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Review Article

Shade selection in esthetic dentistry

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ABSTRACT

For dentists, selecting the exact tooth color is a complex task when restoring the natural appearance of teeth. Several factors can affect the determination of shade, such as the lighting conditions, the teeth's condition, the viewing angle, the background, eye fatigue, color vision impairments, and medication use. Thus, it is crucial to have complete knowledge about different shades and criteria for their selection to achieve the best results. In order to attain optimal esthetics, four critical elements are necessary: precise position, shape, surface texture and shade. This article focuses on various aspects of color and shade, the optical properties of teeth, the factors that contribute to shade determination, and the visual and instrumental methods used for shade matching.

1. Introduction

Ensuring patient satisfaction with the shade match is essential when fabricating a restoration. However, it is important to recognize, the patient's perception of color, may not necessarily be same as that of dental practitioner. Recently, a sharp rise in aesthetic expectations among the patients have been observed. Determining color and shade is typically thought to be challenging in dental practice. A poor choice of shade is the main aesthetic reason why most prostheses fail. For accurate shade matching, it is crucial to have a solid understanding of color and it's different aspects.[1] The integration of conventional shade guides and modernized shade-taking devices, along with advancement in human color vision research, has enhanced the ability of dentists to achieve excellent color-matched restorations. However, to achieve optimal results, it is essential for dentists to possess a comprehensive understanding of color and the natural appearance of teeth in addition to utilizing these new devices.[2]

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2. Discussion

2.1. Color

Color is psycho-physical sensation provoked in the eye by the visible light & interpreted by the brain. There are three different measurable characteristics of all colors, which are commonly known as the three dimensions of color, hue, value and chroma. Hue is the fundamental tone of a color which is determined by the wavelength of reflected and transmitted light and it is used to describe the primary dominant color of tooth. Value, on the other hand refers to relative lightness or darkness of color i.e. grey scale. Intensity or saturation of basic hue is known as chroma which distinguish between a strong color from a weak color.[3] Recently introduced fourth dimension of color i.e. transluceny which can be defined as gradient between transparency and opaqueness[4] The color of the teeth depends on: The light falling on the teeth i.e. illumination, object i.e. the teeth themselves and their surroundings and the observer

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2.2. Properties of light affecting shade perception[5] (Figure 1)

2.2.1. Reflection (Figure 1A)

The colour of an object that one observes is actually the reflection of the light that strikes it. The amount of reflected light helps to determine the brightness of a tooth (ie, the more light that is reflected, the brighter the tooth will appear).[4]

2.2.2. Absorption (Figure 1B)

It is the most common cause of the creation of color when an object selectively absorbs some wavelength from white light while reflecting some other wavelengths. Light is absorbed by teeth and occurs to a greater extent in dentine than enamel.[5]

2.2.3. Transmission (Figure 1C)

When light passes through a transparent medium such as a plain glass, it is neither reflected nor absorbed but totally transmitted through.[4]

2.2.4. Refraction (Figure 1D)

When a light beam travels from one medium to another, both with different refractive indices, the light beam is deflected within the body of the incident material. The splitting of white light by a prism into different colors is due to refraction.[3]

2.2.5. Scattering (Figure 1E)

Scattering of the light occurs, when any process changes the direction of the light beam. Light entering the tooth hits various tooth structures and is dispersed in almost all directions.[4]

2.2.6. Fluorescence (Figure 1F)

Fluorescence is a property where a specific wavelength of light is absorbed and then re-emitted as a radiation of a longer wavelength. In a natural teeth, fluorescence generally occurs in dentin due to higher concentration of organic material present. The greater the amount of dentin fluorescence, lower the chroma of the tooth. Fluorescence is considered a subset of reflectivity. Teeth appear to be fluorescent when viewed under a black light. Ceramic crowns that lack a fluorescent component, can give a grayish and non vital appearance[3] (Figure 1-F-a,b).

2.2.7. Metamerism (Figure 1G)

It refers to the the phenomenon of two objects appearing to match in color under one condition but showing differences under another. Performing shade selection under different light sources such as room light, day light and incandescent can prevent metamerism.[6]

2.3. Various color notation systems[7]

Munsell system: In 1915, Albert Henry Munsell created numeric system of color.The "color wheel" forms the dimensions of hue, value, and chroma. Hues are uniformly spaced around the central axis of the color wheel. The chroma increases, along a radius from the axis. The value coordinates varies along the length of the cylinder from black at the bottom, to neutral grey at the centre, to white at the top.

Cielab color system: CIE (Commission Internationale de l'Eclairage, International Commission on Illumination) L*a*b*. It is a three-dimensional color space consisting of –• L*: which represents value by the vertical achromatic axis. The scale ranges from 0-pure black to 100-pure white. • a*: is the green-red chromatic coordinate(–a* green, +a* red)• b*: is blue-yellow chromatic coordinate(–b* blue, +b* yellow)Color measuring devices currently used in clinical practice and related researches use the CIELAB color space for color measurements.

2.4. Teeth and their surroundings

2.4.1. Condition of teeth

Teeth to be matched must be clean. Plaque and stain removal should be done prior to shade selection of the tooth and moisture should be retained in teeth. The treatment procedures dehydrate the teeth and teeth become lighter and less chromatic so shade selection should be done before starting procedures.[8]

2.4.2. Field of view

The field of view should be free from any bright coloured object. The patient should be asked to remove any make-up or accessories that he or she is wearing. The dark red lipcolor next to the tooth being evaluated will fatigue the red receptors, while the blue and green receptors remain fresh and can be fully stimulated. Also the observer should remove any bright coloured gloves if wearing. The operatory wall should not be brightly painted.[4] The neutral gray is frequently recommended for color matching in dentistry. However, black contransters are frequently used for professional picture. An 18% reflective gray colour is an excellent background for evaluation of hue and chroma.[8]

2.4.3. Working distance

It is extremely important that the patient be in an upright position when the shade is selected so that the teeth may be viewed in the clinic under the same conditions under which they will be seen in his day to day life. The comparison should be performed with the clinician's eyes at tooth level, 25 to 35 cm (10 to 14 inches) away. The verification of the shade should be made on more than one occasion & also in the presence of second individual such as dental assistant.[9]

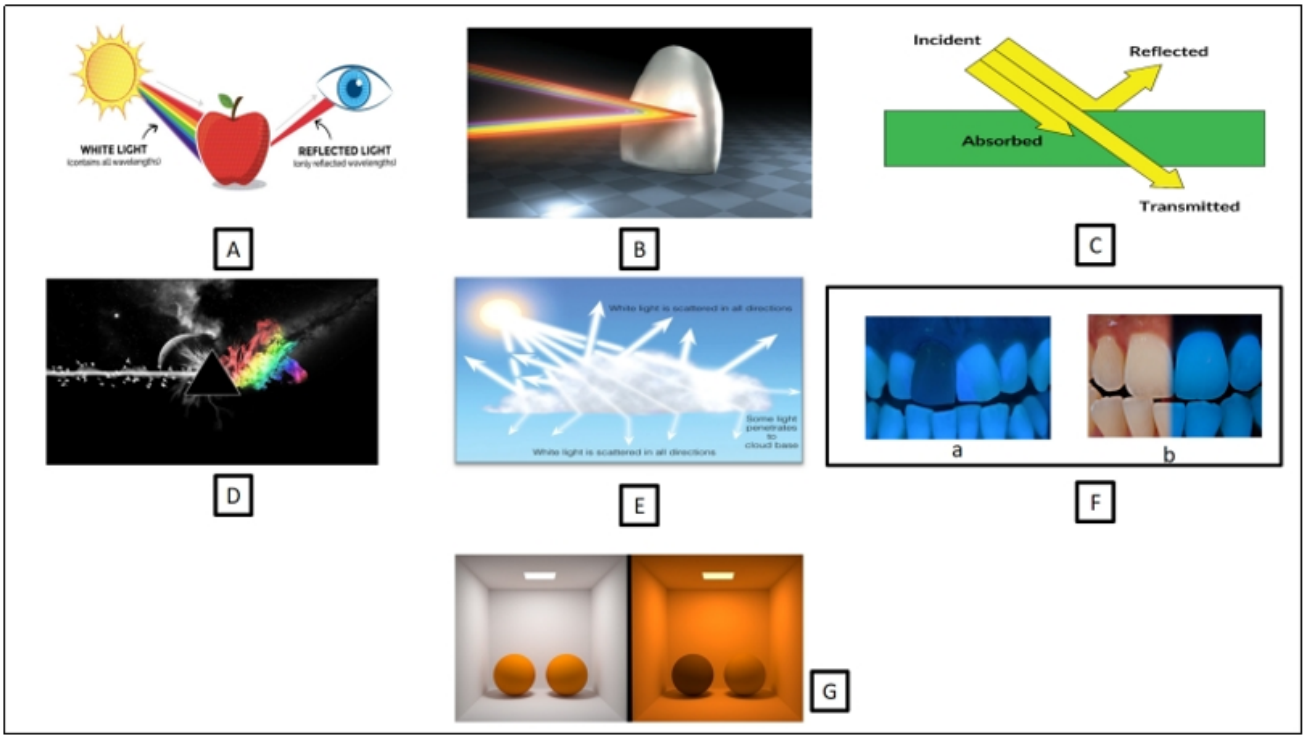

Fig. 1: Properties of light affection shade perception

2.4.4. *Position of tab*

The tab should be placed in the line of the tooth itself, otherwise tab kept ahead will appear more bright while the one behind will appear darker. Also, holding the shade tab over a tooth can give a false impression of the color as the background of the tab is the tooth colour and not the oral cavity.[10]

2.4.5. *Operating site lighting*

Sunlight is the traditional source of light for performing work involving colour. Sunlight in the mid portion of a day that is slightly overcast is considered to be the excellent source. This is known as standard daylight. There are different light sources available commercially for shade selection such as demeteron shade light and rite lit. They are handheld portable lamps, influence of surrounding colors is significantly reduced with these portable lamps.[10]

2.4.6. *Light intensity*

The intensity of light used for shade matching is critical, as both low and high intensities can lead to decreased accuracy in color rendering. Dental unit lights are not recommended for this purpose due to their excessive brightness and tendency to cause glare. The ideal luminosity range for dental shade matching is between 75 to 250 foot candles. To ensure that the recommended color temperature is achieved in the shade-matching area, a color temperature meter should be used periodically. Color-corrected lighting with an ideal color temperature of 5,500 K (D55) to 6,500 K (D65) is preferred for this purpose.[11]

The color should be confirmed by taking patient to the window in the natural daylight after initial selection under incandescent & fluorescent lighting. Teeth tend to appear slightly yellow under artificial light sources like incandescent, fluorescent, etc, whereas fine under the sunlight, due to their inherent yellow hue.[12] If the clinician or the lab technician has access to a natural light source, shade matching should be performed from 10 in the morning to 2 in the afternoon on a clear, bright day when the ideal color temperature of 6,500 K or 5,500 K is present.[13] These guidelines help ensure accurate and consistent shade matching, resulting in better esthetic outcomes.

2.5. *Different contrast in Shade selection*

2.5.1. *Hue contrast*

Hue contrast means color is different when viewed in conjunction with various background colors with contrasting hues. The teeth appear to take the hue of the background's complementary color. For example, a tooth or restoration will appear bluish against an orange background, and purplish if the background is yellow[14]

2.5.2. Value contrast

Value contrast refers to relative lightness of an object and is affected by the lightness of the contrasting background. If the surrounding background is dark, an object will appear lighter. However, if the same object is placed against a lighter background, it is perceived as darker.[15]

2.5.3. Chroma contrast

Chroma contrast means an object will appear more intense against a background that is low in chroma and vice versa.[15]

2.5.4. Area contrast

Area contrast refers to the phenomenon where a larger image or surface area appears lighter due to its ability to reflect more light back to the observer. If the goal is to create an illusion of a narrower restoration, a low value of shade should be selected.[4] This is because low value shades tend to absorb more light, and reflects less resulting in darker appearance.

2.5.5. Spatial contrast

Spatial contrast means teeth that are rotated and/or recessed relative to the adjacent teeth appear to be darker, thus recessed teeth can be made lighter.[16]

2.5.6. Successive contrast

Successive contrast means a positive or negative afterimage of the colored tooth will be seen in the blank tooth after brief or long visual contact. So it is advised to take breaks in between looking at different shades to avoid the effect of after images.[17]

2.6. Shade selection also depends on observer[12]

2.6.1. Age and experience

As individuals age, their shade matching skills may deteriorate due to changes in their vision. The cornea and lens of the eye can become yellowed with age, leading to bias towards yellow- brown color. Additionally, after the age of 60, many people face problems in distinguishing purple and blue colors. As a result, images are observed as more of yellow and brownish with increasing eye age. However, the ability to accurately select or match shades can be develop through experience. As dentist gain more experience, they can improve their shade matching abilities, even if their vision changes with age.[13]

2.6.2. Gender

Generally, women are expected to experience more shades of color than men. What may be simple "purple" to a man, but it could be "lavender" for a woman. Neuroscience says women are better at distinguishing among distinctions in color. Also, linguistic researchers say that women possess a larger vocabulary of shades to describe color than men. The scientists believe that the differences in men's and women's hormones can alter development in the visual cortex leading to differencing in color perception in men and women.[8]

2.6.3. Eye color

There is some evidence to suggest that amount of melanin in the eye may play a role in an individual's ability to perceive color. Brown- eyed individuals typically have more melanin in their eyes then those with lighter eye colors, which may allow them to absorb more light and wavelengths. However, this does not necessarily mean that brown eyed people are better at shade matching than those with lighter eyes. While eye color may have some influence on visual perception, color acuity is a complex process that is influenced by many factors including lighting conditions, age and individual variations in the sensitivity of eye's photoreceptors. Ultimately the ability to accurately match shades, depends on a combination of factors, including training, experience and use of appropriate shade matching tools and techniques.[18,19]

2.6.4. Medications

The abuse of the drugs, alcohol and caffeine will affect the judgment, and color perception. A drug used to treat erectile dysfunction (Viagra), is known to cause blue tint in the vision. Of special concern for female practitioners are the side effects caused by oral contraceptives, i.e., red, green or yellow, blue discrimination defects. Long use of oral contraceptives will cause a reduction in yellow and blue color perception.[20]

2.6.5. Binocular difference

The difference between the perception of the right and left eye is known as binocular difference. For testing binocular difference, two objects are placed side by side under uniform illumination. They may appear different, e.g., the one on right may seem slightly lighter than the one on the left. Placing shade tabs either below or above the tooth to be matched will help to eliminate error caused by binocular difference. Viewing tabs through half-closed eyes can decrease ability to discriminate color but increases the ability to match value.[21]

2.6.6. Eye fatigue

If the eyes are tired, they cannot perceive color as accurately as alert eyes. Any compromised visual perception can be due to systemic, local or mental fatigue. Shade comparison should be made quickly to avoid the potential for eye fatigue in the clinician which can cause similar colors to look the same, so short glances of 2-3 seconds with periods of rest, instead of prolonged stares, are recommended and trials should be limited to 5 to 7 seconds at a time.[22]

2.6.7. Color blindness

Color blindness is a condition in which the individual has difficulty perceiving certain colors and distinguishing between them.[22,23] This condition can be classified as-

1. Achromatism: Complete absence of hue sensitivity leads to inability to perceive any of the color.
2. Dichromatism: Lack of sensitivity to two major hues, usually both red and green are not perceived.
3. Trichromatism: Sensitivity to all three hues with deficiency in one of the three primary pigments or colors in the retinal cones.

2.7. Methods of Shade Selection[24]

There are two methods:- Conventional and Technology based.

The visual shade guide is the basic and the most convenient way in selecting tooth shades.

2.7.1. Visual shade guides

Shade guides used in dentistry are comprised of a set of individually fabricated colour standards, which mimic the colour of dental structures. They are used to determine a colour match visually with natural teeth. They can be prefabricated or manufactured individually and can be used to match ceramic or composite resin. They are very cost-effective and easily available; they also proficiently match the color of the dentition with a standardized reference shade guide. The selection of tooth color by the shade tab method completely depends on human eye observation.[25] Various shade guides are commercially available, some commonly used are:-

2.7.1.1. Vita classical shade guide. The color space is divided into four groups: A, B, C and D; these comprise the leading HUE (name of color). These are A group has red and brown, red and B has yellow in group, gray in group C, and D has red and gray in group. Every letter group has sub-divisions indexed with arabic numbers, ranging from 1 to 4, which makes the overall number of 16 tabs. As the number increases, the value decreases, whereas the chroma increases simultaneously.[26]

Limitations of vita classical shade guide: It is not positioned uniformally throughout tooth color space, no standard incremental difference between adjacent shades and in between shades are not accurate. These limitations led to the introduction of more shade guides.[26]

2.7.1.2. Vita 3D-Master. There are three types of Vita 3D-Master shade guides: Toothguide, Linearguide, and Bleachedguide. 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 and the development in distribution of groups has improved and become more concise.[27]

2.7.1.3. Chromascop. Chromascop uses a numbering system to identify shades. It is organized into various groups depending on the hue (100-white, 200-yellow, 300-orange, 400-gray, 500-brown) and within the groups as chroma increases from 10 to 40.[28]

2.7.1.4. Custom shade guides. The standard shade guide cannot cover the entire range of hue and chroma values of human dentition. It is useful for 85% of the color selection, and its alteration or preparation of custom shade tabs is necessary for the remaining 15%. Composite resin, ceramic, or acrylic materials can be used to fabricate custom-made shade guides. Shade guide modifications can be performed surface abrasion by using aluminum oxide or by using surface colorants. Fine line markers and colored pencils may be used to reproduce the minute variations between shades, analogous translucency, and denominating colors.[29]

Disadvantages of shade guides[30]

The disadvantages of shade guides are described as follows: (a) the colors in shade guides differ of each and manufacturing company; (b) porcelain used for restoration may be different to that used in a guide; (c) guides are unable to direct the fabrication of porcelain/ceramic restorations; (d) the shades in a guide are not organized and do not cover the volume of color space that exists in natural dentition; (e) a standard shade tab is made using synthetic resin and has thickness greater than that of a crown; (f) a shade guide tab reflects and transmits light, creating translucency and an appearance of vitality, however, for a restoration, light is reflected and is less likely to be transmitted, which makes the restoration appear opaque and dense.

2.7.2. New technology-based systems were brought to market to combat the subjectivity inherent in conventional methods that is colorimeter, spectrometer, digital camera and smartphones.[31]

There are many advantage of digital shade analysis

1. It gets rid of subjectivity while performing shade selection.
2. The results are reproducible reliable, and precise as compared to traditional visual systems.
3. If the dental practitioner and the laboratory are using the same software then it is possible to replicate the desired shade completely.
4. It gets rid of the environmental influencing factors because it uses light corrected sources.
5. Involves less chair-side time.
6. The quality control aspect is a real advantage.

2.7.2.1. Spectrophotometer. Spectrophotometers are the most useful, exact and adaptable instruments for color matching in dentistry. They measure the amount of light

energy reflected from an object at 1 to 25 nm interval along the visible range. A spectrophotometer contains a source of optical radiation, a detector, a means for scattering light, an optical framework for estimating and a means of converting light obtained to a signal that can be analysed. The information got from spectrophotometers must be manipulated and converted into a valuable form for dental experts. The measurements got from the instruments are often keyed to dental shade guides and converted to shade tab equivivalent. Examples of spectrophotometers are vita easyshade compact, shade-x, spectroshade micro, crystaleye etc.[32,33]

2.7.2.2. Colorimeter. Colorimeters measure tristimulus values and filter light in RGB (red, green and blue) areas of the visible spectrum. It uses 3 or 4 silicon photodiodes that have spectral correction filters. They do not register spectral reflectance and can be less accurate than spectrophotometers (aging of the filters can additionally affect accuracy). They deliver color information accuracy like that of spectrophotometer and reduce the data load time by avoiding unnecessary color mapping associated with spectrophotometer. It provides greater data efficiency because they store only three data points of hue, value, chroma.[33] Examples of colorimeter are shadevision, optishade etc

2.7.2.3. Digital camera. Consumer video or digital still cameras, commonly referred to as RGB devices, acquire red, green, and blue image information that is utilized to create a color image. Digital cameras are not color-measuring instruments, and they primarily enhance communication between the dentist and the laboratory technician.[34]

Disadvantage of digital shade matching[35]

The color measurement accuracy is affected by the type of lighting used, the condition of teeth being measured (such as presence of stains/ restorations), and the operator's experience and techniques. It is important to take these factors into account and use appropriate techniques and instruments to ensure accurate color matching and restoration.

2.8. Communication with Lab

For a successful matching of shade of indirect restoration, effective communication between the laboratory technician and the clinician is important. Clinician should send photos along with the shade tabs as reference to the lab technician. An aggregate photograph of the selected tabs should be clicked near the dentition, along with photographs of the patient's face and full smile.[12]

3. Conclusion

Understanding the fundamentals of color and light, is crucial for achieving accurate shade matching in dental restorations. In addition to visual analysis with shade guides, modern technologies such as colorimetry, spectrophotometry and digital imaging can also be used to help dentists and technicians achieve better control over the restoration process and achieve optimal results. These tools allow for more objective and precise measurements of tooth color and can help to minimize the impact of factors such as lighting conditions and observer viability on final shade selection.

4. Clinical Significance

Shade matching is the core of esthetic dentistry. Matching the accurate shade satisfies both dentist and patient and gives pleasing appearance to the patient.

5. Source of Funding

None.

6. Conflict of Interest

None.

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