	ISM	Total	DSM	ISM	Total
UPDS Group	93	93	186	50.0	50.0	100
UCDS Group	102	102	204	50.0	50.0	100
PDS Group	66	66	132	50.0	50.0	100
Total Assessment	261	261	522	50.0	50.0	100

4.1.6. Sample distribution according to studied shade and examiner groups

Each of the 3 tooth shades was assessed by each examiner. The number of tooth shade assessments and the percentages of sample distributions are shown in (Table 7).

Table 7. Sample distribution according to studied shade and examiner groups.

Examiner Group	Number				Percent (%)			
	B1	A1	B2	Total	B1	A1	B2	Total
UPDS Group	62	62	62	186	33.3	33.3	33.3	100
UCDS Group	68	68	68	204	33.3	33.3	33.3	100
PDS Group	44	44	44	132	33.3	33.3	33.3	100
Total Assessments	174	174	174	522	33.3	33.3	33.3	100

4.2. Shade Matching Deviation Score (SMDS) Assessments

The assigned values of 16 ordinal categories of the color guide scale in order from less value to the highest is listed as follows:

Table 8. Assigned values of shades guide (108).

Study Color	Assigned value
C4	1
A4	2
C3	3
B4	4
A3.5	5
B3	6
D3	7
A3	8
D4	9
C2	10
C1	11
A2	12
D2	13
B2	14
A1	15
B1	16

Shade Matching Deviation Score (SMDS) calculation for each shade matching assessment was made by the following formula:

SMDS value = Assigned value of examined tooth shade – The assigned value of the real shade

4.3. Statistical Analysis of Assessments for each Factor

In the current study, the effects of each factor; the examiner groups, gender, and shade matching method on the SMDS values and the success frequencies of shade matching results were examined.

4.3.1. Shade matching results according to examiner group

The numbers and the percentages of determined shades according to the examiner groups are shown in (Table 9).

Table 9. Determined shades according to the examiner groups.

Determined Shade	Number			Percent %		
	UPDS Group	UCDS Group	PDS Group	UPDS Group	UCDS Group	PDS Group
C3	1	2	0	0.5	1.0	0
B4	2	0	0	1.1	0	0
A3.5	0	2	0	0	1.0	0
B3	12	5	4	6.5	2.5	3.0
D3	4	0	1	2.2	0	0.8
A3	9	13	5	4.8	6.4	3.8
D4	0	2	0	0	1.0	0
C2	15	19	6	8.1	9.3	4.5
C1	24	36	7	12.9	17.6	5.3
A2	28	44	37	15.1	21.6	28.0
D2	22	11	2	11.8	5.4	1.5
B2	41	38	25	22.0	18.6	18.9
A1	15	15	30	8.1	7.4	22.7
B1	13	17	15	7.0	8.3	11.4
Total	186	204	132	100	100	100

4.3.1.1. The effect of clinical experience on SMDS values

Comparing the SMDS values of examiner groups, the highest SMDS value was observed in the UPDS group, the lowest was obtained in the PDS group. According to the Kruskal-Wallis variance analysis results statistically significant difference was found between the SMDS values of examiner groups ($P < .05$) (Table 10). As a result of the pair-wise comparisons made with the Mann-Whitney U test, a significant difference was observed between the PDS group and the other two groups ($P < .05$) but there was no significant difference between the UPDS and UCDS groups ($P > .05$) (Table 11).

Table 10. Kruskal-Wallis test results for comparison of SMDS value.

Examiner Group	Number	Mean	Standard Deviation	Minimum	Maximum	Chi-Square	P
UPDS Group	186	3.14	2.50	0	13	22.459	<.01
UCDS Group	204	3.07	2.23	0	11		
PDS Group	132	2.06	2.03	0	8		

* P <.05 indicates statistically significant differences.

Table 11. Mann-Whitney U test pairwise comparison of examiner groups SMDS values.

Examiner Group Comparison (I-J)	Mean Difference (I – J)	U value	P
UPDS -UCDS	0.07	18780.5	.861
UPDS-PDS	1.08	9044	<.01
UCDS-PDS	1.01	9696.5	<.01

* P <.05 indicates statistically significant differences.

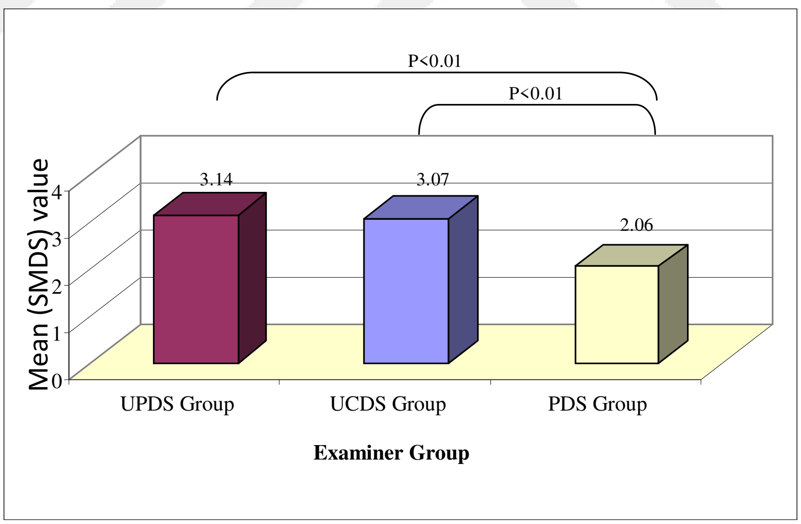

Figure 39. The mean SMDS values of examiner groups.

4.3.1.2. The effect of clinical experience on shade matching success

Comparing the failure and success frequencies and the percentages of examiner groups the highest success value was observed in the PDS group, the lowest value was obtained in the UPDS group (Figure 40). According to the Chi-Square test results, a statistically significant difference was found between the examiner groups (P <.05) (Table 12). As a result of the pair-wise comparisons using the Chi-Square test, a significant difference was observed between the PDS group and the other two groups (P<.05) but it was found that no significant difference between the UPDS and UCDS groups (P> .05) (Table13).

Table 12. Chi-Square test results for comparison of fail and success frequencies and percentages.

Examiner Group	Number			Percent %			Chi-Square	P
	Fail	Success	Total	Fail	Success	Total		
UPDS Group	165	21	186	88.7	11.3	100		
UCDS Group	178	26	204	87.3	12.7	100	17.241	<.01
PDS Group	96	36	132	72.7	27.3	100		

* P <.05 indicates statistically significant differences.

Table 13. Chi-Square test pairwise comparisons of examiner groups' shade matching success.

Examiner Group Comparison (I-J)	Mean Difference (I – J)	P
UPDS -UCDS	0.194	.659
UPDS-PDS	13.405	<.01
UCDS-PDS	11.241	<.01

* P <.05 indicates statistically significant differences.

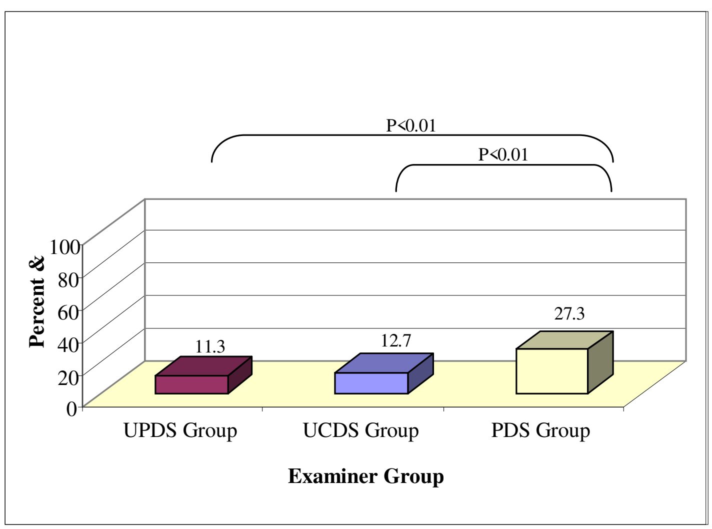

Figure 40. The shade matching success percentages according to the examiner groups.

4.3.2. Shade matching results according to gender

The results were analyzed according to the effect of gender as shown in (Table 14).

Table 14. Determined shades according to gender.

Determined Shade	Number		Percent %	
	Male	Female	Male	Female
C3	1	2	0.4	0.7
B4	1	1	0.4	0.4
A3.5	0	2	0	0.7
B3	10	11	4.0	4.1
D3	4	1	1.6	0.4
A3	12	15	4.8	5.6
D4	1	1	0.4	0.4
C2	22	18	8.7	6.7
C1	34	33	13.5	12.2
A2	49	60	19.4	22.2
D2	13	22	5.2	8.1
B2	51	53	20.2	19.6
A1	33	27	13.1	10.0
B1	21	24	8.3	8.9
Total	252	270	100	100

4.3.2.1. The effect of gender on SMDS values

Comparing the SMDS values according to gender the highest SMDS value was observed in the females' group (Figure 41). As a result of the pair-wise comparisons made with the Mann-Whitney U test, there was no significant difference between the gender groups (P>.05) (Table 15).

Table 15. Mann-Whitney U test results comparisons of SMDS values between males and females group.

Gender	Number	Mean	Std. Deviation	Minimum	Maximum	Mean Differenc	U value	P
Male	252	2.78	2.29	0	11	-0.12	33213.5	0.635
Female	270	2.90	2.35	0	13			

* P >.05 indicates no statistically significant differences.

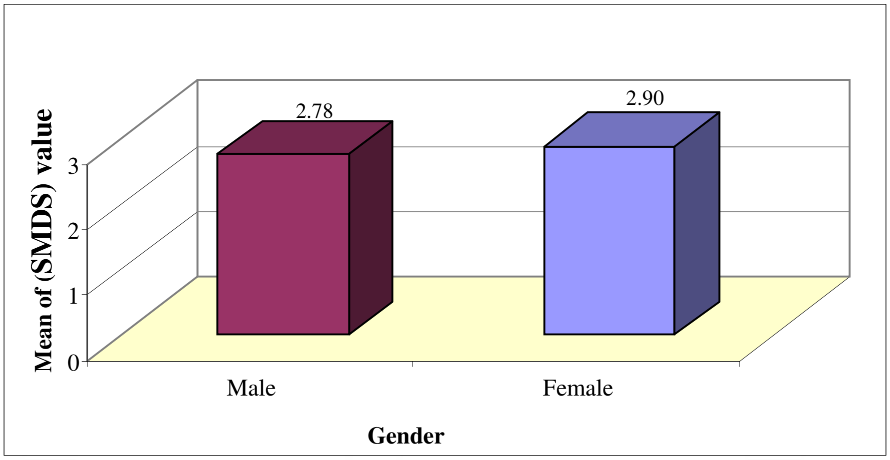

Figure 41. The SMDS values according to gender.

4.3.2.2. The effect of gender on shade matching success

Comparing the failure and success frequencies and the percentages of examiner groups the highest success value was observed in the males' group (Figure 42). As a result of the pair-wise comparisons using the Chi-Square test, no statistically significant difference was observed between the groups (Table 16) (P>.05)

Table 16. Chi-Square test pairwise comparisons of shade matching success between males and females groups.

Gender	Number			Percent %			Chi-Square	P
	Fail	Success	Total	Fail	Success	Total		
Male	204	48	252	81.0	19.0	100	3.609	0.057
Female	235	35	270	87.0	13.0	100		

* P >.05 indicates no statistically significant differences.

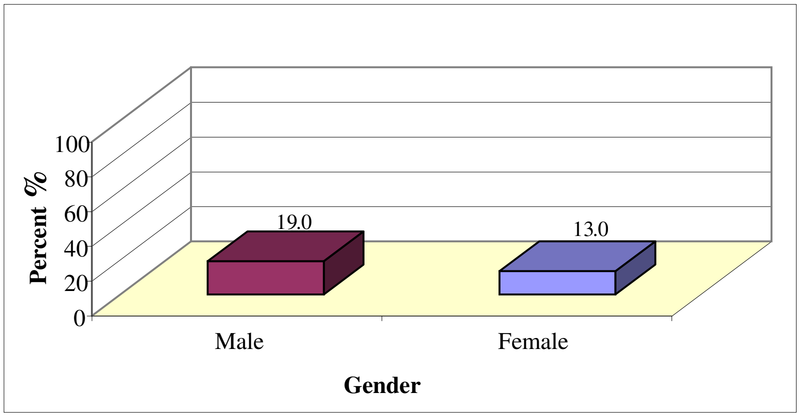

Figure 42. The shade matching success percentage according to gender.

4.3.3. Shade matching results according to shade matching method

The shade matching results were analyzed according to the shade matching method as shown in (Table 17).

Table 17. Shade matching results according to the shade matching method.

Determined Shade	Number		Percent %	
	DSM	ISM	DSM	ISM
C3	3	0	1.1	0
B4	2	0	0.8	0
A3.5	2	0	0.8	0
B3	15	6	5.7	2.3
D3	5	0	1.9	0
A3	19	8	7.3	3.1
D4	2	0	0.8	0
C2	19	21	7.3	8.0
C1	31	36	11.9	13.8
A2	46	63	17.6	24.1
D2	9	26	3.4	10.0
B2	53	51	20.3	19.5
A1	27	33	10.3	12.6
B1	28	17	10.7	6.5
Total	261	261	100	100

4.3.3.1. The effect of shade matching method on SMDS values

Comparing the SMDS values according to the shade matching methods the highest SMDS value was observed in the DSM method (Figure 43). As a result of the Mann-Whitney U test, a statistically significant difference was found between groups ($p < 0.05$) (Table 18).

Table 18. Mann-Whitney U test result comparisons of SMDS values shade matching methods.

Shade Matching Method	Number	Mean	Std. Deviation	Minimum	Maximum	Mean Difference	U value	P
DSM	261	3.14	2.63	0	13	0.61	30639.5	0.044
ISM	261	2.54	1.92	0	8			

* P <.05 indicates statistically significant differences.

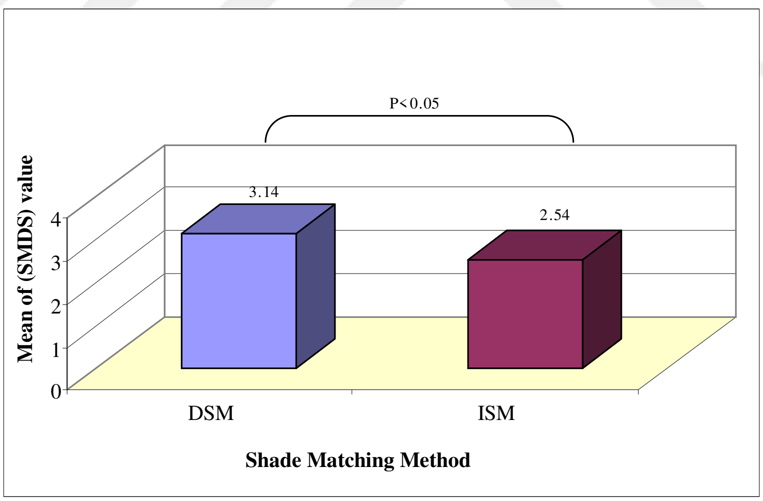

Figure 43. The mean SMDS values according to the shade matching method.

4.3.3.2. The effect of shade matching method on shade matching success frequencies

Comparing the failure and success frequencies and the percentages of the shade matching method, the highest success value was observed in the ISM method (Figure 44). According to the Chi-Square test results, there were no statistically significant differences between the two methods ($p > 0.05$) (Table 19).

Table 19. Chi-Square test results for comparison of shade matching success between shade matching methods.

Shade Matching Method	Number			Percent %			Chi-Square	P
	Fail	Success	Total	Fail	Success	Total		
DSM	222	39	261	85.1	14.9	100	0.358	0.550
ISM	217	44	261	83.1	16.9	100		

* P >.05 indicates no statistically significant differences.

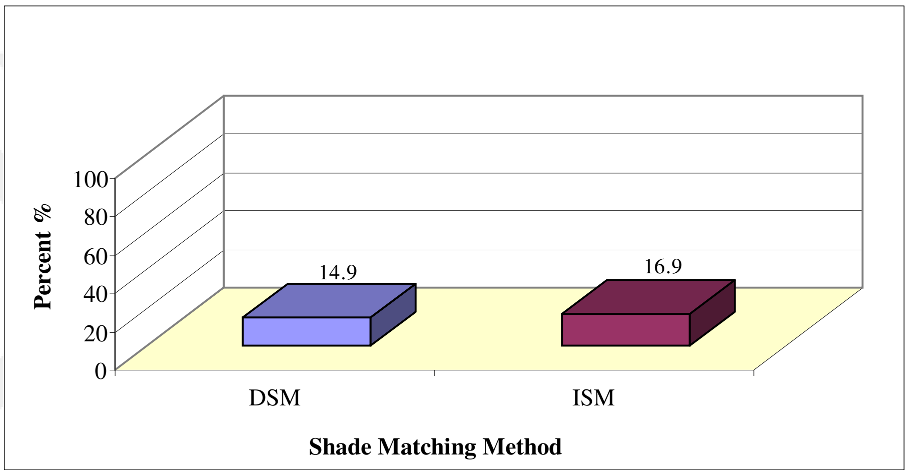

Figure 44. The shade matching success percentages according to the shade matching method.

4.4. Statistical Analysis of Assessments for more than one Factors

In this part, the analysis was performed to compare the effect of each factor on other factors, as follows:

4.4.1. Shade matching results according to examiner groups and gender

The results were analyzed to evaluate the effect of gender and clinical experience on shade matching accuracy, regardless of the used shade matching method.

Table 20. Shade matching results according to examiner groups and gender.

Gender	Determined Shade	Number			Percent %		
		UPDS Group	UCDS Group	PDS Group	UPDS Group	UCDS Group	PDS Group
Male	C3	0	1	0	0	1.0	0
	B4	1	0	0	1.1	0	0
	B3	6	2	2	6.7	2.1	3.0
	D3	4	0	0	4.4	0	0
	A3	4	6	2	4.4	6.3	3.0
	D4	0	1	0	0	1.0	0
	C2	7	11	4	7.8	11.5	6.1
	C1	12	16	6	13.3	16.7	9.1
	A2	14	18	17	15.6	18.8	25.8
	D2	8	4	1	8.9	4.2	1.5
	B2	20	18	13	22.2	18.8	19.7
	A1	7	11	15	7.8	11.5	22.7
	B1	7	8	6	7.8	8.3	9.1
	Total	90	96	66	100	100	100
Female	C3	1	1	0	1.0	0.9	0
	B4	1	0	0	1.0	0	0
	A3.5	0	2	0	0	1.9	0
	B3	6	3	2	6.3	2.8	3.0
	D3	0	0	1	0	0	1.5
	A3	5	7	3	5.2	6.5	4.5
	D4	0	1	0	0	0.9	0
	C2	8	8	2	8.3	7.4	3.0
	C1	12	20	1	12.5	18.5	1.5
	A2	14	26	20	14.6	24.1	30.3
	D2	14	7	1	14.6	6.5	1.5
	B2	21	20	12	21.9	18.5	18.2
	A1	8	4	15	8.3	3.7	22.7
	B1	6	9	9	6.3	8.3	13.6
	Total	96	108	66	100	100	100

4.4.1.1. The effect of gender on SMDS values according to the examiner groups

Comparing the SMDS values according to the gender and examiner groups the highest SMDS value was observed in the UCDS female group (Figure 45). As a result of the pair-wise comparisons made with the Mann-Whitney U test, there was no significant difference between the groups (P>.05) (Table 21).

Table 21. Mann-Whitney U test results comparisons of SMDS values between males and females according to examiner groups.

Examiner Group	Gender	Number	Mean	Std. Deviation	Minimum	Maximum	Mean Difference	U value	P
UPDS Group	Male	90	3.19	2.48	0	10	0.10	4172.5	0.684
	Female	96	3.09	2.53	0	13			
UCDS Group	Male	96	2.86	2.20	0	11	-0.39	4692.0	0.235
	Female	108	3.25	2.26	0	11			
PDS Group	Male	66	2.09	2.03	0	8	0.06	2131.5	0.829
	Female	66	2.03	2.04	0	8			

* P >.05 indicates no statistically significant differences.

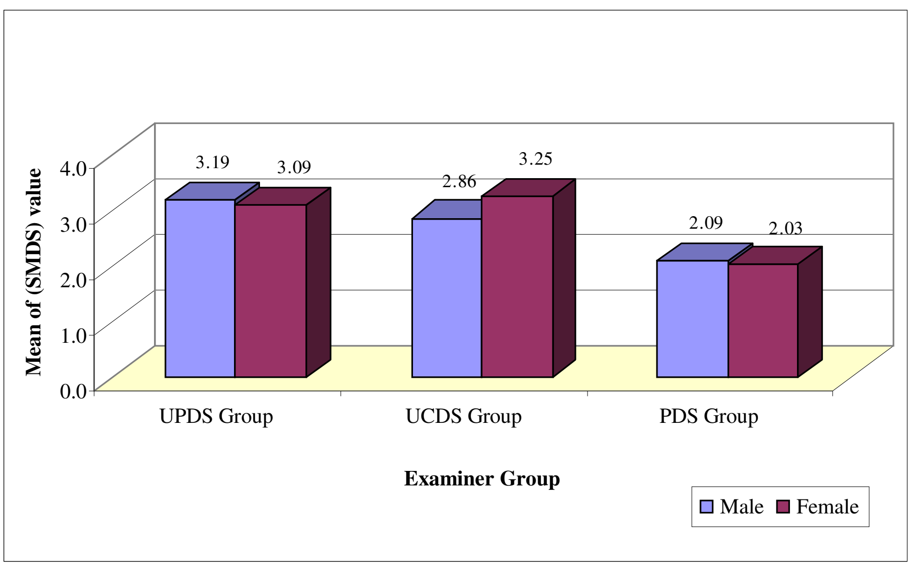

Figure 45. The mean SMDS values according to gender and examiner groups.

4.4.1.2. The effect of gender on shade matching success according to the examiner groups

Comparing the failure and success frequencies and the percentages of examiner groups the highest success value was observed in the PDS male group (Figure 46). As a result of the pair-wise comparisons using the Chi-Square test, no statistically significant difference was observed between the groups (Table 22) (P>.05)

Table 22. Chi-Square test pairwise comparisons of shade matching success results between gender according to the examiner groups.

Examiner Group	Gender	Number			Percent %			Chi-Square	P
		Fail	Success	Total	Fail	Success	Total		
UPDS Group	Male	77	13	90	85.6	14.4	100	1.732	0.188
	Female	88	8	96	91.7	8.3	100		
UCDS Group	Male	80	16	96	83.3	16.7	100	2.508	0.113
	Female	98	10	108	90.7	9.3	100		
PDS Group	Male	47	19	66	71.2	28.8	100	0.153	0.696
	Female	49	17	66	74.2	25.8	100		

* P >.05 indicates no statistically significant differences.

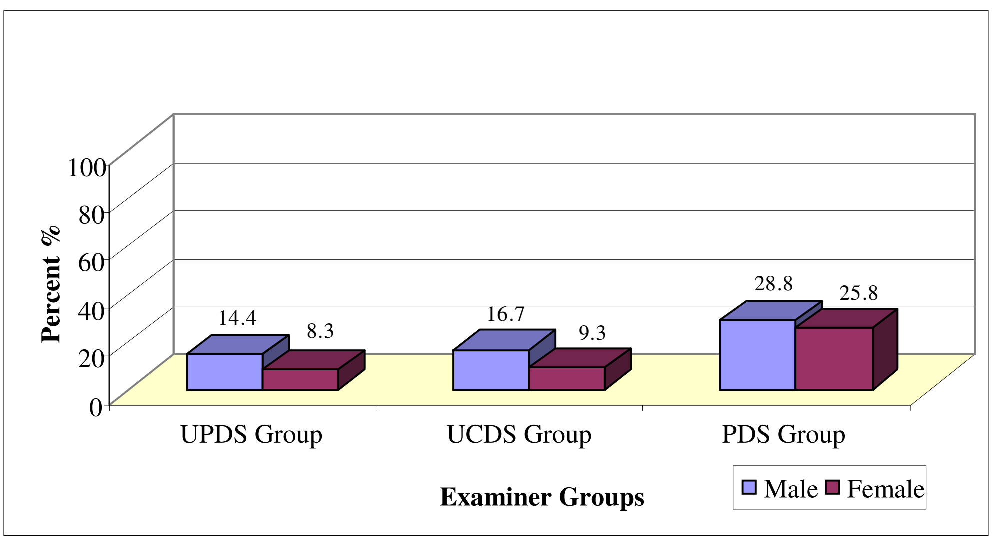

Figure 46. The shade matching success percentages according to gender and examiner groups.

4.4.1.3. The effect of clinical experience on SMDS values according to gender

Comparing the clinical experience effect on SMDS values according to the gender, the highest SMDS value was observed in the UCDS female group and the lowest was observed in PDS female group (Figure 47). According to the Kruskal-Wallis variance analysis, a statistically significant difference was found between the groups ($p < 0.05$) (Table 23). As a result of the pair-wise comparisons made with the Mann-Whitney U test, a significant difference was observed between the PDS group and the other two groups in both male and female groups ($p < .05$) but there was no significant difference between the UPDS and UCDS groups ($p > .05$) (Table 24).

Table 23. Kruskal-Wallis test results for comparison of SMDS values between examiner groups according to gender.

Gender	Examiner Group	Number	Mean	Std. Deviation	Minimum	Maximum	Chi-Square	P
Male	UPDS Group	90	3.19	2.48	0	10	8.858	0.012
	UCDS Group	96	2.86	2.20	0	11		
	PDS Group	66	2.09	2.03	0	8		
Female	UPDS Group	96	3.09	2.53	0	13	15.381	<.01
	UCDS Group	108	3.25	2.26	0	11		
	PDS Group	66	2.03	2.04	0	8		

* P <.05 indicates statistically significant differences.

Table 24. Mann-Whitney U test pair-wise comparisons of SMDS values between examiner groups according to gender.

Gender	Examiner Group (I-J)	Mean Difference (I – J)	U value	P
Male	UPDS-UCDS	0.32	4063	0.479
	UPDS-PDS	1.10	2194.5	0.005
	UCDS-PDS	0.77	2485.5	0.018
Female	UPDS -UCDS	-0.16	4787.5	0.338
	UPDS-PDS	1.06	2317.5	0.003
	UCDS-PDS	1.22	2349.5	<.01

* P <.05 indicates statistically significant differences.

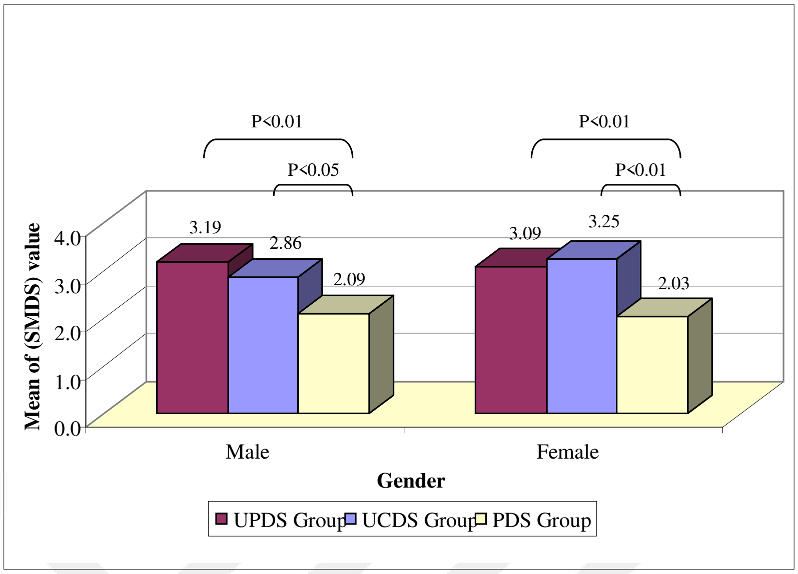

Figure 47. The mean SMDS values according to the examiner groups and gender.

4.4.1.4. The effect of clinical experience on shade matching success according to gender

Comparing the failure and success frequencies and the percentages of examiner groups the highest success value was observed in the PDS male group, and the lowest value was obtained in the UPDS female group (Figure 48). According to the Chi-Square test results, a statistically significant difference was found in female groups (P <.05) (Table 25). As a result of the pair-wise comparisons using the Chi-Square test, a significant difference was observed between the PDS group and the other two groups (P<.05) but there was no significant difference between the UPDS and UCDS groups (P> .05) (Table 26).

Table 25. Chi-Square test results for comparison of shade matching success between examiner groups according to gender.

Gender	Study Group	Number			Percent %			Chi-Square	P
		Fail	Success	Total	Fail	Success	Total		
Male	UPDS Group	77	13	90	85.6	14.4	100	5.651	0.059
	UCDS Group	80	16	96	83.3	16.7	100		
	PDS Group	47	19	66	71.2	28.8	100		
Female	UPDS Group	88	8	96	91.7	8.3	100	12.713	0.002
	UCDS Group	98	10	108	90.7	9.3	100		
	PDS Group	49	17	66	74.2	25.8	100		

* P <.05 indicates statistically significant differences.

Table 26. Chi-Square test pairwise comparisons of shade matching success results of female groups between the examiner groups.

Gender	Examiner Group (I-J)	Chi-Square	P
Female	UPDS-UCDS	0.054	.816
	UPDS-PDS	9.099	.003
	UCDS-PDS	8.506	.004

* P <.05 indicates statistically significant differences.

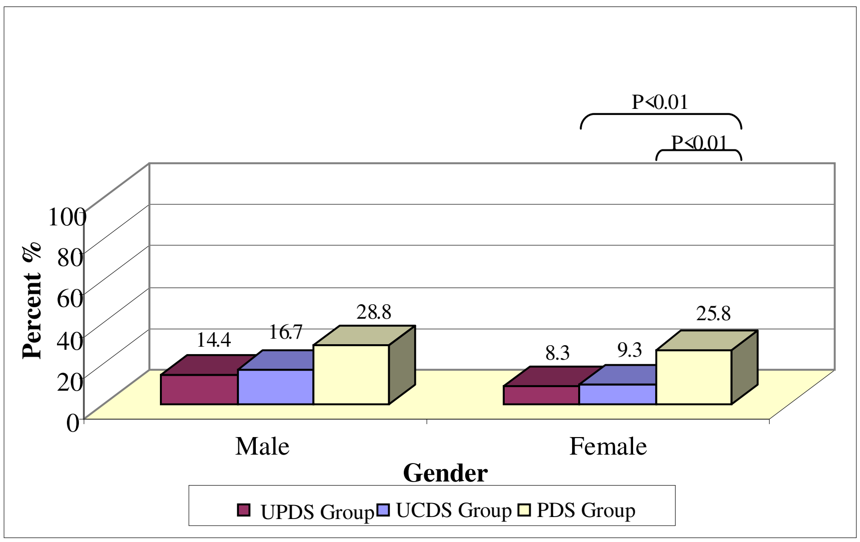

Figure 48. The shade matching success percentages according to the examiner groups and gender.

4.4.2. Shade matching results according to examiner and shade matching method

The shade matching results were analyzed according to the shade matching method and examiner groups as shown in (Table 27).

Table 27. Shade matching results according to the examiner groups and shade matching method.

Shade Matching Method	Determined Shade	Number			Percent %		
		UPDS Group	UCDS Group	PDS Group	UPDS Group	UCDS Group	PDS Group
DSM	C3	1	2	0	1.1	2.0	0
	B4	2	0	0	2.2	0	0
	A3.5	0	2	0	0	2.0	0
	B3	8	4	3	8.6	3.9	4.5
	D3	4	0	1	4.3	0	1.5
	A3	5	9	5	5.4	8.8	7.6
	D4	0	2	0	0	2.0	0
	C2	4	10	5	4.3	9.8	7.6
	C1	10	19	2	10.8	18.6	3.0
	A2	11	21	14	11.8	20.6	21.2
	D2	8	1	0	8.6	1.0	0
	B2	22	17	14	23.7	16.7	21.2
	A1	11	6	10	11.8	5.9	15.2
	B1	7	9	12	7.5	8.8	18.2
	Total	93	102	66	100	100	100
ISM	B3	4	1	1	4.3	1.0	1.5
	A3	4	4	0	4.3	3.9	0
	C2	11	9	1	11.8	8.8	1.5
	C1	14	17	5	15.1	16.7	7.6
	A2	17	23	23	18.3	22.5	34.8
	D2	14	10	2	15.1	9.8	3.0
	B2	19	21	11	20.4	20.6	16.7
	A1	4	9	20	4.3	8.8	30.3
	B1	6	8	3	6.5	7.8	4.5
	Total	93	102	66	100	100	100

4.4.2.1. The effect of clinical experience on SMDS values according to the shade matching method

The results were analyzed by Kruskal-Wallis variance analysis to study the effect of clinical experience on SMDS values according to the shade matching method. Statistically significant differences were found between the groups ($p <.05$) (Table 28). According to the pair-wise comparisons made with the Mann-Whitney U test, for both methods (DSM and ISM), a significant difference was observed between the PDS group and the other two groups (UPDS and UCDS) (p <.05), no significant difference was determined between the UPDS and UCDS groups (p> .05) (Table 29). For the two shade matching methods, the lowest value was obtained in the PDS group (Figure 49).

Table 28. Kruskal-Wallis variance analysis of examiner groups SMDS values according to the shade matching method.

Shade Matching Method	Examiner Group	N	Mean	Std. Deviation	Minimu	Maximu	Chi-Square	P
DSM	UPDS Group	93	3.28	2.88	0	13	11.224	0.004
	UCDS Group	102	3.55	2.51	0	11		
	PDS Group	66	2.32	2.28	0	8		
ISM	UPDS Group	93	3.00	2.05	0	8	14.921	0.001
	UCDS Group	102	2.59	1.81	0	8		
	PDS Group	66	1.80	1.71	0	8		

* P <.05 indicates statistically significant differences.

Table 29. Mann-Whitney U test pairwise comparisons of examiner groups SMDS values according to shade matching method.

Shade Matching Method	Examiner Group (I-J)	Mean Difference (I – J)	U value	P
DSM	UPDS-UCDS	-0.27	4250.0	.206
	UPDS-PDS	0.96	2468.5	.033
	UCDS-PDS	1.23	2342.0	.001
ISM	UPDS-UCDS	0.41	4260.5	.211
	UPDS-PDS	1.20	2015.0	<.01
	UCDS -PDS	0.79	2511.0	.005

* P <.05 indicates statistically significant differences.

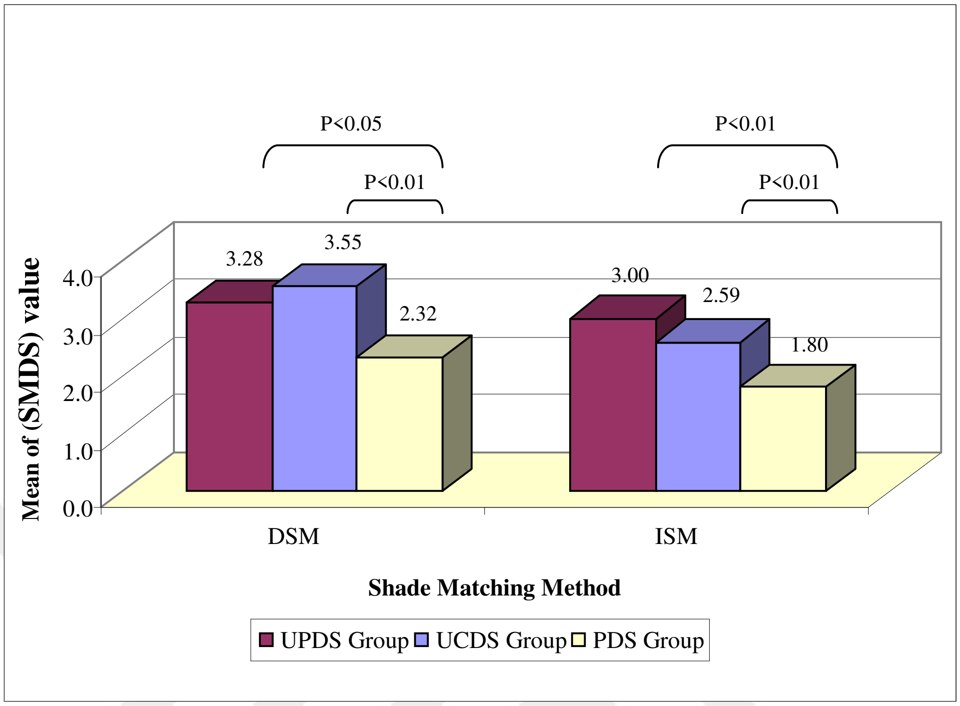

Figure 49. The mean SMDS values according to the examiner groups and shade matching method.

4.4.2.2. The effect of clinical experience on shade matching success according to the shade matching method

The results were analyzed by the Chi-Square test to study the effect of clinical experience on shade matching success according to the used matching method (Table 30). For both matching methods, statistically significant differences were found between the groups ($p < .05$). In pairwise comparisons, significant differences were observed between UCDS and PDS groups for DSM and ISM methods ($p < .05$), also significant differences were determined between UPDS and PDS group for ISM method ($p < 0.05$) (Table 31). The shade matching success percentages according to the examiner groups and shade matching method is shown in (Figure 50).

Table 30. Chi-Square test results of examiner groups shade matching success according to shade matching method.

Shade Matching Method	Examiner Group	Number			Percent %			Chi-Square	P
		Fail	Success	Total	Fail	Success	Total		
DSM	UPDS Group	81	12	93	87.1	12.9	100	6.183	0.045
	UCDS Group	91	11	102	89.2	10.8	100		
	PDS Group	50	16	66	75.8	24.2	100		
ISM	UPDS Group	84	9	93	90.3	9.7	100	12.270	0.002
	UCDS Group	87	15	102	85.3	14.7	100		
	PDS Group	46	20	66	69.7	30.3	100		

* P <.05 indicates statistically significant differences.

Table 31. Pair-wise comparisons of examiner groups matching success according to the shade matching method.

Shade Matching Method	Examiner Group (I-J)	Chi-Square	P
DSM	UPDS-UCDS	0.210	0.647
	UPDS-PDS	3.421	0.064
	UCDS-PDS	5.381	0.020
ISM	UPDS-UCDS	1.140	0.286
	UPDS-PDS	11.013	0.001
	UCDS-PDS	5.910	0.015

* P <.05 indicates statistically significant differences.

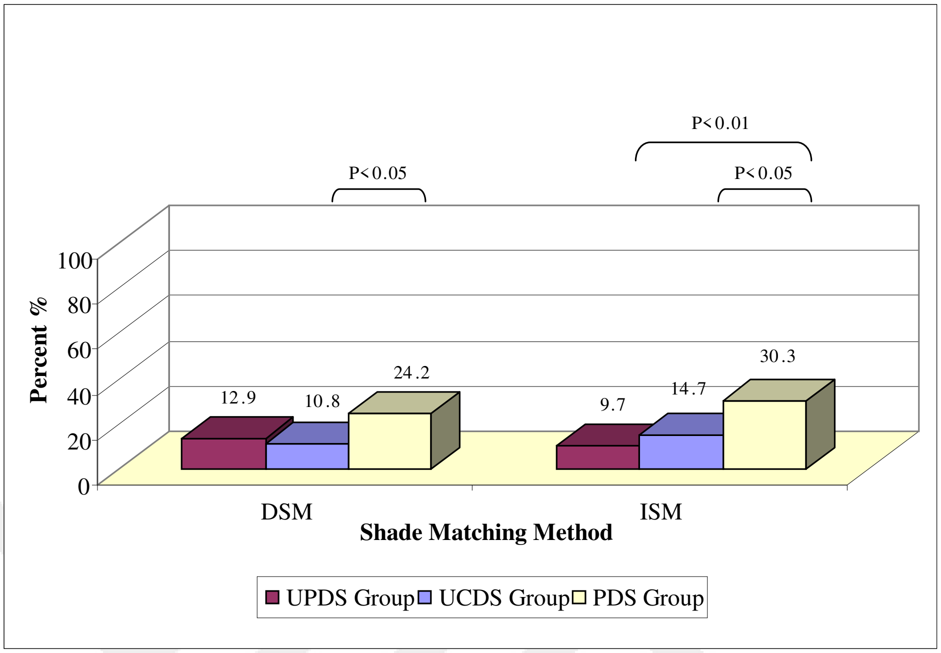

Figure 50. The shade matching success percentages according to the examiner groups and shade matching method.

4.4.2.3. The effect of shade matching method on SMDS values according to the examiner groups

The results were analyzed by the Mann-Whitney U test to study the effect of the shade matching method on SMDS values according to the examiner groups (Table 32). The lowest values for the two shade matching method were determined for the PDS group (Figure 51). A statistically significant difference was found between the two shade matching methods of the UCDS group (p <0.05) while there was no significant difference between other groups (p>.05).

Table 32. Mann-Whitney U test results for SMDS values according to shade matching method and examiner groups.

Examiner Group	Shade Matching Method	Number	Mean	Std. Deviation	Minimum	Maximum	Mean Difference	U value	P
UPDS Group	DSM	93	3.28	2.88	0	13	0.28	4276	0.894
	ISM	93	3.00	2.05	0	8			
UCDS Group	DSM	102	3.55	2.51	0	11	0.96	4054.5	0.006
	ISM	102	2.59	1.81	0	8			
PDS Group	DSM	66	2.32	2.28	0	8	0.52	1976	0.348
	ISM	66	1.80	1.71	0	8			

* P <.05 indicates statistically significant differences.

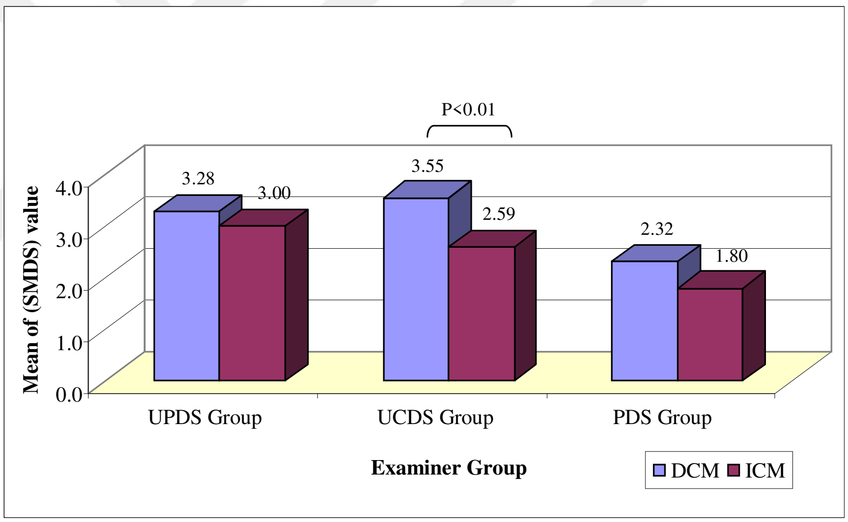

Figure 51. The mean SMDS values according to the shade matching method and the examiner groups.

4.4.2.4. The effect of shade matching method on shade matching success according to examiner groups

The Chi-Square test results indicating the effect of the shade matching method on shade matching success according to examiner groups are shown in (Table 33). The PDS group was shown the highest success percentage in both methods (Figure 52). Also, it was observed that in all examiner groups there was no significant difference between the two methods (p > .05).

Table 33. Chi-Square test results for shade matching success of DSM and ISM shade matching methods.

Examiner Group	Shade Matching Method	Number			Percent %			Chi-Square	P
		Fail	Success	Total	Fail	Success	Total		
UPDS Group	DSM	81	12	93	87.1	12.9	100	0.483	0.487
	ISM	84	9	93	90.3	9.7	100		
UCDS Group	DSM	91	11	102	89.2	10.8	100	0.705	0.401
	ISM	87	15	102	85.3	14.7	100		
PDS Group	DSM	50	16	66	75.8	24.2	100	0.611	0.434
	ISM	46	20	66	69.7	30.3	100		

* P >.05 indicates no statistically significant differences.

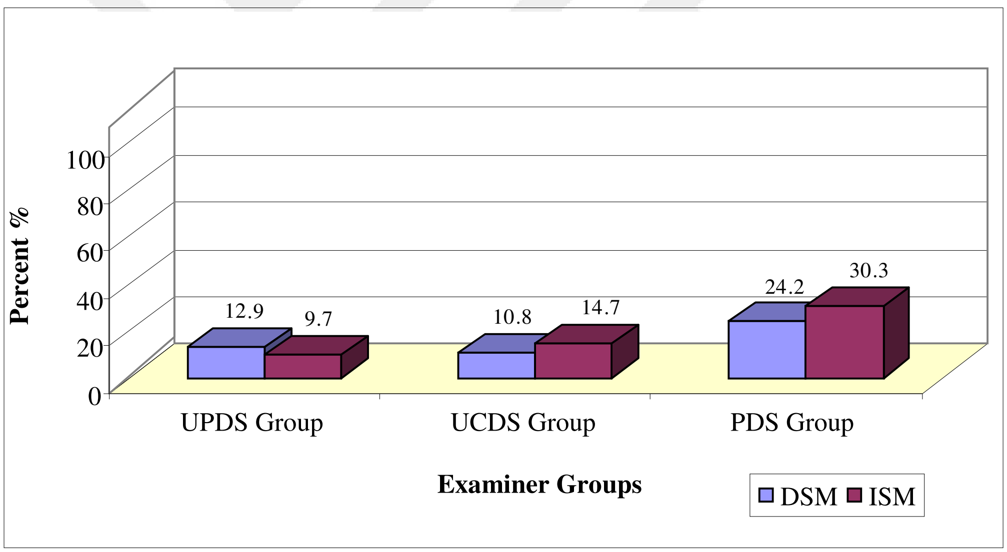

Figure 52. The shade matching success percentage according to shade matching method and examiner groups.

5. DISCUSSION

Shade matching is an important part of esthetics dentistry (34). Visual shade matching is the most common method applied in dental practice. Visual and instrumental shade matching methods complement each other (23, 29). Digital photography offers significant benefits to esthetics dentistry (29). Shade matching procedure can be influenced by several factors such as color vision defects, clinical experience, age, and gender (109).

The aim of our study was to compare the results of shade matching by conventional visual method (direct) and visual shade matching on image method (indirect) and to evaluate the effect of experience and gender on the results of shade matching for both methods.

There is no exact match in clinical shade matching (110), Culpepper (111) reported that dentists disagreed about shade matching for the same teeth and cannot duplicate their matching on other days. Value is considered to be the most important color characteristic for shade matching (24). It is the quantity of darkness or lightness of color and it is of great significance to esthetic dentistry. The prosthesis can be successful if the value is correct even if the chroma and hue are not matched (112). In our study to evaluate shade matching, SMDS values that express the difference between the assigned value of examined tooth shade and the assigned value of the real shade were determined, and each shade-matching result was ranged from 1 to 16 (1 the worst match while 16 the best match) (113). The success frequencies of the examiners on the shade matching were also calculated.

In the current study, the first null hypothesis was accepted because the clinical experience affected the shade matching results. Visual shade matching is considered one of the most commonly followed methods in dental clinics for a long time and this method is influenced by differences among people in terms of reliability and repeatability (114). Clinical experience is an important factor in shade matching skills that improve progressively over clinical experiences (115). Alfouzan et al. (116) evaluated the effect of shade matching training on the shade matching quality of dental students from both genders. A total of 120 dental students, in their third year of the dental education program, were included in the study and divided into four groups randomly. The first group attended a lesson and exercised weekly on color and dental shade matching, the second group only attended the lesson, the third group has only attended the exercise, and the last group that was considered as a control group did not join any lesson nor exercise. All groups matched the shade of four chosen shade tabs from VITA Linearguide 3D MASTER. Correct matches were calculated based on the best-matching shade guide method described by Paravina (117). The study showed that the lesson and exercises led to more accurate shade matching. A significant difference was detected between dental students' shade matching quality before and after the training process for both genders. No statistically significant difference was reported between the shade matching quality scores of males and females. Although this study differs from our study in terms of the shade matching methods and the fact that the students included in the study are only the 3rd year students of the dental program, the results indicating the positive effect of training on shade matching success were similar with our study.

Erzincanlı and Kazazoğlu (118), evaluated the effect of color knowledge, gender, and experience on the quality of shade matching. The study included 218 undergraduate and prosthodontic postgraduate students. Half of the undergraduate students received a lecture about color and shade matching. Toothguide Training Box (TTB) with Toothguide Trainer (TT) software, was used by all examiners for training procedure and at last, the final test is applied by using Vita Tooth Guide 3D Master. The shade matching score for each examiner was calculated as a sum of color differences ($\sum\Delta E$) between target tabs and selected tabs. The results showed that participants who have basic color knowledge matched the shades more successfully. Also, there was no significant difference between genders. Although the method and the shade guide used in this study don't correspond to our study method, the effect of clinical experience and training on shade matching success was found to be similar. In another study, Bona et al. (119), tested the agreement between examiner's visual dental shade matches and instrumental shade identifications. The study involved a total of 600 examiners (299 females and 301 males) included non-dental examiners (GP), first-year dental students (DS) with no clinical shade matching experience, and dentists (DD) with a range of years of experience. All examiners used both shade guides (Vita 3D-Master and Vita classical) in two different lighting conditions separately, cool white fluorescent lighting and natural sunlight. The percentage of the visual-instrumental shade agreement (PVIA) scores (42%) was significantly higher for clinically experienced dentists (DD) for both shade guides and lighting conditions. In our study, the direct method was performed under the clinic light condition, which is a combination of daylight and fluorescent lighting, while the indirect method was performed on images taken under a specific requirement of lighting and camera setting to get the ideal lighting condition. Even though the situations of this study were not valid for both the method and examiner groups of our study, the impact of clinical experience was similar.

The results indicating the effect of clinical experience in the present study were not parallel to the studies of Haddad et al. (6) and Aswini et al. (120). Haddad et al. (6), evaluated the influence of experience and gender on shade matching quality. The study included 614 examiners (305 females and 309 males). 319 of them were dental students (S), and 295 were professionals – dentists and dental technicians (P). The examiners received a lecture about shade matching. The training and the tests were conducted by the usage of Toothguide Trainer software (TT) and Toothguide Training Box (TTB). Examiners were asked to match 15 shade guide tabs with referenced shade guides. Color difference (ΔE^* ab) between the task tab and selected tab was detected. It was found that females have scored much better than males in shade matching and the level of experience has no important role in shade matching. Aswini et al. (120), evaluated the effect of gender and clinical experience on shade perception. A total of 100 dental professionals were categorized as dental students (with a minimum of 1 year and a maximum of 2 years of clinical experience), dental doctors (with a minimum of 2 years and a maximum of 5 years of clinical experience), and dental specialists (with more than 5 years of clinical experience). The authors reported in the study that experience has no significant effect on shade matching in prosthetic and restorative dentistry.

The differences between the present study and previous studies (Haddad et al. (6) and Aswini et al. (120)) may be attributed to different factors. Haddad et al. (6) provided training for all examiners prior to the shade matching. Similarly, Aswini et al. (120) conducted the study with the examiners that have at least one year of clinical experience. In our study, there was no training for the examiners before shade matching and the examiners had different levels of clinical experience. In addition, in these studies, shade matchings were performed only by using tab-to-tabs matching while natural tooth shade matching was used in our study. Schropp (121) mentioned that it is easier to match identical shade tabs to each other than matching to a natural tooth. Hence, this may be considered as a factor for the different results of our study. Furthermore, the study results of Haddad et al. (6) were analyzed according to color difference (ΔE) values for each shade and were calculated using L*, a*, and b* value between target tabs and selected tabs. While in our study the correct frequencies and SMDS values were used.

The impact of gender on shade matching capabilities is still an argumentative topic between scholars (88). It is traditionally believed that females are better at shade matching than males (6). Those who do not support this belief called it ‘‘scientific fiction’’ (6, 11). In the current study, gender had no statistically significant effect on shade matching which rejects our second hypothesis that expresses gender has an effect on shade matching and females show better results than males. This result is similar to the study findings of Alfouzan et al. (116), Erzincanlı and Kazazoğlu (118), and Aswini et al. (120). Also, the result of our study corresponds with the study of Negahdari et al. (122). They compared shade matching using two shade guide systems of Vitapan Classical and 3D Master by dental students. The study reported that there was no significant difference between the two genders, but males exhibited higher results when the Vitapan Classical shade guide was used and females exhibited better results by using the 3D Master system. In fact, several studies reported that eyes are more sensitive to changes in lightness-darkness and chroma rather than subtle changes in hue (123, 124). However, it had been concluded that females have a better chromatic perception, especially for red-green stimuli (89), while males show better lightness perception (87, 125).

On the other hand, the results of the present study disagreed with the results of Pecho et al. (126) who evaluated gender influence on the accuracy of visual shade matching (VSM). The study included 100 examiners (65 females and 35 males). Brief instructions about the use of the shade guide were given to examiners. Vita Classical (VC) shade guide was used. The examined teeth were four human upper central incisors (UCI). Color differences (ΔE) between each UCI and VC shade tabs were evaluated using two-color difference metrics: CIELAB and CIEDE2000. In the study, the gender effect was found to be statistically significant for females, only when CIEDE2000 color difference metric was used. Pecho et al. (126) have analyzed the results according to the color differences (ΔE), and the unbalanced examiners' gender ratio (65 females to 35 males) in their study may be the reason for the significant gender effect. In addition, the results of our study disagreed with the results of Haddad et al. (6) who found that females have a much better result than males in shade matching. Haddad et al have analyzed the results according to the color differences (ΔE) and used Vita 3D-Master shade guide and they included 614 examiners (305 females and 309 males) in 15 universities in 9 countries. The reason for this disagreement may be due to that the result analyzed method, the used shade guide, and the number of examiners. Since 87 examiners were taken apart in the present study (45 females and 42 males) and they were all from one university.

The third null hypothesis of the current study was partially accepted because there was no difference in the shade matching success between indirect and direct methods according to success frequencies but there was a difference according to SMDS values. To overcome the discrepancies of visual shade matching, instruments such as colorimeter, spectrophotometer, and digital cameras were implemented in dental practice (127). Effective communication occurs when the technician meets with both the patient and the clinician to discuss the case (78). However, this meeting may not be possible for every patient (76). Photographs are the ideal solution to this dilemma (112). Photography is a valuable tool for communication between the clinician and the technician. Thus, it is recommended for the clinician to send photographs to the technician along with the shade tabs as a reference (75). In the present study, the direct visual shade matching method was compared with the indirect shade matching method. Vita Classical Shade Guide which is expressed as the "gold standard," was used (5). A previous study expressed that using Vita Classical Shade Guide in shade matching is easier for those who do not have previous experience (119).

The results of the current study are in agreement with the study findings of Schropp (121). In Schropp's study (121), the efficacy of digital photographs and graphic computer software for shade matching comparing with conventional visual matching was evaluated. Half of the examiners (nearly the same number of examiners in our study) were not familiar with the use of shade guides, and no instructions were given to them. The study results showed that the performance of conventional visual shade matching and shade matching with digital photographs presented on a computer screen was comparable. However, no significant difference was detected between the methods. Even though the results were in accordance with the results of our study, the details of the technical methods were different. Schropp (121) used graphic software to adjust and analyze the colors of the taken photos, the camera type, and flash settings were also different from that of our study.

On the other hand, the results of the present study were not parallel with the study findings of Jarad et al. (73). Jarad et al. (73) aimed to develop a shade matching technique relying on digital imaging. Additionally, they compared examiners' ability using this method with the visual method against a spectrophotometric 'gold standard'. The authors reported that the examiners' shade matching performance was significantly better with the computer method compared with the conventional method. They reported that the digital camera can be used as a means of color measurements in the dental clinic. The difference between our study and Jarad et al. (73) may be that they performed shade matching only using tab-to-tabs matching while the natural tooth was used in our study. It is easier to match identical shade tabs to each other than matching shade guide tabs to a natural tooth (121). In addition, the examiners in Jarad et al.' s study (73) were more experienced (four postgraduate students, two consultants, and four dental technicians from the conservation department) than examiners in our study. Also, the PDS and UCDS groups were not familiar with the use of the Vita Classical shade guide, which was used in this study. Similarly, the camera type and flash settings used in their study were different from that of ours. Moreover, they used Adobe Photoshop Software to analyze and obtain the CIELAB values of the shade tabs. While in our study, the results were determined as "right" or "wrong" without using any image software analysis.

The indirect method of using the digital camera can be recommended as a good alternative to the direct method, however, more research is needed. In the present study, the results of shade matching by the ISM method were better than the results of DSM methods. The reason may be that the procedures performed chairside are more difficult due to the various variables such as weather conditions and clinical lighting. In the photographic method, the effects of these conditions can be eliminated more easily with special requirements of lightness and camera settings (114). In addition, the ISM method reduces distraction factors from the surrounding environment like clinical decorations and equipment. Also, using the ISM method reduces the stress of the examiner when facing patients during the DSM procedure. Moreover, the ISM method for shade matching can be done at any time while the DSM method is usually performed in the clinic in the presence of the patient. Another disadvantage of the DSM method, it is preferred to be done in mornings for better lighting and to avoid fatigue which is one of the most common causes of incorrect shade matching (80). Finally, shade matching using digital photos could decrease the gap of color communication between clinicians and dental technicians (65). According to Jarad et al. (73) using the ISM method can make the communication between the dentist and the technician easier by sharing the image online. In this way, the technician may help in shade matching and have preliminary knowledge about the shape and surface of the teeth. This is particularly important for clinicians with insufficient experience in complex cases and clinicians who have a color deficiency. Also, the technician can evaluate different shade tabs in relation to different teeth areas on the image (114). Fondriest et al. (83) stated that well-exposed clinical photographs can document numerous details that normally are not noticed at the chairside. The disadvantages of the digital imaging method for shade matching include the need for a DSLR (Digital Single-Lens Reflex) camera, knowledge about digital imaging software, and adequate and constant illumination (127).

Our study has some limitations. Three different tooth shades (B1, A1, and B2) that were chosen in the study were near to each other in terms of value and this may make the matching more difficult for non-experienced examiners. For examiners, without clinical experience, it is preferable to examine shade matching using identical shade tabs to each other than to natural teeth. Besides, the number of examiners in our study could be another limitation. Furthermore, using Gray Card (WhiBal® card) which has a known L, a, b value that will be useful in evaluating color to check the accuracy for each image in the Photoshop program should be taken into consideration. Additional studies could be performed using other commercially available shade guides to check the accuracy of the digital image method.

6. CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn :

1. Clinical experience has a positive effect on the accuracy of shade matching results.
2. Gender is not an influential factor in the shade matching process.
3. No significant difference was found between visual indirect and direct method shade matching according to success frequencies. However, there was a significant difference according to SMDS values between the methods.

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