ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 5, Issue – 4, August - 2022, Page No. : 199 - 208

Color - Its role in conservative dentistry

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Citation of this Article: Dr. Kanwal Preet Kaur Bhullar, Dr. Rupam Kaur Virk, Dr. Shantun Malhotra, Dr. Aashish Handa, Dr. Roohan Malhar Sandhu, "Color - Its role in conservative dentistry", IJDSIR- August - 2022, Vol. – 5, Issue - 4, P. No. 199 – 208.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

The success of restorative treatment is evaluated according to functional and Esthetic results. Esthetics is considered one of the most important parameters in the success of restorative dentistry and color matching is an essential component for achieving natural-looking restorations. If not performed properly, it can yield unsatisfactory results for both the clinician and the patient. The knowledge of the concept of color, various dimensions of color, optical properties of teeth, perception of color and various factors affecting it including viewer associated factors are imperative for obtaining an Esthetic restoration. The purpose of this review is to critically analyse the present literature, and discuss in detail various factors associated with color perception, visual and instrumental methods of color measurements, different shade guides, various color measuring instruments, recommended protocols for shade selectrion and various clinical factors affecting shade selection to ensure Esthetic life like restorations.

Keywords: shade guides, visual color matching, instrumental color matching, shade selection

Introduction

The success of restorative dentistry is determined on the basis of functional and Esthetic results. To achieve esthetics, four basic determinants are required in sequence; viz position, contour, texture and color.[1.]

Because estheic dentistry imposes several demands on the artistic abilities of the dentist and the technician, knowledge of the underlying scientific principles of color is essential. Color combination not only improves esthetics but also makes the restoration appear natural and life-like. Continued research on the human visual system has given us greater insight regarding color discrimination by human eye and various factors affecting it like disease, drugs and aging.

The perception of color is influenced by three factors namely, the light source, the object being viewed and the observer viewing the object. For teeth the colour is determined by a combination of its optical properties. Joiner A (2004)[3] stated that when light encounters a tooth, four phenomena takes place namely specular transmission of the light through the tooth, specular reflection at the surface, diffuse light reflection at the surface and absorption and scattering of light within the dental tissues. All these factors should be considered while aesthetic rehabilitation of teeth for more lifelike restorations.

While shade matching of the restoration with adjacent teeth there are various factors that need to be considered like translucency, contour, surface texture, luster, and fluorescence.

An understanding of the science of color, knowledge of color perception, optical characteristics of object and behaviour of restorative procedures under various optical conditions, environmental factors need to be considered to ensure success of aesthetic restorative procedures.

Physics of color

Emission: Emission of light from a source occurs through a chemical or physical process.

Transmission and absorption: Transmission occurs when light passes through a transparent or translucent material. If the material is completely opaque, all light is absorbed,

Reflection: Reflection occurs when light rays strike a solid object, and then bounce off of it. The wavelengths that are reflected compose the color that is perceived

Perception: As light enters the eye through the cornea and lens, an image is focused on the retina. The amount of light entering the eye is controlled by the iris, which dilates or constricts depending on the level of illumination.

Three dimensions in color

Color is usually described according to the Munsell color space in terms of hue, value, and chroma.

Hue: "Hue" is the quality that distinguishes one family of color from another. It is specified as the dominant range of wavelengths in the visible spectrum that yields the perceived color.

Value: "Value" or brightness, is the amount of light returned from an object. Munsell described value as a white-to-black Gray scale.

Chroma: "Chroma" is the saturation, intensity or strength of the Hue. chroma and value are inversely related, as chroma is increased, the value is decreased.

Additive color theory: The additive primary colors are red, green and blue (RGB). Combining one of these additive primary colors with equal amounts of another one results in the additive secondary colors of cyan, magenta and yellow. Combining all three additive primary colors in equal amounts will produce the color white.

Subtractive color theory: The subtractive primary colors are cyan, magenta and yellow. Subtractive color mixing occurs when light is reflected off a surface or is filtered through a translucent object. For example, a red surface only appears red because it absorbs (subtracts)

all of the light that is not red and only reflects or allows the red light[1]

Optical properties of teeth

The colour of a tooth is determined by a combination of its optical properties. When light encounters a tooth, four phenomena associated with the interactions of the tooth with the light flux can be described

(1) specular transmission of the light through the tooth

(2) specular reflection at the surface

(3) diffuse light reflection at the surface

(4) absorption and scattering of light within the dental tissues.[3]

Vaarkamp et al.[4] measured the light propagation through 0.85 mm thick human enamel and dentine bars. For enamel it was found that the hydroxyapatite crystals contribute significantly to light scattering, whereas for dentine the optical anisotropy observed supported the idea that tubules are the predominant cause of scattering.

The various factors affecting color perception are

- Illumination
- illuminants
- Light intensity
- Metamerism:
- Contrast Effects
- Viewer-Associated Effects:

Illumination

Color can be accurately perceived only with proper illumination.

Illuminants

The type of illuminants used can significantly impact the perception of color. It is recommended to the clinicians to use D50 illuminants, which provide the closest lighting rendition to natural sunlight.

Light intensity

The intensity of light is the most common regulator of pupil diameter, which is a crucial factor in accurate shade matching.[5]

Metamerism

The phenomenon of two objects appearing to match in color under one condition but showing apparent differences under another is termed metamerism.

The only sure way to avoid metamerism is to achieve a spectral curve match. Pairs of colored objects that have the same spectral curve will always match regardless of the light in which they are viewed.

To combat metamerism, the clinician can perform shade selection and assessment under various lighting conditions.

Contrast Effects

Contrast effects are visual phenomena that can considerably alter the perception of color, as well as the ability to evaluate color in a clear, concise, and objective way.

Simultaneous contrast

Simultaneous contrast occurs when two colors are observed at the same time.

Perception of the color therefore is affected by three factors

- The surrounding relative lightness (the color will appear to be darker in lighter surroundings and vice versa)
- The surrounding color (the color will appear to have shifted toward its surrounding color's complement)
- The surrounding relative saturation (the color will appear to be more intense in less chromatic surroundings and vice versa).
- These effects are referred to as value contrast, hue contrast, and chroma contrast, respectively.

Value contrast

Lightness of an object is affected by the lightness of the contrasting background or surroundings. if the same object is placed against a lighter background, it is perceived as darker, This is due to the fact that the retina is very sensitive to light.

A practical dental example of this phenomenon is when a restoration is viewed adjacent to inflamed gingival tissues. The redness (darkness) of the gingiva distorts color perception, making the restoration (object) appear lighter than it actually is.

Hue contrast

A color will be perceived differently when viewed in conjunction with various background or adjacent colors with contrasting hues. When a color is viewed simultaneously with another color, the perceived hue of the first color will appear more similar to the complementary color of the second color.

Chroma contrast

An object will appear more intense against a background low in chroma, and less intense against a more chromatic background.

Areal contrast

The size of the object can also influence visual color perception. For instance, a larger object will appear lighter than a smaller object of the same color and vice versa.

Spatial contrast

An object closer to the observer will appear larger and lighter, whereas an object more recessed will appear to be smaller in size and darker. This phenomenon is frequently seen with rotated and overlapped teeth.

Successive contrast

Successive contrast occurs when one color is viewed following the observation of another color. The visual perception remains after the eye has left the object.

Viewer-Associated Effects

Various operator related factors may influence the color perception and affect the shade matching abilities of the clinician. These include:

- Color blindness
- Age
- Fatigue
- Nutrition
- Emotions
- Medications
- Binocular difference

Color blindness

It is the inability to distinguish the differences between certain colors. This condition results from an absence of color-sensitive pigment in the cone cells of the retina. color deficiency may be hereditary or due to Aging, certain medications, and retinal or optic nerve disease may interfere with normal color vision.

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 and causing the differentiation between white and yellow to become increasingly difficult.

Fatigue

Tired eyes cannot perceive colors as accurately as alert eyes can. Compromised visual perception is the consequence of systemic, local, and/or mental fatigue.

So it is recommended to perform procedures requiring shade matching to be done during early part of the appointment.

Nutrition

An individual’s nutritional status plays an important role in the health of the eye.

Emotion

It is generally known that emotion can affect pupillary diameter, causing dilation or constriction which has a direct effect on color discrimination.

Medications

- The abuse of drugs, alcohol, and caffeine will affect not only judgment, but also color perception.
- There are several studies that indicate that long-term use of oral contraceptives will cause a decrease in color perception of blues and yellows.

Measurement of tooth colour

Color determination in dentistry can be divided into two categories[6]

- Visual
- Instrumental

Visual technique

Shade guide systems: Dental shade guides are shade matching tools used most commonly by the clinicians in day-to-day practice.

The most popular shade guides include the Vita pan classical shade guide, Vita 3D master shade guide system, and the chromoscope shade guide system.

Vita Classical

In the Vita Classical shade guide, the tabs are arranged alphabetically according to hue. It has been the gold standard for shade matching in dentistry since it was introduced in 1956 with the majority of restorative materials, particularly composite resins keyed towards it.

Limitations

1. Not uniformly positioned throughout tooth color space.
2. No standard incremental difference between adjacent shades.
3. In between shades (A2.5) are inaccurate.

Vita 3D-Master shade guides

There are three Vita 3D-Master shade guides:

1. Tooth guide
2. Linear guide
3. Bleached guide

The 3D Master tabs are marked using a number-letter-number combination (e.g., 3M2), representing value, hue, and chroma, respectively. The primary group division is based on value.

Value (lightness) determination

The user selects the value level (from 0 to 5, with 0 being the lightest [high value] and 5 being the darkest [low value]) that is closest to the value of the tooth to be matched, and then takes the medium (M) shade sample from the selected value group.

Chroma determination

The user selects the color sample from the M group with the chroma level (from 1 to 3, with 1 being the least chromatic and 3 being the most chromatic) that is closest to that of the tooth to be matched.

Hue determination

The clinician checks whether the natural tooth displays a more yellowish (L) or more reddish (R) shade than the color sample of the M group selected in the second step. Now the best matching shade sample can be determined and the information recorded in the color communication form.

The linear guide Vita 3D-Master

It has the same shade tabs as the Tooth guide but a different design, and shade matching is reduced to two steps

1. Value selection. A dark-gray holder, containing only 6 middle tabs (0M2 to 5M2) is used. The small number of tabs with large color differences and the linear tab arrangement simplify group selection.
2. Chroma and hue selection. A final selection based on chroma and hue is made from the initial value group selected.

The Bleached guide Vita 3D-Master

It is the only shade guide developed specifically for visual evaluation of tooth whitening.

Bleached guide exhibits a wider color range and more consistent color distribution than the Vita Classical and other shade guides, such as Trubyte Bio form (Dentsply).

Chroma scope

It was developed by Ivoclar Vivadent. The tabs are initially divided based on hue, and then further intra-group selections are made.

Stump shade guides

With the increasing use of all-ceramic restorations there has been introduction of "stump" shade guides to build the restoration with the right opacity/translucency e.g., IPS Natural Die Material Shade Guide (Ivoclar, (Vivadent).

Gingival shade guides

Dummet[7] described that the color of gingiva is variable ranging from a pale pink to deep bluish purple. Color depends on intensity of melanogenesis, epithelial cornification, and depth of epithelization. Okubo et al[8] stated the most popular method to be the visual shade selection with the help of shade guides. Bayindir[9] described the use of commonly used gingival shade guides presently i.e., Luci tone 199 shade guide system (Dens ply Trubyte), Ivo clap plus gingival indicator set (Ivoclar Vivadent), and IPS gingival shade guide (Ivoclar Vivadent).

The Luci tone 199 Shade Guide

Four durable high-gloss uniquely shaped tabs are displayed on a convenient ring, featuring Luci tone 199 aesthetic shades: Original, Light, Light Reddish Pink, and Dark Pink.

The Ivo cap Plus gingiva indicator set consists of 4 shades as well: pink, fibered light pink, fibered pink, and "Preference" (a shade which should correspond to the original shade of Luci tone 199).

The IPS Gingiva shade guide system (Ivoclar Vivadent) offers 10 shades: 5 regular shades, 4 gingival modifier shades, and 1 gingival opaquer shade.

Instrumental methods

Various instruments used are:

- RGB devices
- Digital cameras
- Spectrophotometers
- Colorimeters

RGB devices

Acquire RED, GREEN, BLUE image information to create a color image. The Shade Vision system from X-Rite is an example of an RGB device. Cho, BH conducted a study to measure the difference in the color and color parameters of natural teeth measured by a tristimulus colorimeter (CM) and Shade Vision System (SV) and found out that the values measured by SV were higher than those with CM.

Digital cameras

They are efficient and easy to use and can be an ideal supplement for the clinician and lab technician in quantifying shade but alone not a very reliable method for shade analysis. The factors that most affect image quality are the optical properties of the lens.

Alvin et al [11] stated the use of Commercial SLR cameras when combined with the appropriate calibration protocols showed potential for use in the color replication process.

Colorimeters

They have colour filters that approximate the spectral function of the standard observer's eye and are generally designed to measure colour in X; Y; Z tri stimulus terms or in CIE Lab values. Chang J [12] evaluated the accuracy of tooth color measurement by combining the Munsell

color system and dental colorimeters and concluded that the colorimeter can conduct precise color matching but the way it transforms the measured result into VITA notation should be adjusted to obtain more accurate results measurement by comparison with Munsell color tabs.

Spectrophotometers

Spectrophotometers are amongst the most accurate, useful and flexible instruments for overall color matching and color matching in dentistry.[13] Compared with observations by the human eye, or conventional techniques, it was found that spectrophotometers offered a 33% increase in accuracy and a more objective match in 93.3% of cases. E.g., Crystal eye, Vita Easy shade Compact, Shade-X (X-Rite, Grandville, MI), Spectro Shade Micro. Parmesan V compared the shade matching abilities of an intraoral spectrophotometer and the conventional visual method using two shade guides and found out that The spectrophotometer showed far better interrater agreement scores irrespective of the shade guide used.[14]

The Spectro Shade

It is the dental shade-taking device that combines digital color imaging with spectrophotometric analysis. Spectro Shade Micro II device is equipped with the LED spectrophotometer and a digital camera that ensures accuracy while acquiring measurements, images, and data for shade-mapping and analysis.

Recommended protocol for conventional shade matching[15]

- The patient removes any lipstick or other makeup that could affect shade matching and covered with a neutral-coloured bib.
- The existing tooth structure on which the restoration will be fabricated is cleaned and evaluated.
- The translucency and opacity of the patient's natural teeth are determined to help in the material selection process. Surface roughness, gloss, and local color characteristics should also be noted.
- The shade selection is made at the beginning of the appointment, before the eyes become too fatigued.
- The eyes should be aligned evenly with the patient's teeth level, at a distance of 25 to 35 cm. It is important not to view the comparison for more than 5 to 7 seconds at a time to avoid fatiguing the cones of the retina. A neutral Gray card should be observed between trials.
- Shade tabs should be held and aligned so that light reflects off the shade tab and the natural teeth in a similar manner.
- A variety of shade tabs are used to analyze the opposing dentition's value in the gingival, body, and incisal areas. Value is analyzed first, followed by chroma, then hue.
- The number of potentially matching tabs should be reduced to a few as quickly as possible
- Final shade selection can be verified using different lights, observation angles, and distances; during different appointments; and/or by different clinicians.

A systematic review by Borse, S and Cha ware, S.H, 2020.[16] evaluated the methods of the dental shade selection and provided a summary of different factors affecting the shade selection. The recommended guidelines for visual shade selection procedure were:

Clinician position

- Patient should be seated at an upright position at the elbow level of the clinician.
- Squint test (partly close the eye): Increase the value of the shade.

Light condition and background

- Use color-corrected light illumination.
- cover the patient with Gray drape

- dark-colored lipstick should be removed before shade selection.
- Shade selection should be done at forenoon between 10 a.m. and 2 p.m.
- To reduce the background light, use 18% Gray card.

Shade comparison

- The selected tooth should be clean, shade should be selected before tooth preparation as dehydration reduces the translucency of the tooth.
- the selected shade tab should be viewed from above or below the tooth to match and not adjacent to the selected tooth (binocular effect).
- Hold the shade tab at the incisal edge of the tooth to be matched to minimize the reflection of the adjacent tooth.
- The selected should tab should be viewed from different angles (vectoring)

Another review by Allayed et al, 2021[17] outlined various principles for shade selection which are as follows:

- Patients should be viewed at eye level to engage retina
- The shade should be checked under different types of lighting after the initial shade is selected in natural daylight. The shade is then confirmed under fluorescent and incandescent lighting
- Teeth should be cleaned before matching is done
- At the beginning of the patient visit, shade comparison should be initiated
- Any cosmetics such as lipstick should be removed, and bright-colored clothing should be draped
- The procedure of shade matching should be done quickly
- After comparison, rest should be given to the eye by focusing on a Gray–blue surface as this helps resensitize and balance the sensors in our eye

A step-by-step protocol to shade matching is comprehensively outlined through a case study using a combination of technology-based instrumentation, conventional techniques (i.e, shade tabs), and reference photography by Chu, S.J, 2007.[18]

Step 1: evaluation

Preoperative evaluation will determine the choices of materials that can be used for the definitive restoration (i.e, metal-ceramic or high-strength computer aided design-computer aided manufacturing (CAD-CAM)–based ceramics, such as alumina or zirconia and hence will ultimately dictate the tooth preparation design.

The stump shade of the tooth must be taken into consideration because it may influence the value, chroma, and hue of the final restoration if a translucent or semitranslucent material is used.

Step 2: image capture and shade analysis

One way to analyze the shade is to use technology. Technology requires image capture or image acquisition. Once the images are brought into the database and stored, they can then be analyzed for shade. Today's technology streamlines shade analysis by indicating which shade tabs the clinician should select for reference photography (shade communication).

Step 3: transferring the information into a visual format (shade communication)

- Shade tabs and reference photography should be used together to gather and communicate the precise shade information, respectively.
- Shade tabs provide a visual reference marker, and using contrasting shade tabs that are both bright and dark allows clinicians and their laboratory technicians to determine better the value and chroma of the restoration.

Step 4: interpreting the shade information (inter pretation)

- When the laboratory technician receives the shade information, he or she must interpret all of the pieces of submitted information.
- The reference photography is tantamount to the laboratory technician.

Step 5: fabricating the restoration (fabrication)

Step 6: verifying the accuracy of the shade match (verification)

- It should always be done in the laboratory by the laboratory technician before being returned to the clinician for try-in or insertion.
- The simplest means of shade verification is through the use of shade tabs.
- The ultimate verification of the restoration's accuracy happens when the clinician fits the restoration

Step 7: placement (clinical insertion and cementation)

- The ultimate verification of the restoration's accuracy happens when the clinician fits the restoration
- If the restoration does not match, steps 2 through 6 should be repeated. The reference photographs should be taken with the new restoration in place and referenced accordingly.

Conclusion

Color of teeth and its appearance is a complex phenomenon, with many factors such as lighting conditions, Trans lucency, opacity, light scattering affecting the human eye and brain influences the overall perception of tooth color.

The basic understanding regarding fundamentals of color and light, the radiation spectrum and the optical characteristics of the object is critical before evaluating and selecting the proper color shade for the restoration. Successful shade taking involves a combination of technology, shade tabs, and reference photograph. Despite of the limitations in materials and techniques, a harmonious restoration can almost always be achieved if a methodical and organized manner is followed during shade selection.

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