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# The Importance of Color in Dentistry: A Review

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Shade matching is a crucial aspect of restorative dentistry, playing a pivotal role in achieving aesthetic harmony and patient satisfaction. Replicating and reproducing the color of natural tooth with restorative material is a challenge. Shade selection is influenced by various factors, difference in which gives unsatisfactory results. Selection of shade play a important role in obtaining good esthetic restoration. This article discuss about dimensions of color, age related color changes in tooth, different shade selection methods like visual and digital, shade selection protocol using accurate methods and devices. Shade matching in dentistry is not merely a technical requirement but a holistic approach that combines scientific precision, technological advancements, and psychological considerations. Dentists must continuously refine their skills, stay abreast of technological innovations, and prioritize patient satisfaction to ensure the success of restorative procedures and the overall prosperity of their dental practice.

*Keywords: Colorimeters; intraoral scanner; shade matching; shade guide; spectrophotometer.*

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## 1. INTRODUCTION

Matching the color of a restoration with that of natural teeth is important for patient satisfaction. Due to increased demand for esthetics, composites and ceramics are being used more often to achieve a natural-looking appearance [1].

Natural teeth have varying shades, making shade selection difficult. Composite resins come in different enamel and dentin shades with varying translucencies and opacity. These shades are measured using the vita classic guide, making it easier to create a natural-looking restoration that matches the surrounding teeth [2].

The discoloration of tooth can be classified as intrinsic, extrinsic or combination of both. Intrinsic color of the tooth is associated with light reflecting and absorption properties of enamel and dentin (tetracycline stains). Extrinsic color of the tooth is associated with the absorption of external materials (eg- Tea, Chlorhexidine, Red wine) onto the enamel surface [3].

Colors exist due to the interaction of light with objects, which reflect particular wavelengths that are received by the eye's receptor cells. Brain then recognizes these wavelengths as specific colors [3].

Our perception of color can be influenced by factors like our physical environment and individual physiology. These factors include background effects, lighting, color blindness, eye fatigue, binocular differences, age. For color to exist, light, object, and a viewer must all be present and interact [4].

## 2. IMPORTANCE OF COLOR IN DENTISTRY

Color matching is crucial in restorative dentistry to achieve patient satisfaction and aesthetic harmony. Even a slight color change can be noticeable and make the patient unhappy. Understanding color perception and reproduction is crucial for shade matching, using pigment colors and dimensions of color. By prioritizing color matching, dentists can ensure the success of their restorative procedures and prosperity of their practice [4].

Color is an important aspect of dentistry, as it impacts the appearance of dental restorations. Pigment color contributes to the hue of an object, and understanding primary, secondary, and complementary colors is important for achieving accurate and esthetic shades in materials like composite and ceramics Fig. 1 [4].

**Primary colors:** Red, Yellow, Blue.

Red color is perceived when the green color is absorbed; yellow color is perceived when the blue color is absorbed; and blue color is perceived when the red color is absorbed [4].

**Secondary colors:** Orange, green, violet - They are formed by combination of 2 primary colors.

**Complementary colors:** When two complementary colors are combined, they create a dull gray that absorbs and reflects all wavelengths equally. This fact can actually be quite useful in a clinical setting, as it allows for the combination of complementary colors to reduce the brightness of restorations that may be too bright [3].


**Fig. 1. The terms red, yellow, and blue refer to the three fundamental pigment hues. When two primary colors are combined, orange, green, and violet are the colors of the secondary pigment. Gray is created when complementary hues are combined and neutralize one another**

## 3. DIMENSIONS OF COLOR

**Hue-** It describes the pigment of tooth or dental restorations (blue, red or yellow).

**Value-** measures the light or darkness of hue. Value is 0 for black and value 10 for white.

**Chroma –** defined as a saturation of the hue. The value and chroma are inversely related. As the value decreases chroma increases [4,5,6].

## 4. COLOR CHANGES OF TOOTH RELATED TO AGE

Multiple factors could be responsible for the influence of age on the color of the teeth:

1. Gradual decrease in the pulp chamber with compensatory deposition of secondary dentin.

2. The secondary dentin is darker and less porous.

3. Darker dentin color results from the gradual reduction of the enamel thickness caused by wear and tear.

4. It has been noted that dentine enamel junctions with deposition of organic and inorganic pigment have more saturated dentine chroma.

## 5. DIFFERENT METHODS OF SHADE MATCHING

### 5.1 Visual Method

Visual shade selection uses dental shade guides to check the shade of the teeth or restoration. The shade tabs are placed near to the tooth in the same plane. Then, for fabrication of a restoration, the shade that is most similar to the shade of the tooth and shade of the surrounding teeth and restorations is chosen. Shade guides should have specific characteristics like proper distribution in color space, rational arrangement, acceptable precision and accuracy [3,5].

#### 5.1.1 Dental shade guides

Dental shade guides can be categorized according to their concept (theoretical, empirical, evidence-based), fabrication type (custom or stock), material (ceramic, composite resin, or acrylic resin), and shape (strip, disk, or tooth-shaped). There are no changes in shade matching precision between tabs and disks. These are made of different materials like composite resin, ceramics, denture teeth. Manufacturers have created their own shade guides for the products due to variations in colors and optical properties among different materials and brands. To ensure a better match between the shade guide and the restorative material, it has been suggested to fabricate shade guides using the actual restorative material. This is because using nonhomogeneous shade guides may result in differences in shade and optical properties. Specifically, when it comes to ceramic restorations, using actual ceramic shade guides has been found to produce more acceptable color matching [3,5].

#### 5.1.2 Various conditions and factors related to visual method

The light source, the object, and the observer are the three variables that influence how an observer interprets an object's color. The electromagnetic radiation emitted by a light source can be identified by its color temperature. The temperature of an ideal black-body radiator that emits light with a color close to the light source's is known as the color temperature of the light source. The features of the object influence the shadow taking outcomes. When evaluating shade and translucency, teeth should be moist to prevent any influence on value, hue, and chroma, among other color qualities [7,8].

Wetting teeth and shade tabs with a medium-viscosity clear glazing liquid is advised since dehydrated teeth have more lightness, less chroma, and less translucency. This can also counteract the impacts of tooth morphology and surface roughness on the choice of shade. Therefore, choosing a shade should be done as soon as possible during the visit, preferably within the first minute, and before isolation or restoration procedures cause teeth to become dehydrated. Matching shades by the observer determines how effective shade selection is. Age, gender, experience, kind of shade guide, training, potentials for color perception, and illnesses can all have an impact on this capacity. Despite the fact that gender has been acknowledged as a significant factor—that is, the fact that women perceive color better than men [9,10,11].

The accuracy and precision of the observer might be positively impacted by professional

experience. For shade discrimination, precisions between and among observers are essential. Experienced general practitioners have a lower intra-observer precision of the visual approach than prosthodontists. There have been reports of interobserver precision ranging from 22.5% to 55% for observers without color vision deficiencies, with intra-observer precision estimating from 11% to 64%. If VITA 3D-Master (Fig. 2) is used instead of VITA classical, the interobserver color matching could be lessened [3,5,12,13].

### 5.1.3 VITA 3D-master -instructions for use:

STEP 1- Determining the lightness level (value):

When selecting the shade for a patient's teeth, it's important to hold the shade guide at an arm distance to their mouth. You can choose from groups 0, 1, 2, 3, 4 or 5. It's best to start with the darkest group first to get an accurate representation of the shade.

STEP -2 Selecting the chroma:

Selecting the middle hue group (M) will allow you to select the chroma once you've determined the brightness level. Choose one of the three shade samples that have been spread out like a fan.

STEP-3 Determining the hue:

Verify whether the natural tooth's color is more yellowish or reddish in relation to the chosen shade sample [6,14,15].

### 5.1.4 Factors affecting clinical shade selection:

Shade guides are another name for shade-matching devices. Value, chroma, and hue selection come first in the shade choosing process.

A methodical approach to color matching is necessary to guarantee precision, consistency, and predictable outcomes—all of which are crucial for aesthetic dentistry [16].

#### i. Operating site lighting

Midday sunlight provides an approximately equal distribution of all light wavelengths, making it an excellent opportunity to choose the perfect shade. In contrast, exposures in the morning and evening tend to have more wavelengths that are reddish and yellow in color [17,18,19].

#### ii. Environment

When it comes to color matching, it's best to avoid bright-colored surroundings as they can interfere with the process by influencing the colors in the reflected light. Additionally, if a patient's clothing or jewelry has undesirable colors, a drape can be used to mask them. It's also important to remove lipstick before color matching to prevent it from affecting color perception. Try to make your selection quickly and trust your initial decision, since your eyes can tire after approximately 5-7 seconds [18,19].

#### iii. The state of the teeth

Plaque, deposits, and surface stains should not be present on the tooth of interest or the teeth nearby. Furthermore, saliva should be applied on the tooth to ensure that it is wet, as dehydration can make the tooth appear whiter. It's crucial to do color matching before applying the rubber dam to guarantee a good match because the tooth may get drier afterward [19,20].


**Fig. 2. VITA 3D MASTER Shade guide**

**iv. The patient's position and the operator's distance from the tooth**

For shade matching, the recommended distance from the mouth cavity is between 61 cm (2 feet) and 183 cm (6 feet). The dental chair should be adjusted so that the patient's teeth are level with the operator's sight.

## 5.2 Digital Methods

For choosing a dental shade, a variety of instruments are available, including intraoral scanners, digital cameras, spectrophotometers, and colorimeters. Features like shock-proof construction, simple control, quick measurement, respectable working life, appropriate light source, affordable price, accuracy, and precision are all important for a color-measuring gadget. It is essential to take these things into account while choosing a device [20,21].

### 5.2.1 Colorimeters

A colorimeter is an optical instrument that uses filtered photodetectors to read the visible spectrum. Originally, the response of the human visual system was simulated using three glass filters (red, green, and blue), whose transmittance spectra mimicked the CIE color matching functions. A filter bank was then used to improve the accuracy of the gadget. To determine an object's color, the colorimeter's sensors may calculate the total of the various wavelength spectra that the object reflects. Thanks to advancements in sensor technology, colorimeters can now measure opaque objects with accuracy [22].

Dental colorimeters use light reflection to measure tooth shade. Compared to visual approaches, they provide more accurate measurements and remove inaccuracies [23].

### 5.2.2 Conditions and effective factors pertaining to colorimeters

Results from colorimeters can differ for a variety of reasons. Errors may arise from a variety of factors, such as variations in color among identical nominal shade tabs, difficulties interpreting translucent objects, and variations in color value assessment algorithms. However, with the right orientation, a consistent distance between the instrument and the tooth, and an appropriate specimen port opening size, accurate measurement can be obtained. It's interesting to note that colorimetry appears to be most stable near the middle of the labial tooth surface. According to studies, there is only roughly a 30% match in CIELab values between the colorimeter and camera outputs when it comes to accuracy. This discrepancy may be caused by variations in L* and b* values even though the a* values are close. Concerns have also been raised regarding colorimeter accuracy, since some research indicates that they can be 10–20% less accurate and produce lighter hues than spectrophotometers [3,5,24].

### 5.2.3 Spectrophotometers

Spectrophotometers can measure an object's color by analyzing its transmittance curve or spectral reflectance. They provide light output in the 400–700 nm wavelength range using a white light source, which can be an LED lamp or a tungsten filament bulb [25]. After that, the light is focused via a prism to produce a spectrum of wavelength bands, usually ranging from 10 to 20 nm. After then, the light is focused on the object, where it may scatter, pass through, or reflect. The quantity of light that the object emits or transmits through it for each visible spectrum wavelength band is then measured by the spectrophotometer. It's critical that handheld spectrophotometers have properties including high accuracy and precision, high shock resistance, simple control, quick measurement, respectable working life, suitable light source, and affordable price. Certain dental spectrophotometers have the ability to use a mouthpiece to separate the oral cavity from outside light, removing the influence of ambient light on color readings. The tooth shade is calculated using VITA 3D-Master and VITA classical, and the CIE L ab/CIEL Ch values are measured with the VITA Easyshade spectrophotometer (Fig. 3) [3,5,25].

One of the most representative dental spectrophotometers is SpectroShade, which is also quick, accurate, and simple to use. Digital color imaging and spectrophotometry based on LED (light emitting diode) technology are combined in SpectroShade Micro (Fig. 4). The linear polarized filter on this instrument helps to eliminate gloss reflections. The device memory stores a variety of shade guide data, allowing for the comparison of obtained images with various shades. Its program can perform coarse and fine color mapping, email data to labs, and offer virtual examination by superimposing the restoration image over the dental image. With the

ability to compare two color measurements, SpectroShade Micro may be used to map dental surface inhomogeneities, assess teeth both before and after treatment, and ensure that the restoration is an accurate replica of the original tooth [3,26,27].

The spectrophotometric results are influenced by the tooth's position. Tooth surface (mesial or distal portions) and tooth type (posterior teeth, lower incisors) have an impact on SpectroShade's repeatability and reproducibility. The labial surface of the lower incisors and the convex surfaces of the posterior teeth must therefore be measured carefully. The type of processing—freehand or standardized—certainly influences the outcome. To prevent the effect of probing angulation and also similar areas of the teeth, the use of specially designed acrylic jigs is advised in this regard. Exceptional precision is what dental spectrophotometers provide, not great accuracy. Nevertheless, taking into account their precision (87.4% to 99.0%) and accuracy (66.8% to 92.6%) [3,5,28].

### 5.2.4 Intraoral scanners

Even though intraoral scanners were first used to take digital impressions, some of them came with a dental shade guide tool. The device makes use of a portable digital scanner with a high-definition camera inside. Following an LED light scan of the teeth, software analyzes the tooth's color and displays it using VITA shades rather than color characteristics. The restoration is fabricated using the chosen shade and digital imprint [29,30].

**Fig. 3. VITA Easyshade Spectrophotometer**


**Fig. 4. Spectro shade Micro Spectrophotometer**

### 5.2.5 Conditions and effective parameters pertaining to intraoral scanners

Intraoral scanners need to meet two important criteria in order to be taken seriously as a feasible method of shade selection: color imaging and data processing. While intraoral scanners are capable of measuring tooth color and gathering three-dimensional data from the tooth surface, there are several circumstances that could compromise their capacity to match colors. Dental shade guides are used by intraoral scanners to display color results. having the use of VITA shade guides as references, an LED light, a high resolution camera, and color analysis software. More recent scanners, such TRIOS 3 Fig. 5, demonstrate both superiority over the eye approach and findings that are comparable to those of a spectrophotometer [31,32].

In contrast to spectrophotometers, lighting conditions can have an impact on intraoral scanners operating in VITA Classical or 3D-Master mode. As a result, it is advised to estimate the shade using a second instrument. When the shade is recorded as VITA 3D Master shades (53.3% accuracy, 90.3% accuracy) rather than VITA Classic shades (27.5% accuracy, 87.2% accuracy), TRIOS 3 has higher accuracy/precision. Furthermore, there is a discrepancy between the shade results obtained from the spectrophotometer and the intraoral scanner. Generally speaking, factors including ambient light, image capture, color analysis software, and the tone control mode being utilized affect the choice of shade while using scanners [3,5].

### 5.2.6 Accuracy and precision of intraoral scanners

SpectroShade Micro, SpectroShade, VITA Easyshade, and VITA Easyshade Advance 4.0 all have better shade matching accuracy than Trios 3. Though TRIOS 3's precision is respectable (>85%), it is not as accurate as a spectrophotometer that has undergone validation.

Intraoral scanners and Spectrophotometers are more accurate than visual techniques that rely on a skilled clinician's shade guidance, whether or not a light correction device is used. While some researchers suggest using an intraoral scanner instead of a spectrophotometer for shade selection, others come to the conclusion that a scanner like the CEREC Omnicam cannot match shades accurately enough. TRIOS has a maximum color measurement precision of 86.66%, whilst TRIOS 3 has a maximum precision rating of 87.17% to 90.33%. While accuracy ranged from 44.3% (Easyshade V) to 51.9% (Omnicam), it was 78% for Easyshade V, 66% for TRIOS, 57% for Omnicam, and 63% for Primescan. Because scanners use a non-polarized light source, they are able to report lighter hues than spectrophotometer and visual approaches [3,5,29].


**Fig. 5. TRIOS intraoral scanner**

## 6. CONCLUSION

Everybody has a unique way of seeing color. Understanding the fundamentals of color and the variables that may influence the dental and color judgment is therefore crucial. The dentist has to take a few things into account when applying conventional shade matching methods. Appropriate selection of tooth shade yields positive outcomes and patient and dentist satisfaction. A difficult process that has a big impact on how restorative treatments look is choosing the hue of the teeth. There have been successful attempts to increase tone accuracy and precision by switching from subjective visual approaches to objective computer ones.

## CONSENT AND ETHICAL APPROVAL

It is not applicable.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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