Review

An Overview of Shade Selection in Clinical Dentistry

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Abstract: The selection of an accurate tooth shade has always been a challenging task for dental practitioners in restoring the natural appearance of teeth. Various factors can influence shade selection, such as different lighting conditions, clearness and opaqueness of teeth, eye fatigue, aging and color vision problems. It is imperative to have a sound knowledge about the concept of shades and its selection protocol for obtaining good esthetics outcomes. To attain the best esthetics, four elementary contributing factors are essential: exact position, shape, surface texture and shade. The current analysis focuses on several features of shade, sensitivity of shades, optical properties of the teeth, visual and innovative instrumental techniques for shade selection, protocols for shade selection and factors affecting dental shade selection.

Keywords: chroma; colorimeter; clinical dentistry; digital camera; hue; shade selection; spectrophotometers; value

1. Introduction

Currently, esthetic dentistry rotates around three mainstays: application of composite resins and ceramics; adequate bonding with dental structures; and finally, restoration of esthetically pleasing look [1]. In cosmetic dentistry, clinical success for dentists is to choose the accurate shade of a tooth color, then select and apply the most closely matched quality material, and finally, communicate precisely with the lab technicians to achieve good esthetic results [1].

The effect of tooth shade is achieved by the combination of intrinsic and extrinsic colorations [2,3]. Intrinsic coloration is related to the light scattering and properties of absorption of the enamel and dentine [2,4]. Extrinsic coloration is linked with material absorption (e.g., red wine, tea, iron salts and chlorhexidine,) onto the surface of enamel and, specifically, the pellicle coating that eventually causes extrinsic stain [2,5].

A surge in interest using tooth-colored materials for their restoration and the systems in the present day have partially recognized the speedy improvements and developments in restoration materials for a tooth and also the demands of a patient, as well as interest of a user. Due to these developments in tooth-colored restorative materials, a number of modalities for traditional treatment for good tooth esthetic are available. However, traditional esthetic dentistry laid emphasis on the artistic features; therefore, restorative dentistry can be defined as a combination of the conception of beauty and art [5].

It has also been observed that knowledge about esthetically attractive restorations among patients has increased. However, it is the responsibility and esthetic sensibility of dentists to offer the rebuilding of a tooth that can be effectively made to improve a person's appearance with a natural look [6]. According to scientific evidence regarding modifications in the visual matching of color shades, different devices have been developed but their use is very rare. The purpose of the present research is to review the literature to analyze the accurateness of color matching using different shade-selection techniques.

Significance of Shade Selection in Dentistry

In the last few years, the conception of beauty and esthetic restoration sensibility of teeth has increased and been extensively improved among both dental practitioners and patients. It is necessary for dentists to provide an esthetic restoration of a tooth that perfectly matches with the natural teeth of a patient [7]. However, due to the availability of a wide range of natural tooth shades, it has now become a challenging task for dental practitioners to provide an accurate counterpart to adjacent teeth shade between natural teeth and prosthesis. It has also been observed that various prostheses have been unsuccessful in providing a perfect tooth match due to inappropriate shade choice; therefore, it is imperative for dental practitioners to be well aware and conscious at the time of selection of shade in order to get the best results. Researchers have viewed that almost one million color shades can be distinguished by the human brain, whereas around 10 million different shades can be sensed through the latest designed electronic devices. As opposed to the human eye, which can only distinguish 1% of these dental hues, electronic instruments can classify about 100,000 dental shades [8].

2. Literature Review

2.1. Three Color Dimensions

Selection of shades has not always been easy to define perfectly and communicate verbally. In the Munsell system, hue, value and chroma are the three variables that are applied to distinguish the acuity of light, which reflects from the surface of a tooth [9]. Value indicates the lightness or darkness of a tooth shade's hue, while chroma gives quality that distinguishes the hue's grade of brightness. Hue defines the leading shade of the teeth, such as more reddish or yellowish, as seen in Figure 1 [10].
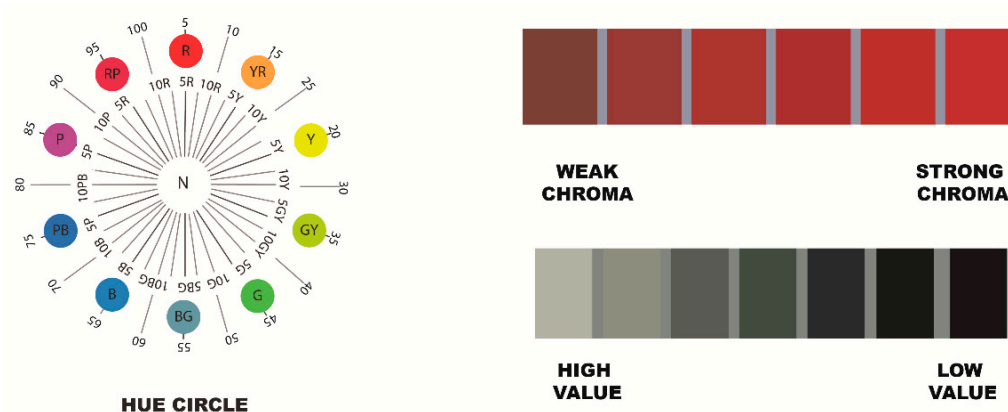
Figure 1. Three dimensions of color (adapted and re-drawn from ©1994 Encyclopedia Britannica, Inc., Chicago, IL, USA).

2.1.1. Hue

The particular variety of a color is called hue. Hue differentiates color from one family to another [11]. In Munsell's words, "it is that quality by which we distinguish one color family from another, as red from yellow, green from blue, or purple. It is a physiological and psychological interpretation of a sum of wavelengths. It is denoted by A (reddish brown), B (orange yellow), C (greenish-gray) or D (pinkish gray) on the commonly used shade guide of Vita Classic" [12] Figure 1.

2.1.2. Value

Value measures light or dark shades or the brightness of a tooth color. The brightness of any object is directly responsible for the status of energy of light for which the object reflects or transfers. The importance was classified by the Munsell method as a white-to-black gray scale. Bright items have less gray, but low-value objects include more gray and appear darker. [12]. Increasing the surface reflectivity or reducing chroma are two

common ways to improve dental crown brightness. Lowering the value means a lesser amount of light reflects from the lightened object and the extra light absorbs or is dispersed somewhere else (Figure 1).

2.1.3. Choma

The saturation, intensity or power of a color is referred to as chroma. Chroma and value have a converse relation; if chroma is increased, the value is decreased or vice versa [9,12]. Figure 1 shows a Munsell color system, where the radii of the different disc represent the chroma and the color at the outer edge of the disc is the pure color; as it goes toward the central axis, it becomes progressively less saturated [11]. Chroma ranges from 2 to 10 for natural teeth (Figure 2).
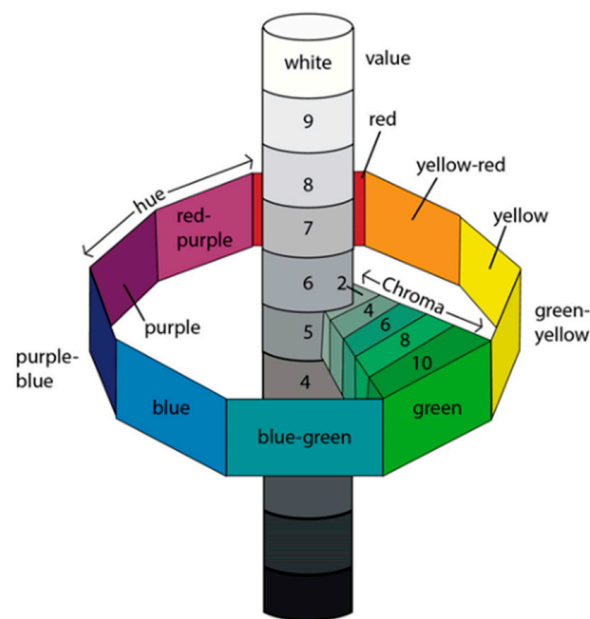
Figure 2. Munsell color system (adapted and re-drawn from ©1994 Encyclopedia Britannica, Inc., Chicago, IL, USA).

2.2. Main Optical Properties of Teeth

Other indirect optical characteristics of teeth, including translucency, opalescence, opacity, surface roughness, surface gloss and fluorescence, are also relevant in addition to hue, value and chroma. Such optical properties give a natural restorative look to teeth.

2.2.1. Translucency

Human teeth can be categorized by variable grades of translucency, such as gradient between opaque and transparent. Usually, increasing the crown translucency consequently decreases its value because a smaller amount of light reflects towards the eye. With augmented translucency, light passes through the surface and is dispersed inside the restoration. The enamel translucency differs with the angle of occurrence, surface of a texture and polish, wavelength and level of dryness [11]. The translucency of the enamel is also a characteristic related to the refractive index of the enamel (RI = 1.62) and intercrystalline spatial composition. Demineralization alters the physiological reflectivity of the enamel, and the difference in RI between the healthy enamel and the demineralized area generates color alterations [13]. This color alteration can be managed effectively using the resin infiltration technique [14].

2.2.2. Fluorescence

A material that has absorbed light or other electromagnetic waves will emit light when it is fluorescent. It is a type of luminescence. In many cases, the emission of light has a

longer wavelength. Because there is a higher concentration of organic material in the dentin of a human tooth, this condition predominately occurs there. Therefore, the chroma is lower the more the dentin luminesces [11].

2.2.3. Opalescence

Opalescence is the optical property of a material in which it seems to be of one color upon the reflection of light, while on transmission of light, it appears to be another color. This distinctive impact is most frequently seen in enamel, which improves the brightness, liveliness and depth perception of teeth [11].

2.2.4. Texture of Surface

This affects the esthetics of a tooth by determining the quantity and path of light that are reflected off the facial surface. Natural teeth may have various categorizations with lobes, stippling, striations and ridges [15].

2.2.5. Surface Gloss

Surface gloss affects teeth vitality and appearance. It is also an optical property that gives a glossy look [9].

2.2.6. Metamerism

When two colors appear to match under specific lighting conditions yet have differing shadow-like reflectances, known as metamers, the phenomenon is known as metamerism, and the entire process is considered to be metamerism. By selecting a shade and authenticating it in general lighting conditions, such as fluorescent light and natural daylight, the problem of metamerism may be avoided or disregarded [16].

2.3. Measurement of Colour

The manufacturing of indirect restoration of a tooth needs strong communication between dental practitioners and laboratory technicians. Moreover, the choice of shade has always been the most challenging phase in the restoration to maintain the natural esthetic of teeth [17]. Some previous studies stated that variances among practitioners about the matching of shade for the same teeth arise after a few days [18,19]. Indeed, investigators have measured the matching of shade as a subjective technique, which is dependent on some influences, such as source of light, object and viewer [20].

Shades can be measured using two techniques:

a.　Visual Technique;
b.　Instrumental Technique.

2.3.1. Visual Technique

The Munsell system, which may be depicted in three dimensions of color, is a commonly used method for visually measuring tooth shade (Figure 2). The use of visual shade guides is the conservative technique of shade selection, which is the most common and suitable approach in shade selection of a tooth. It is very economical and easily available in the market; the color of a tooth can also accurately match with a regular reference shade guide. When employing the shade tab approach, choosing a tooth's shade entirely depends on the observer's sight. [21].

The visual approach is used most frequently in clinical dentistry to identify the shade of a patient's teeth. However, it has been shown that the visual approach for determining shade matching is inaccurate. The visual shade matching approach has some limitations, including inadequate ambient lighting conditions, age, eye impairment and a strong reliance on individual abilities in shade matching and metamerism [22–25].
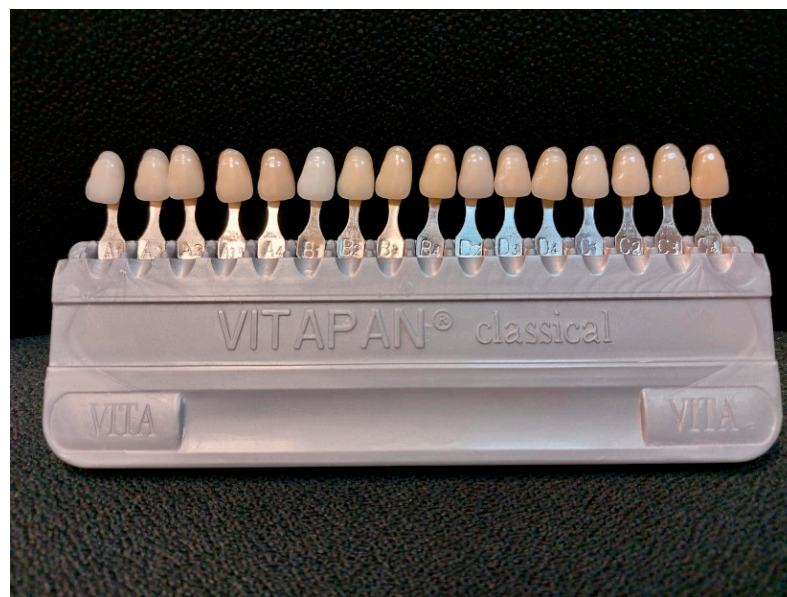
Shade Guides

In dentistry, shade guides are used to match with the natural tooth structure that comprise of a set of standard or independently fabricated shades [26]. Shade guides can be classified on the basis of material from which they are made, such as composite resin based, acrylic based and ceramic based [27–29]. Generally, shade guides should have a full range of natural color for dental structures. As a general standard, each shade tab is composed of an incisal, middle and cervical part that varies in shade on the basis of translucency and color density [30]. In prosthetic dentistry, selection of shade is a significant phase in all directions, which, later on, is delivered to the laboratory technician to fabricate indirect restoration [31].

Presently, there are a number of accessible shade guides applied in the clinical practice of dentistry: Vita classical (Bad Säckingen, Germany: VITA Zahnfabrik H. Rauter GmbH & Co.), Vita Tooth guide or 3D-Master shade guide (Bad Säckingen, Germany: VITA Zahnfabrik H. Rauter GmbH & Co.) and Chromascop (Buffalo, NY, USA: Ivoclar Vivadent Inc.). They are based on Munsell's guiding principles that distribute the color space into three dimensions: hue (name of the color), chroma (color density) and value (vitality of color) [27,32].

Vita Classical Shade Guide

In Vita Classical, the color space is classified into four groups: A, B, C and D; these comprise the leading HUE (name of color). These are red and brown in group A, red and yellow in group B, gray in group C, and red and gray in group D. Every letter group has sub-divisions indexed with Arabic numbers, ranging from 1 to 4, which makes the overall number of tabs 16 (Figure 3). As the number increases, the value decreases, whereas the chroma increases simultaneously [33].

Figure 3. Vita Classical Shade Guide.

Vita 3D Master Shade Guide

This shade guide entails 26 tabs that are organized into five groups with respect to their value. Figure 4 shows the shade tabs are further arranged along with two axes inside the groups, i.e., vertical in relation to chroma and horizontal axes according to hue. The first group consists of two tabs, the second, third and fourth comprise seven each, whereas the fifth one has three tabs. Moreover, every shade tab has three markers ranging from 1 to 5, presenting the group and the level of value that decreases as the number increases [34].

Figure 4. Vita 3D Master Shade Guide.

It has been observed that a number of improvements have been developed for the Vita 3D Master shade guide, as compared to Vita Classical:

- There is an extensive range of value.
- The red spectra are wide-ranging.
- The shade tabs are more correspondingly divided into the color space.
- The development in distribution of groups has improved and become more concise [32].

Chromascop Shade Guide

To identify hues, the Chromascop numbering system is employed. Depending on the color, it is divided into categories (100 = white, 200 = yellow, 300 = orange, 400 = gray, 500 = brown) and within the groups, as chroma increases from 10 to 40 [35] Figure 5.
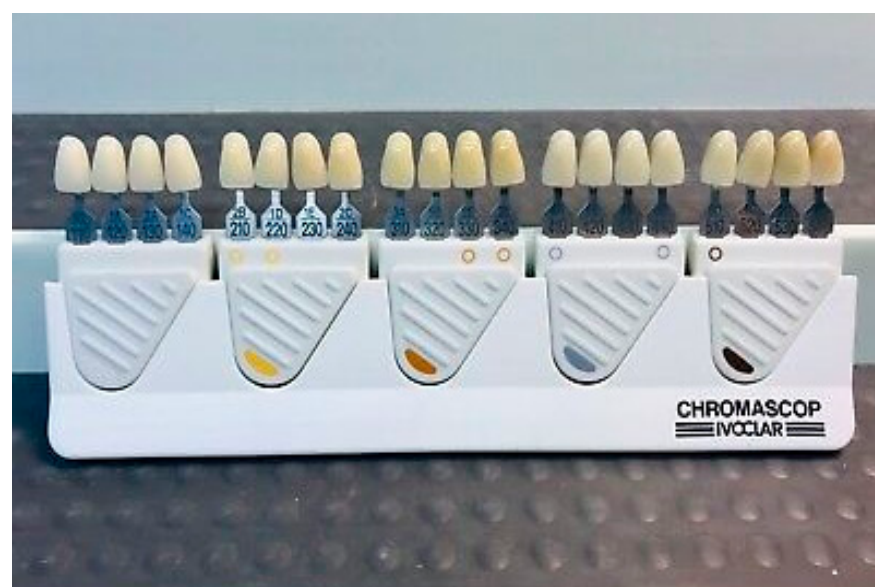
Figure 5. Chromascop Shade Guide.

Merits of Shade Guides

i.   The most common method of shade selection is using a visual shade guide [6].
ii.   It is economical and durable, i.e., does not require frequent replacement of the shade guide.
iii.   It provides an efficient comparison with natural tooth color.
iv.   Most frequently used by dentists, dental assistants and dental laboratory technicians to communicate the proper tooth color, brightness and translucency [9].
v.   Easily available.

Demerits of Shade Guides

i.   In shade guides, the colors may differ for each company.
ii.   Porcelain that is used for restoration of teeth may be different with a shade guide.
iii.   Guides are not able to direct the manufacturing of porcelain restoration.
iv.   The shades of a tooth in a shade guide are not rationally arranged and do not cover the capacity of color space that is normally unoccupied in natural teeth.
v.   A normal shade tab is prepared from synthetic resin having greater density than a crown.
vi.   A shade guide tab reflects and transforms light-forming translucency and provides a look of vitality [36,37].

2.3.2. Instrumental Techniques in Tooth Shade Selection

Shade guides are used for shade selection, which is the most frequent practice in dentistry. However, this technique is regarded as subjective, as it is influenced by age, gender, eye fatigue, observer skill and surrounding light [38]. Even though instrumental techniques in dental color matching are very costly and not easily accessible to dental practit0ioners, they have been growing rapidly and accepted in dentistry [39]. An instrumental technique includes spectrophotometers, colorimeters, scanners, digital cameras and smartphones [40].

Spectrophotometers and Spectroradiometers

In dentistry, spectrophotometers are amongst the most precise, expedient and flexible instrumental method used for general color matching [41]. They quantify the extent of reflected light energy from an object at 1–25 nm intervals alongside the observable spectrum [42]. A spectrophotometer comprises an optical radiation source, a means of scattering light, an optical system for determining, an indicator and a means of transforming light to a signal that can be evaluated. The data acquired from spectrophotometers must be employed and explained in a form valuable for dental experts. The dimensions gained by the instruments are commonly entered to dental shade guides and changed to shade tab correspondent [43].

A spectrophotometer varies from spectroradiometer as it mostly comprises a stable light source. These gadgets have been made using two different straightforward designs. The standard scanning apparatus has a single photodiode sensor that counts the amount of light at all wavelengths [44]. The latest designed devices employ a diode arrangement with a specified element for every wavelength. This design supports the synchronized incorporation of all wavelengths simultaneously. Both types are crucial for research into the development of more precise color-measuring equipment, even though they operate much more slowly than filter colorimeters [45]. Vita Easy Shade® V is an illustration of a spectrophotometer (Figure 6).

In comparison with interpretations by the human eye, or conventional techniques, it was observed that spectrophotometers presented a 33% accuracy increase and 93.3% of cases offered a more objective match [46]. A number of researchers recommend that visual color-matching methods along with the instrumental technique are more valuable when used in combination, as they complement each other [46].

Figure 6. Vita Easyshade® V, Bad Säckingen, Germany.

Colorimeters

Colorimeters record tri-stimulus values and filter light in red, green and blue regions of the visible spectrum. Colorimeters are not capable of recording spectral reflectance and their accuracy can be diminished because of over usage of the filters as compared to spectrophotometers [47]. A colorimeter presents a complete measurement of light absorbed; however, a spectrophotometer quantifies the light absorbed at differing wavelengths [48]. Shade Vision (X-Rite, Grandville, MI, USA) is an imaging colorimeter. Comprehensive tooth appearance is provided by the use of three distinct records, particularly for gingival, middle and incisal third [47].

Digital Cameras and Imaging Systems

Digital cameras show the most basic method for electronic shade measurement, still demanding a certain degree of independent shade selection with the human eye [49]. Digital imaging systems are becoming progressively more widespread in measuring the shade of teeth. The quality of the camera and image-processing method affects its precision and accuracy. A number of researchers found that digital cameras may be dependable instruments for determining the color of teeth and gingiva when applied in combination with the proper standardization procedures [33].

Hybrid Devices

Spectro Shade delivers an amalgamation of digital imaging as well as spectrophotometric exploration. It applies the Clear Match Software System (Hood River, OR, USA: Smart Technology) and it is a product of independent hardware, which is developed for use on PCs that have the Windows platform and virtually any digital camera [50].

Restrictions of Digital Shade Guide

a. The color measurement accurateness is affected due to the loss of power supply.
b. For all systems, translucent recording is insufficient.
c. Settlement of the probe or mouthpiece appears to be vital for the reappearance of the measurement.
d. No digital shade guide is satisfactorily progressive to function in a mode of formulation.

e. The research laboratory must be well equipped with the latest and most updated systems for the effective use of this process [6].

2.4. Recommended Protocols for Clinical Shade Selection

Shade selection is performed in an organized way that assures accuracy, consistency and predictable effects that are categorically essential in esthetic dentistry. At first, the value is selected for the arrangement of the selection of shade followed by chroma, and finally hue.

2.4.1. Working Site Lighting

Midday sunlight is ideally considered for the best shade selection, because the exposure of midday sunlight comprises nearly the same blend of whole-light wavelengths as compared to the sunlight exposure of morning and evening timings, which are more affluent with reddish and yellow wavelengths. Since dental clinics have no access to sunlight exposure, artificial light must be applied to mimic sunlight. Lamps of artificial light cannot be a perfect replacement for sunlight, but they are sufficient for clinical purposes [51].

2.4.2. Environment

Surroundings with bright colors should be evaded as they affect suitable color matching through influencing the colors in the reflected light. Unwanted colors in the patient's jewelry and clothing can be covered with a wrapper, and the patient's lipstick should be removed to prevent any changes in color perception. The ideal backdrop for color matching is a very light shade of gray. High-gloss surfaces create disturbing shines and should be avoided [51].

2.4.3. Condition of Teeth

The tooth to be matched and its neighboring teeth must be free of surface stains and plaque along with other deposits. The tooth of interest must be moist with saliva because a lack of moisture will result in a whiter look. Color matching of a tooth ought to be done before applying the rubber dam as the tooth becomes dryer after its use [52]. Selection of shade should not be executed quickly after bleaching as the patient has to be revisited and recalled after 2 to 3 weeks for the comparison of shade [52]. During the selection of shade, teeth must be distributed into three areas each time, such as gingival area (it provides perfect measurement of dentinal chroma), middle and incisal area (where enamel is more dense and differs from translucent to transparent) [10].

2.4.4. Distance of the Operator from the Tooth, Position of the Patient and Timing

A distance from the oral cavity of about 61cm (2 feet) to 183 cm (6 feet) is preferably considered for the matching of shade. The position of a patient on the dental chair should be in such a way that the teeth of a patient are at the level of the operator's eyes. Shade selection must be finalized by the operator in the morning preferably, when eye tiredness is minimal [9].

2.5. Factors Affecting Shade Selection

The ability for shade matching differs with age, experience and an individual's level of color sensitivity (functional ganglion cell density and rod and cone photoreceptor morphology) [53].

2.5.1. Age

Shade-matching skills become unfavorable due to aging because the cornea and lens of the eye yellow with age, conveying a yellow-brown bias. This change starts at the age of 30; it becomes more obvious at 50 years of age and has medical importance after the age of 60. After the age of 60, many people face problems in distinguishing blue and purple colors. Images are observed as more yellowish and brownish with an increase in eye age [53].

2.5.2. Gender

It is generally assumed that women recognize color more precisely than men. However, a study showed no gender differences [54].

2.5.3. Experience

The issue is still indistinct in that the skill of accurateness in shade selection or matching is inherent or can be developed or learned through experience. Interestingly, the literature opposes the concept that experience is significant in shade selection or matching [55].

2.5.4. Eye Color

Brown-eyed people have more melanin and are able to absorb ample light and wavelengths, possibly influencing view but not color acuity. Those with less melanocyte cannot absorb as much light [56].

2.5.5. Color Vision Problem/Color Blindness

In the human eye, the most intricate and misinterpreted region of color perception or sensation is the revealing of radiant energy by the receptors and the clarification of this visual stimulation by the human brain. Misperceptions exist in different types of color vision:

Achromatism: Entire shortage of hue sensitivity;

Dichromatism: Sensitivity to only two major hues, generally both red and green are not perceived;

Trichromatism: Sensitivity to all three hues with abnormality or deficiency in one of the three primary pigments or colors in the retinal cones [57].

2.5.6. Fatigue

Fatigued eyes cannot sense color as perfectly as vigilant eyes. Compromised visual sensitivity occurs due to local, general or mental fatigues. Succeeding shade selection (managing several patients necessitating shade evaluation during a single day of work) can be a main reason for fatigue [57].

2.5.7. Binocular Difference

Binocular difference is the difference between the perception of the right and left eye. Positioning of shade tabs below or above, rather than next to, the tooth of interest will support the removal fault caused through binocular difference [58].

2.5.8. Environmental Influences

The position in which an object is observed can impact the perceived color. The background and environment can influence the permeations or saturations and the hues perceived. A patient's facial appearance, make-up, dental instruments' reflection and even walls can change the color of the oral setting and the shade sample, which can affect the shade measurement. Hence, it is suggested that before shade measurement of a tooth, patient's make-up should be removed and all those dental instruments creating reflection must be cleared from the surroundings to develop a neutral gray background in order to lessen the effect of surrounding colors so as to determine perfect shade match [59].

3. Conclusions

Before evaluating and selecting the precise color shade for the restoration of teeth, it is important to understand the fundamentals of color and light, the electromagnetic spectrum and the visual characteristics of the item. The accurate assessment of a tooth color and shade can be possible by applying a number of techniques and using devices containing visual analysis with shade guides, colorimetry, spectrophotometry and computer exploration of digital images, as they are very useful and appropriate tools for the measurement of tooth color and shade and are considered as a quality control for the restoration of teeth.

Additionally, as they can support the desired esthetic outcome, both instrumental and visual color selection and matching procedures should be used.

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