

REVIEW

Shade Selection: A Review

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Abstract

Esthetics in dentistry relies heavily on accurate shade selection to ensure restorations blend seamlessly with natural teeth. This review explores the fundamental principles of color, including hue, value, and chroma, and examines the various factors influencing shade perception, such as light sources, observer variables, and tooth properties. It provides a comprehensive overview of both visual methods, utilizing various conventional shade guides, and modernized instrumental techniques like spectrophotometers, colorimeters, and digital imaging systems. Ultimately, combining visual analysis with advanced technological devices is recommended to overcome common human errors and achieve optimal esthetic outcomes in dental restorations.

KEYWORDS

Esthetic dentistry, Shade selection, Color perception, Shade guides, Spectrophotometry, Colorimetry

1 | INTRODUCTION AND BACKGROUND

Esthetics has gained wide importance over the last few years among both dental practitioners and patients. It is essential to deliver an esthetic restoration that symmetrically blends with the patient's adjacent teeth. However, owing to the extensive range of natural tooth colors, achieving an intimate shade match between the prosthesis and natural teeth is challenging. Many prostheses fail due to improper shade selection, and therefore, every dentist should be acquainted with the shade selection process to achieve the best outcomes.¹ Esthetic expectations

have exponentially increased over the last few years. Color and shade determination have traditionally been one of the greatest challenges in dental field. Esthetics of any restoration depends not only upon the outline form, surface finish and translucency but also the color. The human brain can identify nearly one million shades, and precise devices that can recognize approximately 10 million different shades have been developed. Human dentition shades differ significantly, and electronic devices can identify approximately 100,000 dental shades while the human eye can identify only 1% of these shades.² The integration of conventional shade guides and modernized shade-taking devices, along with advancement in human color vision research, has enhanced the ability of dentists to achieve excellent color-matched restorations. However, to achieve optimal results, it is essential for dentists to possess a

comprehensive understanding of color and the natural appearance of teeth in addition to utilizing these new devices.³

2 | COLOR AND OPTICAL EFFECTS

These are focused on those properties that are necessary to permit a material to restore the function of damaged or missing natural tissues. Another important goal of dentistry is to restore or improve esthetics—the color and appearance of natural dentition. Since esthetic dentistry imposes severe demands on the artistic abilities of the dentist and technician, knowledge of the underlying scientific principles of color and other optical effects is essential. This is especially true for the increasingly popular restorations that involve ceramic materials.

3 | FACTORS INFLUENCING SHADE SELECTION

NATURE OF LIGHT AND THE ROLE OF HUMAN VISION: Light is electromagnetic radiation that can be detected by the human eye. The eye is sensitive to wavelengths from approximately 400 nm (violet) to 700 nm (dark red). The reflected light intensity and the combined intensities of the wavelengths present in incident and reflected light determine the appearance properties of hue, value, and chroma. For an object to be visible, it must reflect or transmit light incident on it from an external source. Light from an object that is incident on the eye is focused in the retina and is converted into nerve impulses, which are transmitted to the brain. Cone-shaped cells in the retina are responsible for color vision. The signals from the retina are processed by the brain to produce the psychophysiological perception of color. **THE NATURE OF OBJECT UNDER VIEW:** Esthetics is critically important in dealing with dental restorative materials. For good esthetics, the interaction of light with restorative materials must mimic the interaction of light with natural teeth. Electromagnetic radiation in the visible region interacts with an object through reflection from its surface, absorption, refraction, or transmission (i.e., by passing through unchanged.) These phenomena determine the opacity, translucency, or transparency of an object. The opacity of a material is related to the amount of light it can absorb and/or scatter. The opposite of opacity is translucency. **THE EFFECT OF THE OBSERVER:** Signals of color are sent to the human brain from three sets of receptors in the retina called cones, which are especially sensitive to red, blue, and green. Factors that interfere with the true perception of color generally include low or high light levels, fatigue of the color receptors, sex, age, memory, and cultural background. At low light levels, the rods in the retina of the human eye are more dominant than cones, and color perception is lost. As the brightness becomes more intense, color appears to change (Bezold-Brucke effect). Also, if an observer looks at a red object for a reasonably long time, receptor fatigue causes a green hue to be seen when he or she then looks at a white background. **THE EFFECT OF THE LIGHT SOURCE:** Because the spectral distribution of

the light reflected from or transmitted through an object is dependent on the spectral content of the incident light, the appearance of an object is dependent on the nature of the light in which the object is viewed. Daylight, incandescent, and fluorescent lamps are common sources of light in the dental operator or laboratory, and each of these has a different spectral distribution. Objects that appear to be color-matched under one type of light may appear different under another type. This phenomenon is called metamerism. Thus, if possible, color matching should be done under two or more different light sources, one of which should be daylight, and the laboratory shade matching procedures should be performed under the same lighting conditions.

4 | THREE DIMENSIONS OF COLOR

In 1900, American painter Albert Henry Munsell wrote about tri-dimensional property of colour **MUNSELL COLOUR SYSTEM**. **HUE:** referred to as the basic color, The dominant color of an object. **VALUE:** Value is also known as the gray scale. It is the vertical, or Z-axis. Value increases toward the high end (lighter) and decreases toward the low end (darker). Teeth and other objects can be separated into lighter shades (higher value) and darker shades (lower value). **CHROMA:** Chroma is the degree of saturation of a particular hue.

5 | SHADE SELECTION BASED ON (ACCORDING TO JOINER AND ALVIN)

- Physical and Optical properties of tooth being viewed
- Nature of light to which tooth is exposed
- Assessment of tooth shade by observer
- Relationship of tooth to its surrounding colour structure.

PHYSICAL AND OPTICAL PROPERTIES OF TOOTH BEING VIEWED: Most important physical property related to a tooth's shade is its moisture content. On the basis of these normal physiologic phenomena, Wagenaar and Smith have suggested that the shade selection process is directly related to three essential factors: The Tooth being viewed, The Light source being used, The Eyes of the observer. **NATURE OF LIGHT TO WHICH THE TOOTH IS EXPOSED:** Sunlight remains a major source of energy and its distribution and intensity depends on different factors light during morning or evening hours is rich in yellow and orange but lacking in blue and green. For shade selection purposes in the form of "Northern daylight" i.e. sunlight around the noon hour on a bright day with slight overcast. **ASSESSMENT OF TOOTH SHADE BY AN OBSERVER:** Capability of the eyes to decrease when a tooth is viewed for longer than 10 seconds observed color becomes less and less saturated while simultaneously increasing the chroma of complementary colors. **RELATIONSHIP OF THE TOOTH TO ITS SURROUNDING COLORED STRUCTURES AND SURFACES:** Tooth color perceived by an observer is influenced by other colored structures surrounding the tooth such as adjacent teeth, gingival, lips, face skin, clothing of the patient and operatory walls. Presence of dark colored lipstick creates the illusion of

whiter teeth it is believed that individuals with darker skin colors have lighter shades of teeth, which is explained by the illusion of greater contrast between skin color and tooth shade. Clothing worn by the patient and color of operatory walls can create contrast effects during the shade selection process. Therefore, it has been recommended to drape all bright colored clothing prior to shade selection while the operatory walls should be painted in a neutral (pale gray-blue) color.

6 | MEASUREMENT OF COLOR

Shades can be measured using two techniques: 1. Visual Technique; 2. Instrumental Technique. 1. Visual Technique: The Munsell system, which may be depicted in three dimensions of color, is a commonly used method for visually measuring tooth shade. 1. Shade Guides: In dentistry, shade guides are used to match with the natural tooth structure that comprise of a set of standard or independently fabricated shades.⁴ Shade guides can be classified on the basis of material from which they are made, such as composite resin based, acrylic based and ceramic based.^{5,6,7} Generally, shade guides should have a full range of natural color for dental structures. As a general standard, each shade tab is composed of an incisal, middle and cervical part that varies in shade on the basis of translucency and color density.⁸ In prosthetic dentistry, selection of shade is a significant phase in all directions, which, later on, is delivered to the laboratory technician to fabricate indirect restoration. Presently, there are a number of accessible shade guides applied in the clinical practice of dentistry: Vita classical, Vita Tooth guide or 3D-Master shade and Chromascop. They are based on Munsell's guiding principles that distribute the color space into three dimensions: hue (name of the color), chroma (color density) and value (vitality of color).^{5,10} 2. Vita Classical Shade Guide: In Vita Classical, the color space is classified into four groups: A, B, C and D; these comprise the leading HUE (name of color). These are red and brown in group A, red and yellow in group B, gray in group C, and red and gray in group D. Every letter group has sub-divisions indexed with Arabic numbers, ranging from 1 to 4, which makes the overall number of tabs 16. As the number increases, the value decreases, whereas the chroma increases simultaneously.¹¹ 3. Vita 3D Master Shade Guide: This shade guide entails 26 tabs that are organized into five groups with respect to their value. The tabs are further arranged along with two axes inside the groups, i.e., vertical in relation to chroma and horizontal axes according to hue. The first group consists of two tabs, the second, third and fourth comprise seven each, whereas the fifth one has three tabs. Moreover, every shade tab has three markers ranging from 1 to 5, presenting the group and the level of value that decreases as the number increases.¹² The Vita 3D-Master shade guide is considered superior to the Vita classical shade guide. It contains enhanced lightness spectrum and additional chromatic tabs. The hue latitude is expanded against the reddish spectra. Further, the shade tabs are evenly distributed and group division is improved. 4. Chromascop: Chromascop uses a numbering system to identify shades. It is organized into groups depending on the hue (100 =

white, 200 = yellow, 300 = orange, 400 = gray, 500 = brown) and within the groups as chroma increases from 10 to 40. Custom Shade Guides: The standard shade guide cannot encompass the entire range of hue and chroma values of human dentition. It is useful for 85% of the color selection, and its alteration or preparation of custom shade tabs is necessary for the remaining 15%. Composite resin, ceramic, or acrylic materials are used to fabricate custom-made shade guides. Shade guide modifications can be performed using surface colorants or by surface abrasion using aluminum oxide. Fine line markers and colored pencils may be used to reproduce the minute variations between shades, analogous translucency, and denominating colors.¹ Dentin and Extended Shade Guides: Dentin system can be used for the fabrication of translucent all-ceramic crowns and veneers. This shade guide helps in communicating a specific shade to the dental laboratory. Specially colored die materials corresponding to the dentin shade are used, which allows the technician to appraise the esthetics of the restoration. The extended shade guide comprises the tabs of all materials used to fabricate the restoration. It may also be utilized to expand the choice of shade. Advantages of Shade Guides: The most common method of shade selection is using a visual shade guide.¹³ It is economical and durable, i.e., does not require frequent replacement of the shade guide. It provides an efficient comparison with natural tooth color. Most frequently used by dentists, dental assistants and dental laboratory technicians to communicate the proper tooth color, brightness and translucency.¹ Easily available. Disadvantages of Shade Guides: In shade guides, the colors may differ for each company. Porcelain that is used for restoration of teeth may be different with a shade guide. Guides are not able to direct the manufacturing of porcelain restoration. The shades of a tooth in a shade guide are not rationally arranged and do not cover the capacity of color space that is normally unoccupied in natural teeth. A normal shade tab is prepared from synthetic resin having greater density than a crown. A shade guide tab reflects and transforms light-forming translucency and provides a look of vitality.^{14,15}

7 | INSTRUMENTAL TECHNIQUE

Even though instrumental techniques in dental color matching are very costly and not easily accessible to dental practitioners, they have been growing rapidly and accepted in dentistry.¹⁶ Instrumental color analysis, on the other hand, offers a potential advantage over visual color determination because instrumental readings are objective, can be quantified and are more rapidly obtained. Spectrophotometers and colorimeters have been used with modifications in an attempt to overcome problems with visual shade matching.¹¹ An instrumental technique includes spectrophotometers, colorimeters, scanners, digital cameras and smartphones. 1. Spectrophotometers and Spectroradiometers: In dentistry, spectrophotometers are amongst the most precise, expedient and flexible instrumental method used for general color matching.¹¹ A spectrophotometer varies from spectroradiometer as it mostly comprises a stable light source. These gadgets have been made using

two different straightforward designs. The standard scanning apparatus has a single photodiode sensor that counts the amount of light at all wavelengths.¹⁷ The latest designed devices employ a diode arrangement with a specified element for every wavelength. This design supports the synchronized incorporation of all wavelengths simultaneously. Both types are crucial for research into the development of more precise color-measuring equipment, even though they operate much more slowly than filter colorimeters.

2. Colorimeters: A colorimeter measures color (hue, chroma, and value) as perceived by a human eye. Colorimeters record tri-stimulus values and filter light in red, green and blue regions of the visible spectrum.¹⁸ A colorimeter presents a complete measurement of light absorbed; however, a spectrophotometer quantifies the light absorbed at differing wavelengths.¹⁹ Shade Vision is an imaging colorimeter. Comprehensive tooth appearance is provided by the use of three distinct records, particularly for gingival, middle and incisal third.

3. Digital Cameras and Imaging Systems: Digital cameras show the most basic method for electronic shade measurement, still demanding a certain degree of independent shade selection with the human eye.²⁰ Digital imaging systems are becoming progressively more widespread in measuring the shade of teeth.

4. Hybrid Devices: SpectroShade provides a combination of digital imaging and spectrophotometric analyses. It uses ClearMatch software system and is a hardware-independent product developed for use on all personal computers having the Windows platform and almost any digital camera.²¹

Limitations of digital shade guide: The limitations of digital shade guide include the following: (a) the phenomenon of edge loss affects the accuracy of color measurement; (b) translucent mapping is inadequate for all systems; (c) placement of the probe or mouthpiece seems to be important for the repeatability of the measurement; (d) no digital shade guide is sufficiently advanced to operate in a formulation mode; (e) the laboratory must have up-to-date systems for the successful application of this approach; (f) this approach requires a relatively expensive setup.

• Dichromatism: Sensitivity to only two primary hues usually either red or green is not perceived

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

2. Age: Aging is detrimental to color-matching abilities because the cornea and lens of the eye become yellowed with age, imparting a yellow-brown bias. This process begins at age 30, becomes more noticeable at age 50 and has clinical significance after 60 years of age. After age 60, many people have significant difficulties in perceiving blues and purples.

3. Fatigue: Tired eyes cannot perceive color as accurately as alert eyes. Compromised visual perception is due to systemic, local or mental fatigue. Successive shade observations (treating many patients requiring shade assessment during a single workday) can be primary cause of fatigue.

4. Emotions: Color can function as a language. For, e.g., many places in world, red suggest anger, yellow represents joy, blue is associated with sadness. It is generally known that emotion can affect papillary diameter, causing dilation or constriction and this has a direct effect on color discrimination.

5. Medications: The abuse of drugs, alcohol and caffeine will affect not only judgment, but also color perception. Medications can act on any part of the visual system from the visual cortex to the retina. Viagra, a drug used to treat erectile dysfunction, is notorious for causing vision to have a blue tint. Of special concern for female practitioners are the side-effects caused by oral contraceptives, i.e., red-green or yellow-blue discrimination defects. Long use of oral contraceptives will cause a decrease in color perception of blues and yellows.

6. Binocular difference: Binocular difference is the perception difference between the left and the right eye.

7. Environmental influences: The setting in which an object is viewed can influence the perceived color. The background and surroundings can affect the saturations and the hues perceived. Patient's complexion, make-up and even reflection from the operatory equipment and walls can modify the color of the oral environment and the shade sample, which can influence the shade determination.

8 | CURRENTLY AVAILABLE DEVICES

There are at least six commercially available systems, ranging from simple to complicated, with capabilities and prices to match. The devices are generally one of three types—colorimeters, Spectrophotometers, or digital color analyzers—and use various measuring geometries. a. Shofu's Shade Chroma Meter, b. The Vita Easyshade, c. The ShadeScan, d. ShadeRite Dental Vision System, e. The SpectroShade, f. ClearMatch System.

9 | PROBLEMS DURING SHADE MATCHING

²² 1 Color vision problem/color blindness: Color blindness is caused by a deficiency in or absence of one or more of the three types of photosensitive pigments able to detect red, green and blue. Different types of color vision confusion exist: • Achromatism: Complete lack of hue sensitivity

10 | CONCLUSION

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

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