Shade Selection for Indirect Esthetic Restorations

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Conflict of Interest Disclosure Statement

- Dr. Ahuja reports no conflicts of interest associated with this course. She has no relevant financial relationships to disclose.

Short Description

Learn about Shade Selection for Indirect Esthetic Restorations. This free continuing education course seeks to review the concept of esthetic restoration and why optimal shade selection is a key factor in achieving the best outcomes.

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Overview

Esthetics is an important factor that dictates the success of a restoration. An esthetic restoration blends in the patient's mouth. Optimal shade selection is one of the key factors for developing an esthetic restoration. However, due to the wide variety of natural tooth colors, achieving an intimate shade match between the restoration and the natural tooth/teeth may be difficult. Many patients are dissatisfied with their restorations due to improper shade selection, and therefore, every restorative dentist should be acquainted with the shade selection process to achieve the best outcomes.

Learning Objectives

Upon completion of this course, the dental professional should be able to:

- State the importance of shade selection in achieving an esthetic restoration.
- Describe the basic components of color.
- List the guidelines for optimal shade selection.
- Define the various methods/techniques of shade selection.
- Describe the various shade guides and shade recording armamentarium.
- Select the most optimal tool for shade selection.

Introduction

Accurate shade selection is one of the most crucial and challenging steps in the fabrication of indirect esthetic restorations.[1-3] Proper shade matching helps fabricate a restoration that harmoniously blends with the patient's existing dentition.[1,2] However, large variations are present in the natural tooth shades making it challenging to attain a precise shade match;[4,5] These variations may be attributed to intrinsic or extrinsic discolorations, surface texture, gloss, and other optical properties associated with the teeth.[4,6,7] Achieving an accurate shade match not only depends on the inherent variations in tooth color but also on external factors that influence color perception and interpretation.

The perceived color of an object is significantly influenced by factors such as the acuity of the human eye, genetic deficiencies in color perception, the operator's skills and experience in interpreting color, the type and quality of illumination, the environment, and the background color.[7-9] Therefore, in-depth comprehension of color science, the effects of light on color, human color vision, and the optical properties of teeth and restorative materials is essential to achieve an optimally color-matched restoration.[10,11] In addition, it is critical to establish proper communication with the dental technician regarding the shade and the surface features desired in the restoration.1 Improper communication with the laboratory technician will often require a restoration remake thereby increasing the time and cost of restoration fabrication.[12,13]

Shade selection may be performed using conventional visual methods or through the use of instrumental technology.[1,4,7,14,15] Development of improved shade guides, shade-taking instruments, guidelines for shade selection, and research in the area of human color vision has improved dental practitioners' ability to record a precise shade.[11]

Color Perception

Color perception in humans is a complex process that involves the brain interpreting and processing the relayed electrical signals.[16,17] These electrical signals originate in the retina and are transmitted via the optic nerve to the brain's visual center.[16,17] The perception of color begins with the way light interacts with objects and how the eye processes these interactions to generate visual signals.

Human Eye

When light strikes an object, the object absorbs some of the wavelengths of light and reflects the rest of it.[18] The reflected light from an object enters the eye through the cornea.[19] The cornea, along with the lens, directs the light onto the retina.[19,20] The retina contains photoreceptor cells known as rods and cones.[19,21] These cells are sensitive to specific ranges of the light spectrum and are involved in transmitting electrical signals to the brain.[21,22] The center of the retina contains the cone cells whereas its periphery contains the rod cells.[21,22] Rod cells interpret the lightness and darkness (the value scale) of an object.[21] They help with the vision in low light and at night time.[21] Cone cells, on the other hand, detect different colors; however, they are only activated in bright light.[21] Cone cells are classified into three types (red, green, and blue) based on their sensitivity to various wavelengths of light.[21] This trichromatic system functions collectively to facilitate the perception of a full spectrum of colors through the process of additive color mixing.[23]

The eyes are susceptible to color fatigue, wherein constant exposure to one color decreases the eye's response to that color. However, visual color perception is not only influenced by observer-associated factors (eye fatigue, experience, vision disorders, and age)[7-9] but also environmental factors such as surroundings, lighting conditions, and the metamerism phenomenon.[24] While the eye plays a crucial role in detecting light and distinguishing colors, the concept of color itself is fundamentally linked to the interaction of light with objects and the way it is perceived by the human visual system.

Color

Color may be defined as a phenomenon of light or visual perception that enables one to differentiate between objects that are otherwise identical.[25] It may also be defined as the quality of an object or substance with respect to light reflected or transmitted by it.[26] Color is strongly associated with light. Without light, color does not exist! [27,28] Objects have no inherent color—they only reflect specific wavelengths of light from the color spectrum.[27] For example, A red object reflects red wavelengths of light while absorbing all others. The perceived color of an object may appear different with variations in lighting conditions and the surrounding colors.[24,28] For example, the teeth look brighter when the patient is wearing brightly colored lipstick compared to when they are wearing no make-up. In dentistry, an understanding of color is essential, particularly when assessing variations in tooth shade and the factors that contribute to discoloration.

Tooth Discolorations (Intrinsic and Extrinsic Coloration)

A tooth may appear darker or stained due to the combination of intrinsic and extrinsic colorations.[7,29] Intrinsic coloration (Fig. 1) is associated with the absorption characteristics of enamel, dentin, and pulp, as well as light scattering.[7,29] Extrinsic coloration (Fig. 2) arises from the absorption of various materials such as red wine, tea, iron salts, and chlorhexidine onto the pellicle and the surface of enamel.[7,29]

Fig. 1 - Intrinsically discolored maxillary central incisors and canines

Fig. 2 - Mandibular teeth affected by extrinsic discoloration

Color Determination System

The Munsell System

One of the most commonly used color determination systems is the Munsell system (Fig. 3a).[7,28] It was introduced by Albert Henry Munsell in the early 1900s. The 3 main components of color as per the Munsell system include hue, chroma, and value (Fig. 3b).[7,28]

Hue

Hue represents the dominant wavelength/s of light (in the visible spectrum) reflected by an object.[4,7,28] It is the result of both physiological and psychological interpretation of a combination of wavelengths. It is the term by which we identify a color such as red, yellow, green, etc.[7] Hue differentiates one family of color from another (Fig. 4).[7,28] Hue is denoted by letters A, B, C, and D on the commonly used Vita classic shade guide (Fig. 5).

Chroma

Chroma or saturation is defined as the intensity of a hue, the strength of the hue, or the concentration of the pigment (Fig. 6a).[4,7,28] Chroma and value are inversely proportional; as chroma increases, value decreases (Fig. 6b).[4,7,28] Tooth chroma decreases with bleaching and increases with aging.[31] Optimal illumination in the dental operatory is required for assessing subtle variations in hue and chroma.[4] Higher numbers on the Vita Classic shade guide indicate increased chroma (and decreased value).[4]

Value

Value refers to the relative lightness or darkness of a color.[7] It is directly associated with the amount of light energy the object reflects thereby helping to assess its brightness.[4,7] The more light an object reflects, the higher its value; conversely, the less light it reflects, the lower its value.[7]
In the Munsell system, value is categorized on a white-to-black grayscale.[4,7,28] Objects with a higher value have less gray; conversely, objects with a lower value have more gray and appear darker.[4,7,28] Value has ten gradations; a value of 0 indicates a black/dark object, while a value of 10 indicates a white/bright object.[32] The value of natural teeth ranges from 5.5-8.5. Value is the most important determinant in shade selection.[33] If the value is matched accurately with the adjacent natural teeth, small variations in hue and chroma are not easily discernible.[33] Restorations that are too high or too low in value (Fig. 7) are easily detected.

The following characteristics are true regarding value:

- Value is the only dimension of color that can exist by itself. [34,35]
- Objects of different hues/chromas may have the same value.[36]
- Value just like color is affected by its surroundings, lighting conditions, and the observer's perception.[37]
- Increasing the surface reflectivity and decreasing the chroma are two methods of increasing the value.[7]

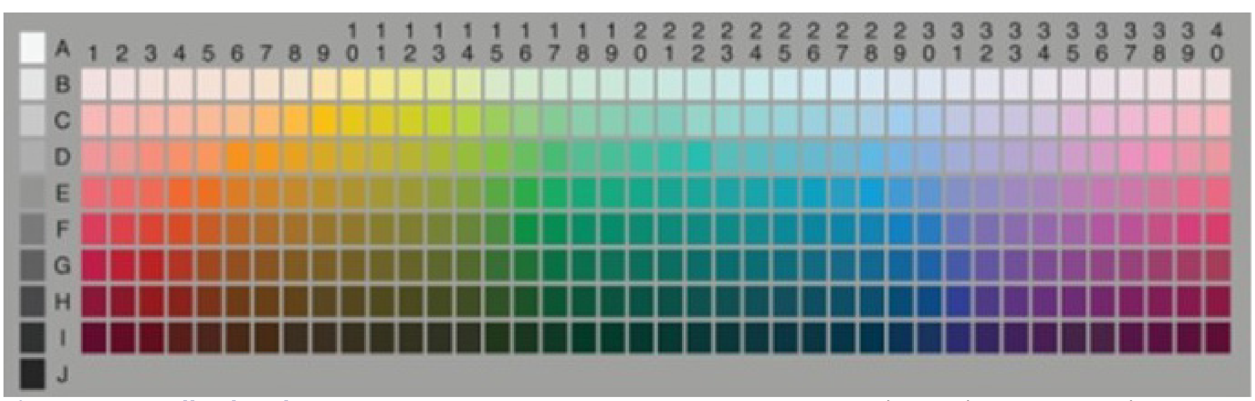

Fig. 3a - Munsell color chart

Image: Vejdemo-Johansson M et al, CC-BY-4.0

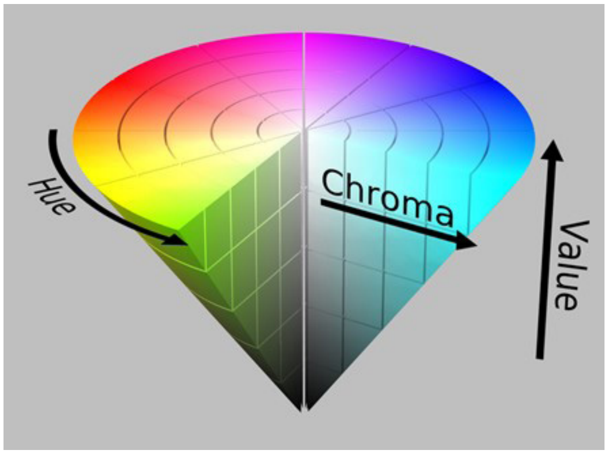

Fig. 3b - The three determinants of color as per the Munsell system *Image: Jacob Rus, CC-BY-SA-3.0*

Fig. 4 - Green, orange, yellow, and blue-hued objects

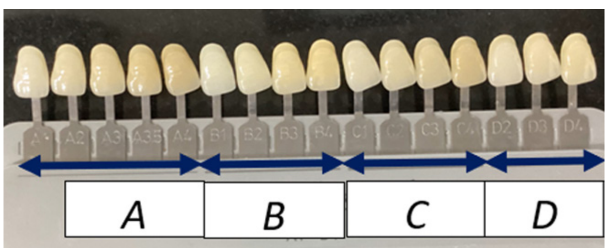

Fig. 5 - Hue denoted by letters A, B, C, and D on the commonly used Vita classical shade guide.

Fig. 6a - Chroma increases from left to right

Fig. 6b - Chroma increases from left to right, while value decreases in the same direction.

Fig. 7 - Restoration on tooth #8 has a lower value (is darker) compared to the adjacent and opposing teeth

CIELAB Color Space

The CIELAB (CIE L*a*b*) color space was introduced by the International Commission on Illumination in 1976.[1,24] It is a three-dimensional color space consisting of three variables: L, a, and b (Fig. 8). The "L" factor indicates the lightness of an object, the "a" factor assesses redness (positive value) or greenness (negative value), and the "b" factor determines yellowness (positive value) or blueness (negative value).[1,24] The "L" in the CIE system corresponds to the value (V) in the Munsell color order system.[24] The advantages of this system include its consistency and reproducibility.[3] Additionally, it enables quick and efficient communication with laboratories.[3] Digital color measuring devices currently use the CIELAB system for color measurements.[1,24]

RGB System

The RGB system is a color system that describes colors through the combination of different intensities of the three primary colors (red (R), green (G), and blue (B)) (Fig. 9).[38] This system forms the foundation of color generation in various digital and electronic devices, such as computer screens, televisions, and cameras.[1] In addition, it has applications in web design and image editing.

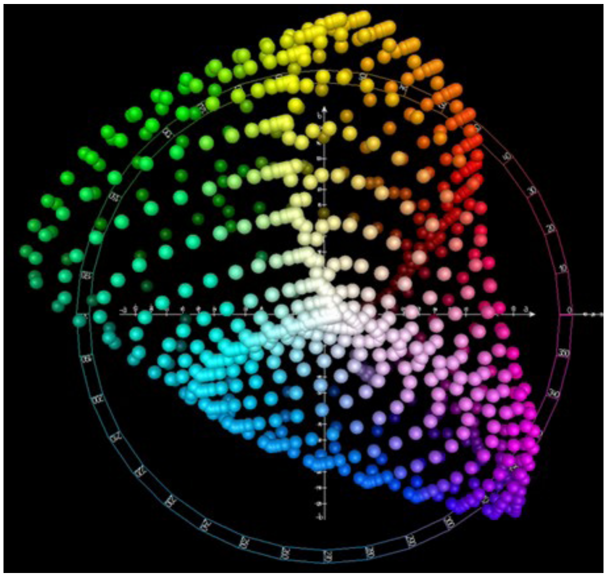

Fig. 8 - CIELAB color space (occlusal view)
Image: Holger kkk Everding, CC-BY-SA-4.0

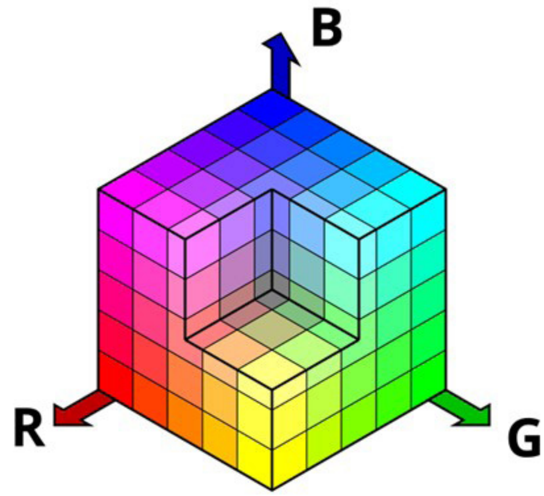

Fig. 9 - RGB color model depicted on a unit cube
Image: Shark D, CC-BY-SA-2.0

Factors Affecting the Perceived Color of Teeth

The apparent color of teeth is influenced by the following five factors:

Physical Properties of Teeth

An object (a tooth) can alter the color of light.[39] When the object (tooth) reflects specific wavelengths of visible light, the color appears.[39] The color and the final appearance of the teeth are not only affected by the hue, value, and chroma but also the surface texture and various other optical properties associated with teeth such as translucency, opacity, opalescence, and fluorescence.[4,7,11] Dental restorations must be fabricated such that not only their color but also their surface texture and optical properties are similar to natural teeth.

Surface texture

Surface texture represents the minute details and irregularities present on the surface of teeth.[4] Natural teeth have various characteristics such as lobes, stippling, striations, and ridges (Fig. 10).[4,7] Teeth have a very rough surface texture when they erupt in the oral cavity.[4] However, with time the tooth surfaces wear and become smooth.[4] The surface of a tooth may be categorized as having a heavy, medium, or light texture.[4] Surface texture affects the appearance of a tooth by influencing the quantity and path of light reflected off its surface.[4,7] A rough or heavy surface texture is associated with a lower value (dull appearance) because it tends to scatter the reflected light in several directions.[4] A light surface texture has a higher value (dynamic appearance) due to more uniform light reflection and a greater amount of light returning to the viewer's eye.[4]

Surface gloss

Surface gloss also affects the appearance of teeth.[7] High gloss surfaces can create mirror-like reflections of light resulting in the surface appearing brighter and more vivid.[4] Low-gloss or matte surfaces result in diffuse scattering of light, making the surface and its color appear duller.[4] Restorative materials must be finished to match the surface texture and gloss of adjacent natural teeth.[41] Surface texture and gloss discrepancies may result in esthetic failure even if the base colors are perfectly matched.

Optical Properties of Teeth

Translucency

Translucency is the gradient between transparent and opaque and is considered the 4th dimension of color after hue, chroma, and value.[4,7,24] Translucent materials allow some light to pass through them. Increasing the translucency of a surface lowers its value as less light returns to the viewer's eye.[4] The different structures of the tooth are associated with varying degrees of translucency; Enamel is

Fig. 10 - Striations, ridges, and lobes are seen on the facial surface of the central incisors

Fig. 11 - Translucency gives the teeth their vital appearance

Fig. 12 - Nearly opaque dental restoration on teeth # 6, 7, 8, 9 and 10

Fig. 13 - Enamel appears reddish-orange in transmitted light

most translucent and transmits approximately 70% of light through 1mm of its thickness whereas dentin is less translucent transmitting approximately 30% of light through the same thickness.[42] However, the translucency of enamel is influenced by several factors including the angle of incidence and the wavelength of light; the gloss, dehydration,[43] the refractive index of its surface; and its intercrystalline spatial configuration.[4,7] Translucency gives a tooth/restoration its color depth and vital appearance (Fig. 11).[44] Therefore, shade matching must be supplemented by recording the translucent areas.

Opacity

Opacity (of teeth) is another important optical feature that must be assessed during the fabrication of esthetic indirect restorations. It is the property of an object that blocks light from passing through it. Dental procedures like tooth bleaching, impression making, rubber dam isolation, and application of curing light can dehydrate teeth. Dehydrated teeth appear to have increased opacity making them appear brighter and whiter than their original color.[4]

Opaque restorations (Fig. 12) may reflect and/or absorb the incident light but will not transmit it. Opacity is directly associated with value; Increasing the opacity increases the value of a restoration.[4]

Opalescence

Opalescence is a phenomenon wherein a material appears to be one color when light is reflected from it and another color when light is transmitted through it.[4,7] Opals and tooth enamel exhibit opalescence;[28] They deflect different wavelengths in the light spectrum to various angulations.[4,28] This property of tooth enamel is associated with it appearing bluish-green color in reflected light and reddish-orange in transmitted light (Fig. 13).[28,45] The opalescent effect of enamel brightens the tooth and gives it, its optical depth and vitality.[4,28]

Fluorescence

Fluorescence is the phenomenon of absorption of light by an object and the subsequent emission of light of a longer wavelength/lower energy.[4,7] The tooth structure associated with fluorescence is dentin as it is composed of a higher concentration of organic material.[4,7]

Fig. 14 - Natural teeth exhibit fluorescence under ultraviolet light

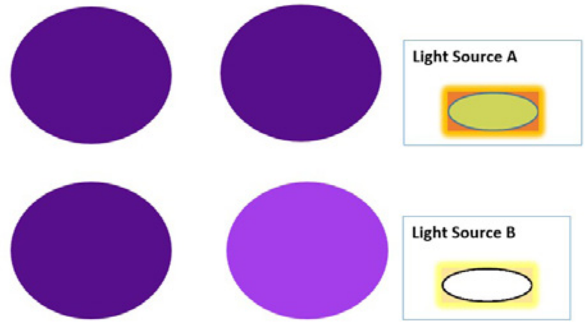

Fig. 115 - Both the objects appear to match when illuminated with light source "A" but appear unmatched under light source "B"

Fluorescence is associated with teeth looking brighter, whiter, and vital.[4] Natural teeth exhibit blue fluorescence under ultraviolet (UV) radiation (Fig. 14).[28] This optical property is relevant to patients who frequent nightclubs and entertainment shows.

The amount of dentin fluorescence is indirectly related to chroma;[4] The greater the amount of dentin fluorescence, the lesser the chroma.[4,24] Rare earths are added to the dentinal layers of porcelain crowns to give them the property of fluorescence, thereby, making them appear similar to natural teeth under different lighting conditions.[4] This is advantageous (when fabricating restorations with higher value) as it helps increase the value of a restoration without affecting the translucency.[28]

Light Source

The surface color of an object is affected by the nature of incident light.[39,45] Metamerism is a phenomenon that may cause two objects to appear to match under one light source, however, they may be perceived as unmatched when the lighting conditions are altered (attributed to different spectral reflectance) (Fig. 15);[4,7] This phenomenon is associated with restorations appearing to blend with natural teeth under the operatory light but looking different when the lighting conditions are changed. Thus, it is advisable to perform shade selection under different light sources to avoid the effects of metamerism.[4,28]

Types of artificial light sources

Various light sources emit different colors of light.[39] Ceiling lighting in a dental office is dull and not sufficiently bright whereas the dental unit lights are too bright and result in a glare.[4] An increase in light intensity and glare decreases the accuracy of shade selection.[4] The common types of artificial light sources present in the dental operatory include the following:

- **Incandescent lights:** These light sources emit a high concentration of yellow waves.[4,28] They make bright colors such as red, yellow, and orange appear more intense, whereas cool colors such as blue and green are muted.[4] Hence, these sources are not suitable for shade-matching.
- **Fluorescent lights:** These light sources emit high concentrations of blue waves.[28] They make cool colors such as blue and green appear more intense. Fluorescent bulbs with a color rendering index between 50-80 are unsuitable for shade matching.
- **Halogen lights:** These light sources emit a bright white light similar to natural daylight, however, they make all colors appear brighter than the original color.[46]

Ideal lighting for shade selection

Natural daylight (Northern) is considered ideal for shade selection as it contains an almost equal blend of all wavelengths of light.[24,44,47] However, ideal conditions may not always be available for shade matching, thus it is recommended to use artificial lighting for color matching.[48] Natural daylight (Northern) is used as the standard for assessing artificial light sources. For the light source to be suitable for color matching, it should have a color temperature close to 5500 degrees Kelvin and a Colour Rendering Index (CRI) greater than 90.[7,44,49] If natural daylight is unavailable during color matching, a color-corrected fluorescent light with a CRI of 90 or higher should be used in the dental operatory for shade selection.[7,28] However, before finalizing the shade, it is also important to make a note of the various lighting conditions the patients are most exposed to in their daily routine and verify the selected shade under multiple lighting environments.[7]

Subjective Assessment of The Observer

Various factors related to the observer may affect the perception of color, they include the following:

1. ***Color vision***: Dental practitioners may have a defect in color vision.[7,24] Several studies have reported that approximately 8% of males and 0.5% of females may be suffering from congenital color deficiencies.[50,51] Hence, dental practitioners should have their color vision evaluated (early on) to ensure accurate shade selection. If a color vision defect is present, the practitioner should seek the assistance of a dental auxiliary and/or digital shade-matching devices for selecting tooth shades. Practitioners may also suffer from binocular disparity (imbalance in the color perception between the right and left eye.)[7] To limit the error associated with binocular differences, it is advised to position the shade tabs below or above the tooth of interest as opposed to beside it.[7,24]

2. ***Aging:*** Aging may cause worsening of shade-matching ability due to alterations in vision.[7,24] Also, the cornea and lens of the eye turn yellow with age, thereby causing objects to appear more yellowish and brownish compared to their original color.[7,24]

3. ***Gender***: Multiple studies report that women can perceive color more accurately than men.[7,24]

4. *S**ubstance abuse and medications**:* The misuse or inadvertent use of drugs, alcohol, and caffeine may impair color perception.[24,28] Medications used for treating erectile dysfunction (such as Viagra) may add a blue tint to the vision.[24] The use of oral contraceptives is associated with difficulty in differentiating various colors, including red, green, yellow, and blue.[24] Also, prolonged use of oral contraceptives may lead to a decrease in yellow and blue color perception.[24,28]

5. ***Eye and Color fatigue***: If the eyes are fatigued, they may not be able to identify colors accurately. Hence, it is recommended to schedule these procedures early in the day and perform them at the beginning of the appointment.[7,24] Color fatigue is associated with constant exposure of the eye to a single color, thereby decreasing its responsiveness to that color.[28,44] To circumvent this phenomenon, it is suggested that the operatory walls be painted neutral gray and the practitioner periodically glance at them during shade selection.[28,44]

Surroundings

The color of the operatory walls, reflective instruments, the patient's clothing, makeup, and bright, heavy jewelry may affect how we perceive the color of teeth, shade guides, and restorative materials.[28] Bright backgrounds and the surroundings can significantly impact shade selection by influencing the colors reflected in the light.[7] Surfaces with high gloss may cause a disturbing glare, hence they should be covered with a neutral color.[48] A very light gray background provides an optimal setting for color matching and minimizes the effect of surrounding colors during the shade selection process.[28]

Shade Selection Process

The process of shade selection can be classified into 2 broad categories visual shade selection and instrumental shade selection.[1,7,24,48]

Visual Shade Selection - Overview

Visual shade selection is the most commonly used method of shade selection as it is quick, easy, and economical.[7,24,48] This process involves the use of shade guides to visually match tooth shades.[24] The two most commonly used shade guides include the Vita Classical (Vita, North America) and the Vita Toothguide 3D Master (Vita, North America.)[24] The huge advantage of this method is that the patient can be involved in the shade selection process. However, the results of this method are hugely dependent on the examiner's vision acuity which is influenced by his/her age, experience, color perception, eye fatigue, and environmental factors including the light source, location, and degree of light intensity.[7,28,48]

Guidelines for Visual Shade Selection

Before beginning the process of shade selection, it is important to understand and follow the recommended guidelines for achieving a consistent and accurate result.[11,39]

Step-by-Step Guidelines for Visual Shade Selection[5]

Step 1: The tooth/teeth of interest should be cleaned free of deposits and surface stains.[11,39]

Step 2: A color-corrected light source with a CRI > 90 and a color temperature of 5500K should be used for shade selection. In addition, the shade should be evaluated under different types of lighting after the initial shade is chosen in natural daylight/color-corrected light.[11,39]

Step 3: A neutral-colored environment should be utilized for shade selection. Bright clothing, vividly colored operatory walls, and/or make-up can alter color perception. If the patient's clothing/ornaments are overly bright, it is advisable to use a drape to mask the undesirable colors (Fig. 16).[39] The patient's makeup should be removed and all the dental instruments creating reflection must be cleared from the surroundings.[39]

Step 4: The practitioner should be positioned in front of the patient, aligning the patient's teeth with their eye level (Fig. 17).[39] A distance of 2 to 6 feet from the oral cavity is considered ideal for visual shade selection and the shade guide should be held at the patient's mouth at arm's length. To detect subtle differences in hue the practitioner may need to move closer to the patient; however, shape, value, surface texture, luster, and opacity can be assessed from a distance of four or five feet.[11]

Step 5: Shade selection should be performed at the beginning of the appointment as the eyes are fresh.[39] If shade selection is performed after performing a crown preparation (Fig. 18), the eyes are tired and the adjacent teeth are dehydrated thereby resulting in errors in shade determination.

Step 6: Practitioners should not stare at the tooth/teeth for a long time as it may result in hue accommodation. The process should be completed in 5-7seconds; If it is taking longer, the practitioner must "reset" his/her eyes, by looking at a neutral gray-colored surface/object.[11,39]

Step 7: The visual method of shade selection involves the use of shade guides (Fig. 19). The middle third of the tooth and the shade tab should be used as a reference for hue determination (Fig. 20). The incisal edges are generally more translucent and lighter than the middle third of the teeth, hence, they may result in the selection of an inaccurate hue.

The shade tabs should be positioned at the same angle as the tooth of interest. The shade

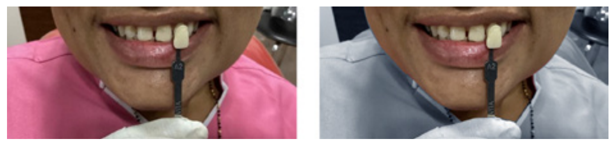

Fig. 16 - Bright-colored clothing may alter color perception during shade selection (left), a drape is used to mask the undesirable colors (right)

Fig. 17 - During shade selection, the patient is positioned at the eye level of the operator.

Fig. 18 - The adjacent teeth become dehydrated following tooth preparation.

tab is placed such that the incisal edge of the shade tab approximates the incisal edge of the tooth of interest (Fig. 21).[52,53] This helps prevent the reflection of the teeth and the shade from falling on each other. The laboratory must be familiar with and use the same shade guide as the practitioner.[11]

Step 8: The appearance of teeth is mostly determined by how light interacts with the curved and varied surfaces of the tooth, hence, it is recommended to use multiple viewing angles during shade selection.[7]

Step 9: The teeth should be dry while assessing value, translucency, surface texture, and luster, and moistened while evaluating hue and chroma to limit the influence of surface morphology.[7]

Step 10: Shade selection should be performed before the application of the rubber dam to prevent tooth dehydration.[48]

Step 11: It is recommended to avoid performing shade selection immediately after the application of a curing light as it also leads to dehydration of teeth.

Step 12: If a bleaching procedure is performed on the teeth, it is recommended to schedule shade selection after 30 days to permit enamel rehydration.[54]

Fig. 18 - The adjacent teeth become dehydrated following tooth preparation

Fig. 19 - Vita classical shade guide

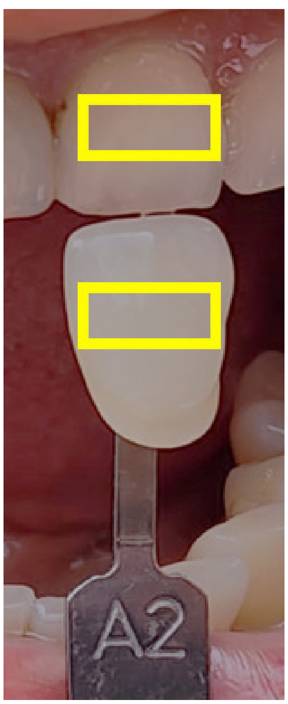

Fig. 20 - The middle third of the tooth and the shade tab is used as a reference for hue determination

Fig. 21 - The shade tab is positioned such that the incisal edge of the shade tab approximates the incisal edge of the tooth of interest

Shade Selection Using the VITA Classical Shade Guide

The VITA classical is the most commonly used shade guide. It has 16 natural tooth shades.[55] The manufacturer-recommended sequence for shade matching includes the following 4 steps:[1]

Steps to Shade Selection using the VITA Classical Shade Guide[1]

Step 1: Hue Selection[1]

There are four hue categories (A, B, C, and D) in the Vita Classical shade guide.[1] Shade tabs denoted by the letter A have a reddish brown hue; the shade tabs denoted by the letter B have a reddish-yellow hue; the shade tabs denoted by the letter C have a greyish hue and the shade tabs denoted by the letter D have a reddish-grey hue.[4,7,28] Thus all the shade tabs that are marked with the letter A including shade tabs A1, A2, A3, A3.5, and A4 will have the same hue. The same holds for all the shade tabs marked with letters B, C, and D.

When selecting the hue, the entire shade guide is held above (for mandibular teeth)/below (for maxillary teeth) the tooth of interest (Fig. 22) and moved from left to right. The hue that is closest to the tooth/teeth of interest is selected. If the intensity of chroma on the natural tooth is low, it becomes very tricky to select the proper hue. In that situation, the area of the tooth with the most intense chroma is used for the hue selection.

Step 2: Chroma selection
After selecting the hue, the next step involves choosing the appropriate chroma.[1] For example, if a B tab is selected for the hue, then chroma is selected from the four gradations within the B tabs: B1, B2, B3, and B4 (Fig. 23a).[1] Several comparisons are usually necessary to determine the most appropriate hue and corresponding chroma (Fig. 23b). The practitioner should reset his/her eyes by looking at a neutral gray surface/object if the process is taking longer than 5-7 seconds.[1]

Step 3: Value selection
The value should be selected by using a value-oriented shade guide with shade tabs arranged in order of increasing darkness.[1] A value-oriented shade guide is created by arranging the shade tabs of the Vita classical shade guide in the following order: B1 (lightest), followed by A1, B2, D2, A2, C1, C2, D4, A3, D3, B3, A3.5, B4, C3, A4, and lastly C4 (darkest) (Fig. 24).[56]

The value-oriented guide is held above (for mandibular teeth)/below (for maxillary teeth) the tooth of interest and moved from left to right. The practitioner can then select the shade tab that matches the value of the natural tooth.

The value should be determined by observing the guide and teeth to be matched from a distance (by standing slightly away from the chair) and squinting.1 Squinting reduces the amount of light reaching the eye thereby increasing the sensitivity of the retinal rods (and decreasing the stimulation of the retinal cones).1 Additionally, black-and-white images may be used to verify the selected value (Fig. 25).

Step 4: Final Check In this step, the practitioner should verify that the selected hue, chroma, and value are aligned with each other to create an aesthetically pleasing restoration. However, there may be instances when the tabs selected for hue and chroma may not coincide with the shade tab selected for value, this will require that the whole process be repeated from the beginning.

Shade Selection Using the VITA Toothguide 3D-Master

The Vita Toothguide 3D-master® is a value-oriented shade guide that offers 26 natural tooth shades (Fig. 26).[5] It replicates the commonly observed natural tooth shades comprehensively in the scientifically developed tooth color space.[5] The shade tabs are organized based on 3 parameters: lightness (value), chroma, and hue.[5] It also permits the creation of intermediate

Fig. 22 - The shade guide is held in position for hue selection

Fig. 23a - Gradations of chroma within the B-shade tabs

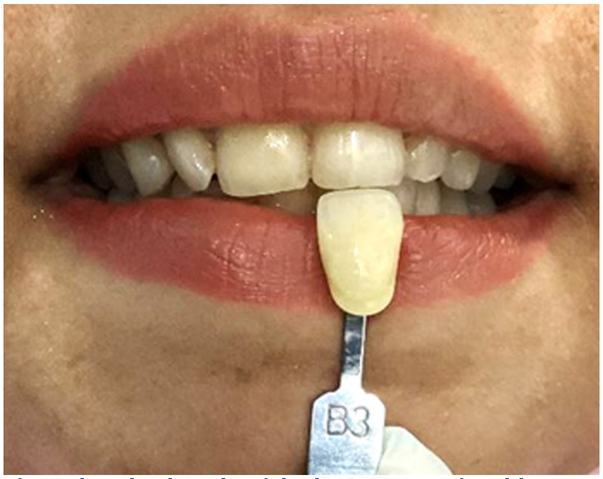

Fig. 23b - Shade tab with the most optimal hue and the corresponding chroma is selected

Fig. 24 - Shade tabs arranged in order of increasing darkness

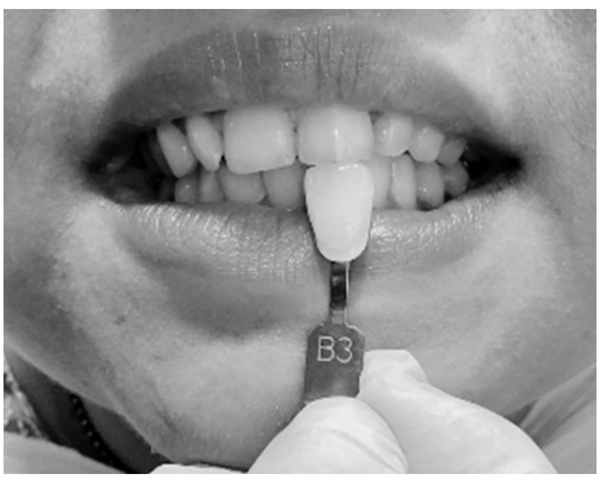

Fig. 25 - A black and white image is used for verifying the selected value

Note:The selected shade tab appears lighter (has a higher value) than the reference tooth.

shades by mixing.[5] The manufacturer-recommended sequence for shade matching includes the following steps:[5]

Steps to Shade Selection Using the Vita Toothguidde 3D-Master[5]

Step 1: Value Selection
The Vita Toothguide 3D-Master shade guide is categorized into 5 groups based on the value and they are denoted by numbers 1 through 5 (Fig. 27a). All the shade tabs belonging to the same group (1, 2, 3, 4, or 5) have the same value/lightness level (but vary in chroma and hue.) For example, all shade tabs in the group labeled "2" will have the same value.

For selecting the value, the arm is bent and the shade guide is positioned approximately 25-30 cm in front of the tooth of interest (Fig. 27b) and then moved from right to left. The value (lightness) is determined first by the selection of a value group that most nearly corresponds with the lightness or darkness of the reference tooth. Rather than picking a single shade tab (from the 26 tabs), a "group of shades" (1, 2, 3, 4, or 5) with the same value that matches the tooth of interest is selected.

Step 2: Chroma Selection[5]
After selecting the value, chroma is selected next from the shade tabs placed in the "M" section of the chosen value group. For example, if the lightness level selected is "2" in Step 1, the shade samples with the middle hue (M) from the selected lightness level are removed and spread out like a fan. Then the chroma level 1, 2, or 3 is selected from this group of shade tabs (Fig. 28).

Step 3: Hue selection[5]
Next, the hue is selected by checking whether the reference tooth/teeth is/are more yellow (L) or red (R) by using the L and R shade tabs from the same value group (Fig. 29).

Step 4: Determination of intermediate shades[5]
Occasionally, achieving a precise shade match requires selecting an intermediate shade of value and/or chroma. If a tooth shade falls between two shade samples, an intermediate shade can be defined. For example, a shade of 3.5M2 may be used to indicate that the lightness level is between 3 and 4 and the chroma level is M2. Similarly, a shade of 1M1.5 may be used to indicate that the lightness level is 1 while the chroma level is between M1 and M2.

Extended Shade Guides

The commonly used shade guides do not cover all the colors found in the natural dentition.[48] In such cases, specialized shade guides may be needed to provide additional information to the laboratory technician; The specialized shade guides may include dentin shade guides, bleach shade guides, or custom shade guides.[48]

The dentin/stump guides are used for communicating the shade of the prepared tooth particularly when planning translucent all-ceramic/zirconia restorations (Fig. 30a). Bleach shade guides (Fig. 30b) typically incorporate shades that are lighter than the color of natural teeth. They are particularly helpful for shade

Fig. 26 - Vita Toothguide 3D Master

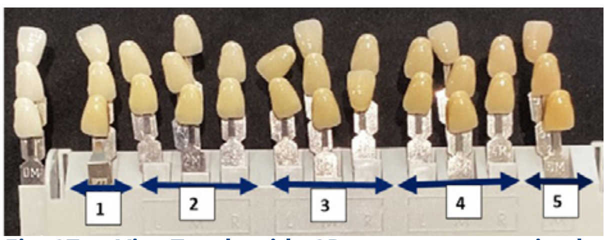

Fig. 27a - Vita Toothguide 3D master categorized into 5 groups based on the value

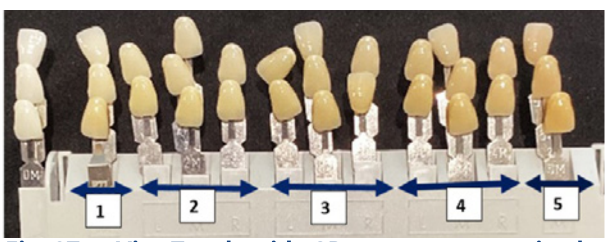

Fig. 27a - Vita Toothguide 3D master categorized into 5 groups based on the value

Fig. 27b - The shade guide is positioned in front of the tooth/teeth of interest

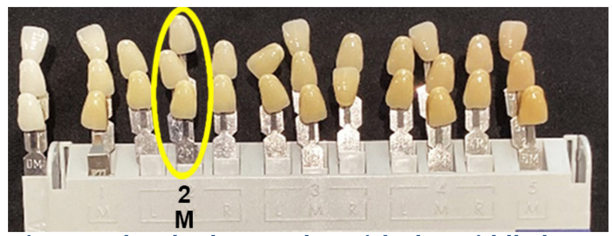

Fig. 28 - The shade samples with the middle hue (M) from the lightness level 2 are spread out like a fan to determine the chroma

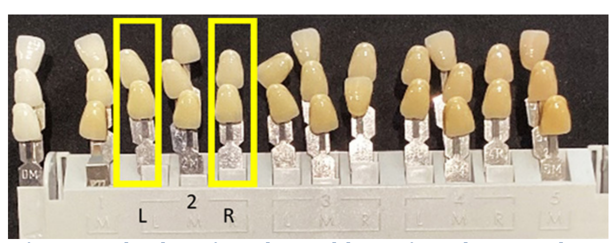

Fig. 29 - The hue is selected by using the L and R shade tabs from the selected value group

determination of teeth that have undergone a bleaching procedure. A custom shade guide is used when it is impossible to match the color of the teeth to commercial shade guides.[58] A custom shade guide can be fabricated by using various combinations of composites/porcelain powders. However, the creation of custom shade guides is time-intensive and hence, not commonly practiced.[58]

Common Causes of Errors During The Visual Shade Selection Process

Errors introduced during the visual shade selection process can lead to the fabrication of unaesthetic restorations (Fig. 31). The most common causes include the following:

1. Determining the shade under poor-quality lighting[11,38]
2. Using cheap and old shade guides
3. Staring at the object and taking too long to select the shade[11,38]
4. Recording shade at the end of the appointment[38]
5. Selecting the shades against a bright background[38]
6. The visual shade selection process is based on subjective evaluation.[1,7] Studies have concluded that there is considerable variation in shade selection among dental practitioners.[28,58,59] Few of them have also reported that the shade selected by the same dental practitioner may be inconsistent for the same patient and restoration on various occasions.[28,58,59]

Fig. 30a Dentin shade guide used to record the stump shade

Fig. 30b - Vita Bleachguide 3D-Master
Image: https://www.vita-zahnfabrik.com/en/VITA-Bleachedguide-3D-MASTER-26260,27568.html

Instrumental/Digital Shade Selection

Digital color measuring devices were introduced to eliminate the subjectivity of visual color analysis, thereby reducing the chances of error in shade determination and permitting the fabrication of aesthetic restorations by dental laboratory technicians.[1,60] Digital shade-matching tools can identify approximately 100,000 dental shades while the human eye can only identify 1% of these shades.[47] They are easy to use and can store shade information digitally, which can be easily transmitted to the laboratory.[38] Several clinical studies have reported that shade selection using digital tools takes less time and is as accurate as the conventional shade determination process.[38,62,63] However, digital shade determination systems are more expensive compared to conventional shade determination systems.[38] Additionally, shade-matching accuracy is influenced by factors such as the type of lighting used, the condition of the teeth (including the presence of stains or restorations), and the operator's experience and techniques.[24]

Digital shade determination instruments usually contain 3 key elements: a detector, signal conditioner, and software that processes the signal in a manner that makes the data usable in the dental operatory or laboratory.[28] Digital shade selection devices may be


Fig. 31 - The restoration on tooth #8 appears unesthetic due to shade mismatch

classified into two types based on the type of measurement: instruments that perform spot measurements and instruments that perform complete tooth measurements.[1] Spot measurement devices measure a small area of the tooth surface.[1] The size of these instruments is generally small, as a result, they cannot be used to create a whole image of the tooth.[1] They record three points of reference on a tooth surface.[1,35] This not only leads to errors but also increases the time for shade information data capture.[1] Therefore spot measurement should not be the sole method of shade determination but used as an adjunct to the visual shade-matching process. Examples of spot measurement devices are the Vita EasyShade Compact (Vita Zahnfabrik, Bad säckingen, Germany) (Fig. 32) and Shade-X (X-Rite, Grandville, MI).[1]

Devices that perform complete tooth measurement record the entire tooth surface, thereby generating a complete shade map of the tooth.[1] They provide all the information in one image.[1] They provide more consistent and reproducible information of the tooth surface.[1] They are larger compared to the spot-measuring devices, hence, their use is limited to the anterior teeth.[1] Examples of these devices are the CrystalEye (Olympus, Tokyo, Japan) (Fig. 33) and SpectroShade (MHT Optic Research, Niederhasli, Switzerland).[1]

Another classification system categorizes the shade-matching instruments into 3 basic types spectrometers, colorimeters, and digital imaging systems.[1]

Spectrophotometers

Spectrophotometers (Fig. 32, 33) are easy-to-use, very accurate, repeatable, and reliable instruments for color matching in dentistry.[1,7] Their utilization helps eliminate the uncontrolled variables during the shade-matching process. They quantify the spectral reflectance of an object, one wavelength at a time, for each hue, value, and chroma present in the entire visible spectrum. [1,7,64] A spectrophotometer contains the following key components: a source of optical radiation, a photodiode detector,

Fig. 32 - Vita Easyshade Spectrophotometer
Image: https://www.vita-zahnfabrik.com/pdb_GG2G50G200_en-US.html_us

Fig. 33 - Olympus CrystalEye Spectrophotometer
Image: https://www.olympus.co.jp/jp/news/2006b/nr061113crystalj.html

an indicator, a system for scattering light, and a monochromator that converts light into a signal.[1,7] The signals obtained from this device are transformed into easily interpretable readings that correspond to shade guide values.[1,7] Examples of spectrophotometers are Vita Easyshade compact (Vita Zahnfabrik, Bad säckingen, Germany), Shade-X (X-Rite, Grandville, MI), SpectroShade Micro (MHT Optic Research, Niederhasli, Switzerland), and Crystal eye (Olympus, Tokyo, Japan).[1]

Colorimeters

Colorimeters (Fig. 34) are designed to directly measure color as recognized by the human eye.[1] Colorimeters quantify the tristimulus values by utilizing three distinct filters to gauge the intensity of the three primary colors: red, green, and blue (RGB).[1,24] They store only three data points hue, value, and chroma.[24] They are easier to use, cost-effective compared to spectrophotometers, and allow quick data loading by circumventing the color mapping process.[24] They measure the total light absorbed but do not quantify the light absorbed at differing wavelengths like the spectrophotometers.[1,24] Hence, they are considered to be less accurate than spectrophotometers.[1,24] Examples of colorimeters are Shadevision (X-rite, Grandville, MI, USA), ShadeStar (Lukadent and ShadeEye (Shofu Dental GmbH, Ratingen, Germany).[1]

Digital Imaging Systems

Digital imaging systems are classified into two types: intraoral scanners and digital cameras.

Intraoral Scanners

Over the last two decades, intra-oral scanners (Fig. 35) have become increasingly popular for making digital impressions and recently, they have been recommended as novel tools for digital shade determination.[65-67] They have inbuilt high-resolution cameras that can capture images detailing both the shape and the color of the dentition in real-time. The images are then analyzed using the imaging software. Scanners permit color determination without the need for additional equipment.

Fig. 34 - Colorimeter
Image: Xrite Inc

Current literature on the use of scanners for digital shade determination is controversial. AKL et al. have suggested that intraoral scanners set to the Vita 3D Master shade guide may be used for shade matching, however; they indicated that the shade determined by the scanner should be verified with visual shade matching.[67] Similarly, Tabatabian et al. reported that intraoral scanners demonstrate acceptable precision but unacceptable accuracy for shade matching.[68] Thus, it can be concluded that intraoral scanners should be used as adjuncts to the visual color determination process rather than as standalone tools.

Digital Cameras

The latest innovation for dental shade matching involves the use of digital camera technology (Fig. 36).[1,7] The cameras used for digital shade matching are usually equipped with three separate sensors that have a filter over each of them.[39] The standardized digital images are recorded with the digital camera, exported to a computer, and then analyzed using imaging software.[48] These cameras are capable of shade matching across the entire spectrum of color space for natural teeth.[69] The advantage of using a digital camera for shade matching is that the process is objective and efficient.1 In addition, the recorded images can be stored digitally and easily shared with dental laboratories, thereby ensuring proper communication and decreasing the risk of inaccuracies in the fabrication process.[66] However, color-matching accuracy is dependent on several factors including the quality of the camera, its calibrations, type of lens, illumination sources, color temperatures, ambient light, and the image-processing

Fig. 35 - Intraoral Scanner
Image: © 3Shape A/S

Fig. 36 - DSLR Camera with Lens
Image Source: https://www.nikon.co.in/z6iii-nikkor-z-24-200mm-f-4-6-3-vr

method.[38,64] If the practitioner is not properly trained in photography and image analysis, there may be errors in image capture and/or shade interpretation resulting in a shade mismatch. Additionally, the cost of high-quality digital cameras and associated equipment may deter their use by many practitioners.[1] Digital photography can be an ideal adjunctive tool for the dentist and laboratory technician for shade matching.[1]

Common Causes of Errors During the Instrumental Shade Selection Process

1. **Errors associated with surface luster:** Smooth tooth surfaces appear brighter compared to uneven/rough surfaces, this may lead to an erroneous reading when a digital system is used. It is suggested that filters be added to the newer shade-matching systems to compensate for this probable error.[48]

2. **Errors associated with translucent teeth/restorations:** The surfaces of a translucent tooth/restoration are associated with light loss.[39,48] Modifications should be made to the software to accommodate the loss of light and/or other light-scattering properties of teeth, crowns, and shade tabs. Most of the current digital systems (except digital imaging) cannot correctly replicate the translucency of natural teeth.

3. **Errors associated with probe position:** Positioning of the probe is an important factor affecting the accuracy and repeatability of the measurement.[39,48] A device with a small diameter contact probe is unable to record a detailed color map of the tooth surface while a larger diameter probe is often limited to the anterior regions of the mouth.

4. **Errors associated with poor laboratory system alignment:** If the laboratory has a different digital system than the practitioner, there will be errors in shade matching.[39,48]

Selecting the Most Optimal Method for Shade Selection

There is no consensus on the superiority of a single system for shade determination.[38] Both the visual and instrumental methods have their merits and limitations. Instrumental methods may be preferred due to their objectivity, accuracy, and precision compared to the visual methods.[3,15,70] However, they are expensive and may not be reliable in the posterior quadrants of the mouth.[71] The visual method may be chosen as it is easy, simple, and economical, and the patient can be involved in the shade determination process. However, the process is inherently subjective.[7,28,48] Hence, it is recommended that a combination of both methods be utilized to achieve the most optimal result.[6]

Communication with the Laboratory Technician

Effective communication between the clinician and the laboratory technician is a prerequisite for achieving a successful match of the indirect restoration. In addition to providing detailed instructions, the following tools should be utilized to enhance the communication process:

1. Shade maps: Teeth are not monochromatic and significant differences in shade and texture are usually present on the various areas of the surface of a tooth. A 'shade map' (Fig. 37) of the facial surface of the tooth of interest is necessary to optimally communicate these details to the technician.[4] It involves drawing a picture (or editing a digital photograph) of a tooth, dividing it into 9-16 regions, and then recording and marking the shade and surface characteristics such as hypocalcified areas, craze lines, proximal discolorations, and translucency present in each region individually.[4,39,64]

2. Images: The images captured by the camera provide laboratory technicians with a visual reference, however, they may/may not help determine the exact shade of the tooth/teeth.[24] Once a few shade tabs have been shortlisted, a photograph is taken with the shade tabs next to the tooth of interest.[72] It's important to get the whole tooth in the picture along with the selected shade tabs and their markings (Fig. 38).

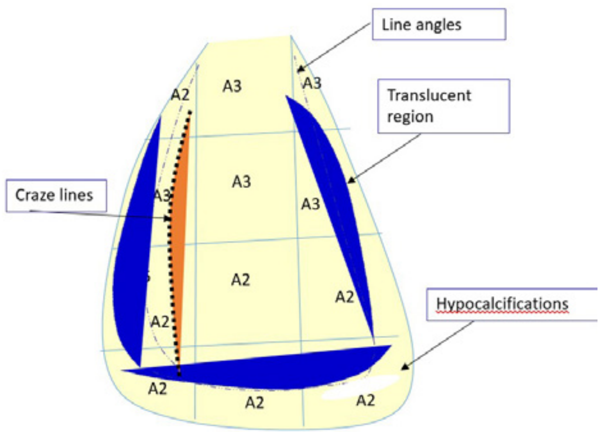

Fig. 37 - Shade Map

The flash system utilized while taking images affects the picture quality. The two most common flash systems that are used to acquire teeth close-up images are the ring flash and the twin flash.[73] The ring flash produces harsh illumination making it less ideal for accurate shade selection.[9] Twin flashes are superior and preferred as the light cast is more diffuse.[9] However, flash photography may cast unwanted reflections on the tooth surface. These reflections may conceal the surface features present on the teeth thereby failing to provide a complete picture to the lab technician. A cross-polarization filter helps remove the unwanted reflections (caused by the flash.)9 The cross-polarization filter allows enhanced perception making it easier to visualize the surface features like deminineralization, decalcification, and white spot lesions (WSLs).[74,75] The filter attaches to the macro flash by small magnets thereby permitting easy attachment and removal.

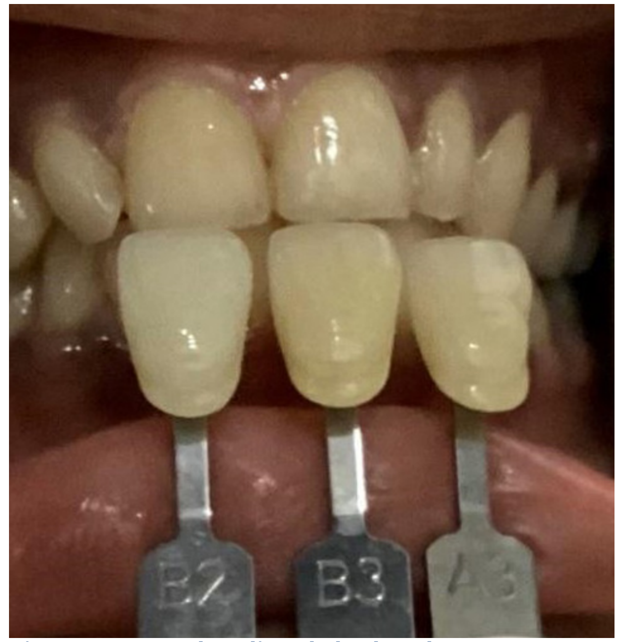

Fig. 38 - A Few shortlisted shade tabs are included in the image along with their markings.

After taking photographs depicting the shade selected and the tooth of interest with a DSLR camera and twin flash, the same image should be captured again using the cross-polarization filter. In addition to photographs of the selected shade tabs clicked near the dentition, images of the patient's face and full smile should also be taken and sent to the technician to ensure they have all the necessary information for restoration fabrication.

Summary

It is critical to match the surface form and color of teeth to create esthetic dental restorations. However, it is challenging to achieve a close shade match due to the wide variations in natural tooth color. Errors in shade selection (particularly value mismatch) can lead to patient dissatisfaction and treatment failure. For accurate shade matching, it is crucial to have a solid understanding of color, its different aspects, and the factors affecting the perceived color of a tooth. An integrated approach combining both visual and instrumental methods should be utilized for shade determination, as they complement each other. In addition, effective communication between clinicians and laboratory technicians is essential to ensure successful results.

Course Test Preview

To receive Continuing Education credit for this course, you must complete the online test. Please go to: *www.dentalcare.com/en-us/ce-courses/ce690/start-test*

1. The center of the cornea contains the cone cells while its periphery contains the rod cells. The cone cells interpret lightness/darkness of an object whereas the rod cells help detect different color.

A. The first statement is true, the second statement is false.
B. The first statement is false, the second statement is true.
C. Both the statements are true.
D. Both the statements are false.

2. Which wavelength/s of light will be reflected by a green colored object?

A. Black
B. Black, white and green
C. Green
D. White
E. All of the remaining wavelengths except green

3. In the Vita Classical shade guide, the hue associated with the shade tabs denoted by letter "C" is:

A. grey.
B. greyish-brown
C. reddish brown.
D. reddish-yellow.
E. reddish-grey.

4. Value is indirectly associated with chroma. The more the light absorbed by an object, higher will be its value.

A. The first statement is true, the second statement is false.
B. The first statement is false, the second is true.
C. Both the statements are true.
D. Both the statements are false.

5. As per the Munsell system, what will be the value of a white colored object?

A. 0
B. 1
C. 5
D. 7
E. 10

6. Which determinant of the Munsell color order system corresponds to the "L" of the CIELAB system?

A. Chroma
B. Color
C. Hue
D. Value

7. Increasing the translucency of a surface lowers its:

A. chroma.
B. color.
C. hue.
D. hue and chroma.
E. value.

8. A phenomenon wherein a material appears to be one color when light is reflected from it and another color when light is transmitted through it is termed as:

A. Fluorescence.
B. Metamerism.
C. Opalescence.
D. Phosphorescence.

9. Which light source is ideal for shade matching?

A. Color-corrected fluorescent light with a CRI 50-80
B. Color-corrected fluorescent light with a CRI greater than 90
C. Color-corrected halogen light with a CRI greater than 80
D. Incandescent light with a CRI greater than 50

10. Which region of the tooth and the shade tab should be used as a reference for hue determination?

A. Cervical third
B. Incisal third
C. Middle third
D. Both incisal third and middle third

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Additional Resources

- No Additional Resources Available

About the Author

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Dr. Ahuja graduated with a BDS from Nair Hospital Dental College in 2002 and an MDS certificate in Prosthodontics from the University of Tennessee Health Science Center, Memphis, TN. She then joined the same University as an Assistant Professor in the Department of Prosthodontics where she worked for 3 and half years. She served as the editor for the Department of Prosthodontics at University of Tennessee Health Science Center, Memphis, TN for the next 6 years. She has lectured nationally and internationally on various prosthodontic topics at various dental conferences. She has more than 60 publications in peer reviewed national and international journals. Dr. Ahuja is also the co-author of the textbook titled, "Applications of the Neutral Zone in Prosthodontics." Currently, she has a private practice in Mumbai.

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