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COLOR AND ITS DIMENSIONS - A REVIEW

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ABSTRACT: In the modern civilized, cosmetically conscious world, well-contoured and well-aligned white teeth set the standard for beauty. Such teeth are not only considered attractive, but are also indicative of nutritional health, self-esteem and hygienic pride. Attention to accuracy and reliability of any spectral or color measurement system, with further attention to the proper statistical parameters to evaluate accuracy and reliability.

KEYWORDS: Hue, Value, Chroma, Color systems.

INTRODUCTION

Visual impressions pervade our daily lives. Esthetics is sometimes defined as the 'art of perception' (Ancient Greece). Color is an energy wave of a specific wavelength that determines the color of what the eye has seen.

Color, as the eye interprets it, is either a result of absorption or reflection. In absorption a white light is passed through a filter. In reflection, as with solid objects, the color is the portion of the spectrum that is reflected back to the eye. Eye is sensitive to a visible part of electromagnetic spectrum – a narrow band with wave-lengths of 380 – 750 nm. Light entering the eye stimulates the photoreceptor rods and cones in the retina. The energy is converted through a photochemical reaction into nerve impulses and carried through the optic nerve into the occipital lobe of the cerebral cortex. The rod cells are responsible for interpreting brightness differences and value. The cone cells function in hue and chroma interpretation.[1]

HISTORY: In 1666, Sir Isaac Newton observed that white light passing though a prism divided into an orderly pattern of colors termed as spectrum. In 1915 Albert Henry Munsel created an orderly numeric system of color description that is still the standard today.[2]

FACTORS THAT INFLUENCE ESTHETICS: Important factors that influence esthetic appearances of restorations are color, translucency, gloss, and fluorescence. Each of these factors, as perceived by an observer such as a dentist, technician, or patient, is influenced by (1) the illuminant (light source) (2) the inherent optical parameters of the restorative materials that dictate the interaction of the light from the illuminant with the material, and (3) the interpretation of the observer.

Illuminant: Light waves emitted from the illuminant interact with the object and are perceived by the observer. The color content of the illuminant is the intensity of light emitted at each wavelength (spectral distribution). The wavelengths of light are associated with hues, commonly referred to as color.

The characteristics of an illuminant are important in color evaluation. In any color description the type of illuminant used needs to be defined, appropriate illuminant needs to be used in shade selection and shade matching. Illuminants that closely approximate daylight are preferred because color considerations for restorations, when seen under these illuminants, are close to those seen under natural light. Several "daylight" sources intended for use in dental operatories are available.

Color-rendering index: Another parameter used in characterizing an illuminant is the color-rendering index. The color-rendering index is a measure of the degree to which the illuminant(manufacturer) can impart the color of an object as compared to the reference source. A color-rendering index of 100 is considered ideal. For an adequate color-matching environment, the illuminant should have a color-rendering index of 90 or above (Preston et al, 1978).[3]

Object: The inherent color property of an object is its characteristic interactions with the light from the illuminant. These interactions include reflection, transmission, and the absorption involved in both processes.

Reflection: A material gains its reflective color by reflecting that part of the spectrum of light incident upon it and absorbing the other parts of the light spectrum. A blue surface reflects only the blue part of the light spectrum and absorbs all other colors.

A white object reflects all incident wavelengths. A black object absorbs all wavelengths and reflects none. An object also appears black when no light is reflected from it;

for example, a blue object appears black when viewed in red light. Materials of different reflected color have different color reflectance spectra. Reflection spectra of objects are usually obtained using a spectrophotometer.

Transmission: A translucent material gains its transmitted color by the resultant spectrum it transmits. As a beam of light passes through a translucent material (eg, glass), it can be changed by the color of the material or scattered by fine particles, giving a milky appearance. For example, a green filter transmits light in the green wavelength region of the light spectrum and absorbs all other wavelengths.

Observer: The observer receives the light reflected or transmitted by the object and then interprets the results. In many cases, the observer uses the human eye as the detector. Eye responses vary among individuals. It is most sensitive in the green color region.

Constant stimulus of one color decreases the response of the eye to that color known as color fatigue. Other detectors may be used as an observer in place of the human eye are photo detectors, such as spectrophotometers or colorimeters.

Color Systems: Color systems are used to describe the color parameters of objects. The following are examples of some color systems used in describing the color of dental materials.

Munsell color system: The Munsell color system uses a three-dimensional system with hue, value, and chroma as coordinates.

Hue: Hue is the name of the color. It is defined as the particular variety of a color, shade or tint. VIBGYOR (Violet, Indigo, Blue, Green, Yellow, Orange, Red) is an acronym for the hues of the spectrum. In the younger permanent dentition, hue tends to be similar throughout the mouth. With aging, variations in hue often occur because of intrinsic and extrinsic staining. Most natural teeth fall into a range between yellow and yellow-red.

Chroma: Chroma is the saturation or intensity of hue; therefore it can only be present with hue. In Munsell color system, maximum chroma depends on the particular hue but can range from 10-14. Achromatic shades have a chroma near zero. Natural teeth:0.5 – 4. For example, if a glass of water had a drop of ink dropped into it, it would exhibit a light blue appearance. As more drops are added, the hue does not change, as all the drops come from the same source. The medium is progressively more saturated i.e. the chroma is raised.

Value: Value is the relative lightness or darkness of a color. A light tooth has a high value; a dark tooth has a low value. It is not the quantity of the "color" gray, but rather the quality of brightness on a gray scale. In Munsel color system, value is divided into 10 gradations, with 0 being black and 10 being white. Value is the most important factor in shade matching. If the value blends, small variations in hue and chroma will not be noticeable.[3-5]

COLOUR (HUE) RELATIONSHIP

The Color Wheel: Hues, as used in dentistry, have a relationship to one another that can be demonstrated on a color wheel. The relationships of primary, secondary, and complementary hues are graphically depicted by the c olor wheel.

Primary Hues: The primary hues – red, yellow and blue from the basis of the dental color system.

Secondary Hues: The mixture of any two primary hues forms a secondary hue.

Complementary Hues: Colors directly opposite each other on the color when are termed complementary hues. When a primary hue is mixed with a complementary secondary hue, the effect is to "cancel" out both colors and produce gray. This is the most important relationship in dental color manipulation. To change hue, lessen chroma, or lower value, place the complementary hue over the color to be modified.

When a portion of a crown is too yellow, lightly washing with violet (the complementary hue of yellow) produces an area that is no longer yellow. The yellow color is cancelled out and the area will have an increased grayness (a lower value). If a cervical area is too yellow and a brown color is desired, washing the area with violet cancels the yellow. This is followed by the application of the desired color, in this case brown. Complementary hues also exhibit the useful phenomenon of intensification. When complementary hues are placed next to one another, they intensity one another and appear to have a higher chroma. A light orange line on the incisal edge intensifies the blue nature of an incisal color.[6]

Hue Sensitivity: After 5 seconds of staring at a tooth or shade guide, the eye accommodates and becomes biased. The original color appears to become less and less saturated until it appears almost gray. Shade selection can be enhanced while glancing at a pale gray-blue surface periodically.

CIE color systems: The CIE tristimulus values system uses three parameters, X, Y, and Z, which are based on the spectral response functions defined by the CIE observer. Another CIE color system (CIE L*a*b*) uses the three parameters L*, a*, and b* to define color. The CIEL*a*b* system was defined by the International Commission on Illumination (1967) and is referred to as CIELAB. The L* represents the value (lightness or darkness). The a* value is a measure of redness (positive a*) or greenness (negative a*). The b* value is a measure of yellowness (positive b*) or blueness (negative b*). The difference between the color coordinates was calculated as: DE* = [(DL*)2 + (Da*)2 + (Db*)2]1/2. Whitening occurs mainly by increasing the lightness.[7-8]

Color Measurements: Apart from visual comparison using color standards such as Munsell color chips, color measurements can be made using either spectrophotometric or colorimetric methods.

Spectrophotometers: Measure the amount of light reflected at each wavelength. A double-beam spectrophotometer compares the responses from the object and a reference standard. From the spectral response, color parameters for the object can be calculated. Spectrophotometric measurements have been used to evaluate the color parameters for restorative resins, denture teeth, porcelains, shade guides, and color changes in dental materials.[9]

Colorimeters: Measure the amount of light reflected at selected colors (eg, red, green, blue). The selections are based on the CIE tristimulus value standard observers. A new approach to tooth shade selection is the use of photography in combination with a spectrophotometer. Although accurate instrumental measurements of color parameters of translucent materials are difficult to use, color measurements on photographs are routine.

This procedure of photocolorimetry involves the following steps:

1. The clinician or assistant holds the 3 or 4 closest-matching shade guide teeth next tothe patient's teeth and photographs them with a 35-mm camera under a balanced light source
2. The photograph is sent to the dental laboratory along with the impression. The laboratory technician measures the color of the patient's teeth and shade guide teeth in the photograph and analysed with computer software.[10-13]

Dental Shade Guides: Shade guides are used in determining the color of natural teeth so that artificial substitute restorations will possess similar color and esthetics. Preferred properties in a shade guide include logical arrangements and adequate distribution in color space, matching with natural teeth, inherent consistency among shade guides, and matching between shade guides and the dental materials such as porcelains and resin composites or denture teeth. Not all these properties are met by the shade guides currently available. Furthermore, not all shade guides are fabricated from the dental materials to which they will be matched. Most shade guides use a designation to denote the shade and color. The same designation may not be comparable among brands. Recently a new shade guide (Vita 3D Guide, Vita) has been introduced that is based on hue, value, and chroma in a logical arrangement. Classical vita shade guide has been the most frequently used one and also listed as a reference shade guide in ADA guidelines for over the counter, dentist dispensed home-use, and professional in-office tooth bleaching products.[14-18]

Shade Matching in the Dental Operatory: Shade matching is a complex situation. It is important to remember the triadic interactions of illuminant, object, and observer described previously. Considerations should also include metamerism, gloss, translucency, and fluorescence. Recognition of the factors influencing shade match improve the result of the match.

The most important factor in shade matching is the illuminant. This is the lighting in the dental operatory used in shade matching. A color-corrected light source with a color temperature of 5,500 K and a color-rendering index of 90 or above is recommended. If possible, the shade matching should also be checked under a different light condition, for example, a warm white fluorescent light. In cases where the patients may have specific requirements, such as extensive activity under certain lighting conditions, shade-matching checks under those conditions are also recommended. The color environment of the dental operatory is another important factor in shade matching. A neutral, light gray background color reduces modification of color perception.[19]

Metamerism: The change in color matching of two objects under different light sources is called metamerism. An example of metamerism is when a shade-guide tooth matches the tooth under fluorescent light but not under incandescent light. Metamerism results from possible differences in illumination between the dental clinic and the dental laboratory, causing poor matching in a fabricated restoration, such as a porcelain crown. Standardization of illuminations (usually similar to the patient's environment) in color matching diminishes the effect of metamerism in shade matching. The ideal situation, of course, is to have the objects possess the same color reflectance curve. The objects are then an isomeric pair; they are color matched under all light sources.

Translucency: The translucency of an object is the amount of incident light transmitted and scattered by that object. A high translucency gives a lighter color appearance. A more translucent material will show more of the backing in the color and appearance. Translucency decreases with increasing scattering within the material.

The opposite of translucency is opacity. Light scattering in a material is the result of scattering centers that cause the incident light to be scattered in all directions. Examples of scattering centers are air bubbles and opacifiers such as titanium dioxide. Another example is the filler particles in a resin composite matrix. The effect of scattering is dependent on the size, shape, and number of scattering centers. Scattering is also dependent on the difference in refractive indices between the scattering centers and the matrix in which the centers are located. Measurements of translucency may be performed using transmission spectrophotometers, reflection spectro-photometers, light meters, or colorimeters.[20]

Gloss: Surface gloss is the optical property that produces a lustrous appearance. Gloss is the amount of collimated incident light that is specularly reflected. In specular reflection, the angle of incidence is equal to the angle of reflectance. When the incident beam is scattered by the object, there is a decrease in gloss as a larger portion of the incident beam is diffuse-scattered. Gloss is an important appearance property of dental restorative materials. A high surface gloss is usually associated with smooth surfaces. In resin composite, surface gloss decreases with increasing surface roughness. Differences in gloss between multiple restorations or between restorations and teeth can be easily detected even in colors that are matched. In addition, high gloss reduces the effect of a color difference, because the color of the reflected light is more prominent.

Fluorescence: Fluorescence is the emission of light by an object at wavelengths different from those of the incident light. The emission ceases immediately upon removal of the incident light. Natural teeth fluoresce in the blue region when illuminated by ultraviolet light. Dental porcelains are also fluorescent under ultraviolet light. The quality of the fluorescence depends on the brand of porcelain, some of which fluoresce in colors different from those of natural teeth.[21]

CONCLUSION: The science and art must be made available to all and should facilitate not only improved results but the enjoyment of accomplishing the difficult task of replicating natural beauty with dental materials. The color of an object involves the modification of the spectral energy from the illuminant by the object and the processing by an observer of this modified spectral energy from the object relative to the energy direct from the illuminant. Further involved are the geometrical relationships of the illuminant, the object and the observer, and any intervening optical interference. Such complexity requires attention to accuracy and reliability of any spectral or color measurement system, with further attention to the proper statistical parameters to evaluate accuracy and reliability.

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