# SHADE MATCHING IN RESTORATIVE DENTISTRY: THE ART AND SCIENCE

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**ABSTRACT**

Esthetic dentistry seeks to achieve harmony between illusion and reality by creating smiles that integrate teeth, gums, and facial features naturally. A central aspect of this process is color perception, which depends on the interaction of light with dental materials and the human eye's interpretation. Color in dentistry is defined by three primary attributes—hue, value, and chroma—described by the Munsell color system, while additional optical properties such as translucency, opalescence, and fluorescence significantly influence restorative outcomes. To standardize shade matching, both visual and instrumental methods are employed. Visual techniques commonly use shade guides such as Vita Classic, Vita 3D Master, Chromascop, and Bioform, whereas instrumental techniques rely on devices like colorimeters, spectrophotometers, and digital imaging systems for objective measurements. The CIE Lab color system further enhances accuracy by numerically defining color in three-dimensional space (L*, a*, b*). As esthetics becomes increasingly important to patients, mastering shade selection and understanding color science are essential for predictable, natural, and harmonious dental restorations.

**Keywords:** Colour ,Hue value chroma Munsell system vita classic

## INTRODUCTION

Achieving the right balance between illusion and reality lies at the heart of esthetic dentistry. This harmony is referred to as perception—the aspect related to how appearance is visually interpreted. The primary goal is to create an attractive smile—not just by shaping beautiful teeth, but by ensuring the teeth have natural proportions and blend seamlessly with the gums, lips, and face.

Effective esthetic restorations rely heavily on understanding how light interacts with materials and how the human eye and brain perceive color. Over recent decades, the importance of color research in dentistry has grown significantly. Dentists must consider both artistic and scientific principles of shade matching when designing esthetic prosthetics.

As esthetics has become increasingly important to both patients and practitioners, it is now essential to provide restorations that integrate naturally with the patient's facial features and existing teeth.

Ultimately, the goal of esthetic dental work is to produce a smile that is both visually appealing and harmoniously integrated. This involves aligning the teeth, gums, and facial features in a natural balance. This article explores the essential color properties that must be considered in esthetic dentistry, along with various tools used for shade selection.

## NATURE OF COLOUR:

Color is explained by making reference to a sensation which is captured by our eyes. The human eye is an organ that is receptor of images obtained from an electromagnetic radiation that we refer to as light. It actually corresponds to a narrow segment between the 400 and 800 nm wavelengths approximately of the entire spectrum. We call it as rainbow. When white light is illuminated to object, the color we see has not been absorbed and that light is reflected to our eyes is color is object. So this fact tells us that the quality of light plays an important role in perception of color of an object **(. Rakesh Vadher,2014)**

## MEASUREMENT OF COLOUR

### Munsell color order system:

Color is usually described according to the Munsell color space in terms of hue, value, and chroma. Hue is the attribute of a color that enables the clinician to distinguish between different families of color, whereas value indicates the lightness of a color. Chroma is the degree of color saturation. When color is determined using the Munsell system, value is determined first followed by chroma. Hue is determined last by matching with shade tabs of the value and chroma already determined **(Vimal k Sikri,2010)**

### Hue

It is the quality that distinguishes one family of color from another. It is specified as the dominant range of wavelengths in the visible spectrum that yields the perceived color, even though the exact wavelength of the perceived color may not be present. Hue is a physiologic and psychologic interpretation of a sum of wavelengths. Hue is represented by A, B, C or D on the commonly used Vita Classic shade guide

### Value

"Value," or brightness, is the amount of light returned from an object . Munsell described value as a white-to-black gray scale. Bright objects have lower amounts of gray and low-value objects have larger amounts of gray and will appear darker. The brightness of a crown is usually increased in two ways: by lowering chroma or by increasing the reflectivity of the surface. Lowering value means less light returns from the illuminated object and the remaining light is being absorbed or scattered elsewhere.

**Chroma**

"Chroma" is the saturation, intensity or strength of the Hue. If any dye (say red) is added into a glass of water and the same dye is added again and again, the intensity increases, but the color remains the same (hue). As more dye is added, the mixture appears darker; thus, the increase in chroma has a corresponding change in value. As chroma is increased, the value is decreased; chroma and value are inversely related. Higher numbers on the Vita Classic shade guide represent increased chroma.

In addition to three primary color attributes such as lightness, hue, and chroma, many other optical properties of tooth, such as translucency, opacity, opalescence, surface gloss and fluorescence, should be considered.

**Translucency**

Translucency has been reported to be the most important following the primary color attributes and is also one of the fundamental factors influencing the esthetic performance of dental restorations. Translucency was used to describe the optical properties of dental resin composites, ceramics, prosthetic elastomers, fiber posts, orthodontic brackets, natural tooth dentine and enamel, and combinations of materials. Translucency is the relative amount of light transmission or diffuse reflection from a substrate surface through a turbid medium. Human teeth are characterized by varying degrees of translucency, which can be defined as the slope between transparent and opaque. increasing the translucency of a crown lowers its value because less light returns to the eye ,With increased translucency, light is able to go by the surface and is scattered within the body of porcelain

**Opalescence**

Opalescence is the fact in which a material appears to be one color when light is reflected from it and another color when light is transmitted through it

**Flourescence**

Fluorescence is the absorption of light by a material and the spontaneous emission of light in a longer wavelength. Ambient near-UV light is absorbed and fluoresced back as light primarily in the blue end of the spectrum, but it will occur at all wavelengths. The more the dentin fluoresces, the lower the chroma.[10, 14] Fluorescent powders are added to crowns to increase the quantity of light returned back to the viewer, block out discolorations, and decrease chroma

**CIE LAB COLOR SYSTEM:**

The Commission International de I'Eclairage (CIE), in 1931, introduced a system of instrumental color measurement for describing colors One of the first color spaces defined is CIE XYZ. These models are created manually with the help of human judgment ability of appearances and visualization matching, and the chosen colorimetry is based on this matching process. In 1976, CIELAB color model was introduced, the second uniform color space, was derived from CIE XYZ space, with a white reference point.. This enables the easy and accurate definition of different colours using numeric representation. One of the first clinical implications of the system lies in the development of the VITA 3D Master shade guide

The CIE color system represents a uniform color space, with equal distances corresponding to equal perceived color variances. In this three-dimensional color space, the three-axis are L*, a*, and b*. The L* represents the value which is a lightness measurement of an object and is quantified on a scale as a 100 L* of value for a perfect black. While the a* value is a quantity of greenness (negative a*) or redness (positive a*). Whereas the b* value is a quantity of blueness (negative b*) or yellowness (positive b*)The a* and b* coordinates approach zero for natural colors and increase in degree for more intense or saturated colors.

CIE Lab system's main advantage is that color variances could be expressed in units that can be related to visual perception and clinical importance

**COLOUR MEASUREMENT :**

There are two main methods for color matching, the visual method using shade guide, and the instrumental method using color matching devices

**CONVENTIONAL VISUAL METHOD:** Visual color matching involves a direct visual comparison of the different color samples in a shade guide with natural teeth in order to determine which tab, or combination of tabs, constitutes the best match .The Munsell color system is a common system for visual color assessment. Also, the visual color assessment of the patient's teeth is the most common method applied in dental practice . It is economical, commonly available, and it efficiently compares teeth color with a standardized reference shade guide . However, the visual method is very subjective, and usually, this method relies on many factors and the observer's psychological and physiologic responses to radiant energy stimulation

Visual color matching tools are called shade guides . The shade guide's main advantage is that generally they can be used almost anywhere and less expensive . The most popular shade guides currently used are: There are 3 main shade guides used in the daily practice, namely the ones developed by VITA, Bioform by DeTrey and Chromascop by Ivoclar. They are based on Munsell's principles, which divide the colour space into three dimensions – name of the colour (hue), the density of the colour (Chroma), and vitality (value)

VITA SHADE GUIDE: Hall creates a shade guide for porcelain restorations, using the principles, which later became the base for the creation of Vita 3D Master. In 1939 VITA Zahnfabrik created its first shade guide. In 1956 VITA Lumin. Vacuum Shade Guide was introduced and marked the first attempt at creating a unified colour standard.

VITA CLASSIC: The colour space in Vita Classical is divided into four groups – A, B, C and D based on the dominating HUE (name of the colour). In group "A" these are red and brown, in group B - red and yellow, in group C – grey and in group D red and grey. Each of the "letter" groups has subdivisions indexed with Arabic numbers ranging from 1 to 4, making the total number of tabs 16. (Fig.1) With the increase of the number, the Chroma increases, while at the same time, the value decreases .


**Fig.1 VITA Clasical shade Guide**

Alternative tab order according to value is B1, A1, B2, D2, A2, C1, C2, D3, A3, D4, B3, A3.5, B4, C3, A4, and C4

Vita 3D Master: This shade guide consists of 26 tabs arranged in 5 groups according to their value. Inside the groups, the shade tabs are ordered along two axes – vertical according to Chroma and horizontal based on hue. The first grouphas two tabs, the second, third and fourth have seven each, while the fifth has three. Each shade tab has three labels – a number ranging from 1 to 5, showing the group and value level, which decreases as the number increases. The letter M defines a mean colour tone, which is representative for the given value, while R and L are arranged relative to the median colour estimate. The last numeric indicator – 1, 1.5, 2, 2.5 and 3 shows the Chroma levels that are increasing incrementally. Three additional tabs are added for bleached teeth – 0M1, 0M2 and 0M3, the latter denoting the value of 0, three levels of Chroma and mean colour tone (M)

**Fig,2 VITA 3 D Master Shade Guide**

**Chromascop (IvoclarVivadent, Amherst, NY, USA):**In this shade guide, the colour space is distributed in five groups based on the Hue dimension. The colour-coding is as follows:

o In group 100 - white

o In group 200 - yellow;

o In group 300 - grey;

o In group 400 - grey;

o in group 500 - dark brown


**Fig.3 Chromascope Shade Guide**

Each group has five shade tabs. With the increase in number the chroma of the colour increases and at the same time the value decreases. The Shade guide consists of 20 tabs. The number for each of them is a combination of he subgroup and the other two colour dimensions. As an addition, accessory shade tabs are added for bleached teeth – 010, 020, 030 and 040

**Bioform**

The overall number of tabs in this shade guide is 24. The colour space is divided into four groups based on the dominating hue - red-brown, yellow, red-grey and grey

**SHADE GUIDE MADE FROM COMPOSITE MATERIAL** :Most of the manufacturers support the claim that the colour of their composite resin or acrylic materials correspond to the ceramic colour standards.


**Fig.4 Tetric Evo Ceram Shade Guide**

Examples : Esthetic-X(Dentsply), TetricEvo Ceram (Ivoclar) and Venus(Hereus Kulzer)

**INSTRUMENTAL TECHNIQUE:**

In this system, the color space consists of three coordinates: L*, a* and b* . The L* refers to the lightness coordinate, and its value ranges from 0 for perfect black to 100 for perfect white. The a* and b* are the chromaticity coordinates in the red–green axis and yellow–blue axis, respectively. Positive a* values reflect the red color range and negative values indicate the green color range. Similarly, positive b* values indicate the yellow color range while negative values indicate the blue color range.

**SHADE TAKING DEVICES:** Color-measuring devices usually consist of a detector, signal conditioner and software that process the signal in a manner that makes the data usable in the dental operatory or laboratory. These devices have been designed to aid clinicians and technicians in the specification and control of tooth color.

**Colorimeters**

Filter colorimeters generally use three or four silicon photodiodes that have spectral correction filters. These filters act as analog function generators that limit the spectral characteristics of the light striking the detector surface. The filter colorimeters are considered inferior to scanning devices such as spectrophotometers and spectroradiometers because of the inability to match the standard observer functions. However, because of their consistent and rapid sensing nature, these devices can be used for quality control.

ShadeEye is an example of a colorimeter based on the natural color concept.

**Digital camera as Filter colorimeter**

The digital camera technology is also being used for shade matching. Instead of focusing light on the film to create a chemical reaction, digital cameras capture images using charged coupled devices (CCDs), which contain millions of microscopically small light-sensitive elements. Like photodiodes, each photosite responds only to the total light intensity that strikes its surface. To get a full color image, most sensors use filtering to look at the light in its three primary colors in a manner analogous to the filtered colorimeter. There are several ways of recording the three colors in a digital camera. The highest-quality cameras use three separate sensors, each with a different filter over it. Light is directed to the different filter/sensor combinations by placing a beam splitter in the camera. The beam splitter allows each detector to see the image simultaneously. The advantage of this method is that the camera records each of the three colors at each pixel location.

The ShadeRite Dental Vision System andShadeScan combine digital color analysis with colorimetric analysis, but SpectroShade is the only one that combines digital color imaging with spectrophotometric analysis.

Spectrophotometers and spectroradiometers:

These are instruments designed to produce the most accurate color measurements. Spectrophotometers differ from spectroradiometers primarily because they include a stable light source. There are two types of basic designs commonly used for these instruments. The traditional scanning instrument consists of a single photodiode detector that records the amount of light at each wavelength. The light is divided into small wavelength intervals by passing it through a monochromator. A more recent design uses a diode array with a dedicated element for each wavelength. This design allows for the simultaneous integration of all wavelengths. Both designs are considerably slower than filter colorimeters. However, these arethe routinely used color-measuring devices. Eg. Vita Easy Shade,Crystal Eye

Some other available devices are:

a) Sofu Shade Chroma meter
b) The Shade T Scan
c) Shade Rite Dental Vision System
d) The Spectro Shade


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