Shade Selection – Basic for Esthetic Dentistry: Literature Review

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ABSTRACT
Shade selection is one of the important aspect of esthetic dentistry. In present scenario patient seeks dental treatment under two situations: pain and esthetics. For esthetics every dentist should know the shade matching procedures. Shade matching includes knowledge of Color (hue, value and chroma), Translucency and opacity Gloss, Surface toughness, Opalescence, Iridescence, Fluorescence and Luminescence Phosphorescence and Metamerism. The aim of this article is to ‘open the doors of perception’ so that the entire dental team can comprehend and use color in daily practice and proper shade selection can be done to provide good esthetics to patient.

Key words: Color–Color rendering index–Metamerism–Shade

1 INTRODUCTION
A proper balance between illusion and reality is the basis of esthetic dentistry. This balance is called the perception - the aspect concerned with visualization of the appearance. [1] The ultimate objective is to create a beautiful smile, not just beautiful teeth but teeth of pleasing inherent proportions to one another and a pleasing tooth in harmony with the gingiva, lips, and face of the patient. [2] “Color is unimportant to the physiological success of dental restoration, yet it could be the controlling factor in overall acceptance by the patient” by Bergen. [3] A need to overcome subjectivity, as the major disadvantage of the visual shade matching method, induced the evolution of color science. Color science is multidisciplinary and it encompasses elements of physics, chemistry, physiology and psychology. [4]

Color
It is the sensation resulting from stimulation of the retina of the eye by light certain wave lengths”. Color is the result of the physical modification of light by colorants as observed by the human eye and interpreted by the brain. [5]

Classification [3]

a) 1. Primary: emitting their own radiation
   2. Secondary: reflecting a part of the radiation from some other light source
b) 1. Natural: sun, moon and fire
   2. Artificial light sources: incandescent light, fluorescent tubes and photographic flash

Color Perception [6, 7]
Numerous hypothesis on the mechanism of color perception was proposed. Ariostle maintained that white light was of greater intensity than colored light, and perception of color resulted from differing degrees of mixing between light and shade. Hooke’s Theory followed, who established the composition of the white light. In 1801, Thomas Young attributed the diversity of colors to combination between three fundamental qualities of the retina. Three types of nerve fiber appear to exist within the eye: excitation of these produces red, green and blue respectively.

Color Rendering Index
Color rendering index, on a scale of 1 to 100 indicates how well a particular light source renders color as compared to a specific standard source. White light has a CRI of 100. Northern day light, which can be close to full spectrum white light has a CRI close to 100. Ideal shade matching is done in northern day light around the noon hour on a bright day. Other option for color matching is fluorescent
lighting. [8]

**Color Temperature**

Northern day light around the noon hour on a bright day has Color temperature of around 6500 degree K. [8]

**Other appearance attributes** [4, 9]

Appearance attributes other than color are

- Translucency and opacity
- Gloss
- Surface toughness
- Opalescence
- Iridescence
- Fluorescence and Luminescence
- Phosphorescence
- Metamerism

**Complications in Color Perception** [6]

- Chromatic adaptation is defined as a color constancy phenomenon of the perceived color of the viewed scene.
- Dichromatism perception of color depends on the thickness of material eg Blood is, yellow if viewed in an extremely thin film but is red in greater depth.
- Metamerism: color of the object vary under different light conditions i.e different spectral reflectance.

Shade guides, dental ceramics and natural teeth are three different substances and therefore have a high potential for exhibiting metamerism.

**To reduce metamerism** [10]

- Work under regulated light sources and always match shades under the following three different sets of lighting:
  - Day light
  - Artificial lighting of the surgery
  - Dim light
- By having the shade selection checked by someone else.
- By testing ones vision and more particularly color vision periodically.
- By shade selection using shade guide made of same material as the dental ceramic.
- By limiting surface staining.

**Visual Comparison**

Visual comparison is a comparison with some known physical standard accepted as referral. There are numerous systems of visual comparison and description of color. Color atlases or color derivation systems are the systematized and precisely repeatable catalogue, which are helpful for visual comparison.

**Color Order System** [11]

A color order system is a systematic way to arrange colors in a three dimensional space. It can also be considered as a rational method or a plan of ordering and specifying all object’s colors within a limited domain by means of a set of material standards selected and displayed so as to represent adequately the whole set of object’s colors under consideration. Color order system has been developed based on various principles. None of them has received universal acceptance.

- The Munsell Book of Color
- The Ostwald system
- DIN (Deutches Institut für Normung) system
- Coloroid Color system
- CIE system (CIE, International Comission on illumination)
- Visual instruments for defining color, based on additive mixing of colored lights, as well as visual colorimeters, based on subtractive color matching, are commonly used.

**Munsell Color Order System**

It is the oldest and the most popular color order system developed by Albert H. Munsell in 1915. For the reasons, including worldwide recognition, consistency, flexibility, and simplicity. It is the system of choice for color matching in dentistry. Its guiding principle is the equality of visual spacing between adjacent specimens in each of its three attribute: Hue (H), Value (V) and Chroma (C) denoted as H/V/C. [11, 12]

**Hue**

Hue is defined as the particular variety of a color, shade or tint. In Munsell’s words, “it is that quality by which we distinguish one color family from another, as red from yellow, green from blue, or purple Hues are divided into 10 quadrants, yellow, yellow-red, red, red-purple, purple, purple-blue, blue, blue-green, green, and green-yellow. Each gradation is subdivided, for e.g. red can be written 1R-10R etc and these can be further subdivided. Most natural teeth fall into a range between yellow and yellow red. Hue always corresponds to the wavelength by the object. [3, 6, 13]


- A (reddish-brown)
- B (orange-yellow)
- C (greenish-gray)
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- D (pinkish-gray)

Value

Value is defined as the relative lightness or darkness of a color or the brightness of an object. In Munsell's words, “is that quality by which we distinguish a light color from a dark color”. Value is far more important factor in color determination. The axis of the Munsell color system correspond to the value scale ranging from 0 to 10 with 0 representing black at the bottom and 10 representing full white present at the top. Natural teeth range in value from 4-8. Common esthetic fault in the metal-ceramic prosthesis is that if restoration has very high value (is too bright) which can easily be detected by observer. [3, 13]

Chroma

Chroma, the third dimension, “is that quality by which we distinguish a strong color from a weak one; the departure of a color sensation from that of white or gray; the intensity of a distinctive hue; color intensity”. Saturation and chroma are the terms used interchangeably in dentistry; both mean the strength of a given hue or the concentration of pigment. A Munsell color system, the radii of the circular color wheel are the chroma of the colors. [15]

Translucency

The amount, location and quality of translucency vary with individual and with age. Young teeth often exhibit a great deal of incisal translucency, with the enamel appearing almost transparent at times. Over year of function, the incisal edges wear and this highly translucent enamel is lost. [15]

Influence of surface appearance [16]

Typically, young teeth exhibit a great deal of surface char-acterization including stippling, ridges, striation and evidences of developmental lobes. These surface features are gradually worn away with daily function, leaving older teeth with a much smoother, highly polished surface. When light strikes a smooth and flat body, the reflected & transmitted rays are parallel. If the body is rough, the rays are scat-tered or diffused. Thus, the visual aspect of the surface is modified by the surface geometry.

The texture of natural teeth is made up of a set of larger and smaller surface fluctuations, which will additionally under age related alteration, a considerable impact on reflection and hence on tooth color.

Opalescent effect of dental ceramic

Opalescent effect is also called as light scattering effect. It depends on refractive index, size and quantity of opalizers.

To match the opalescent effect of natural tooth opalizing substances with a refractive index differing from that of the remainder of the powder are used. For e.g. titania oxide (TiO2; refractive index 2.52), Zirconium oxide (ZrO2; RI-2.2), and Tin Oxide (Sn2O2; RI-2). [3, 15] Translucency created by these fine powders will depend on the amount, grain and composition of the opalizers. Smaller & more numerous the particles the greater is the frequency of diffusion and scattering, which imparts a more or less opaque appearance to material. Incisal ceramic powder contain very low amount of opalizing particles whereas dentin powder contain more amount. [15]

Opaque Porcelain [17]

Proper opaquing procedures is very important for the success of prosthesis and this layer form the foundation of the ceramic portion of a porcelain fused to metal restoration. A heavy consistency is made by mixing opaquer with condensed liquid or distilled water so that it can be easily apply with brush or spatula and this foundation provides an excellent bond, consistent and precise shade control. Drying is avoided and a total thickness of 0.2 - 0.3 mm is preferred and should be applied in two coats.

Color Matching [18]

Color standards or shade guides are the shade matching tools and these are available in different types depending on their purpose and the tissue for which they are intended. Color standards, for tooth, for oral soft tissue and for facial prostheses- commonly known as dental, gingival and facial shade guides, respectively.

Commonly used shade guide [3, 19, 20]

Vitapan classical shade guide: It was a gold standard in dentistry for decades and to a larger extent, still is. It was developed in the 1960s with the name Vita Lumin Vaccum shade guide. Vita (Vita Zahn- fabric, Germany) changed the name to the Vitapan classical shade guide. Tabs are divided into four groups, with primary group division based on hue. According to manufacturer, the hue of group A is reddish-brown, group B is reddish-yellow, group C is gray, and group D is reddish-gray. Within the group tabs are arranged according the increasing chroma. Group A consists of (A1, A2, A3.5, A4); group B & C (B1-B4 & C1-C4) & group D (D2, D3, D4).

Vitapan 3D master shade guide (Vident):

It consists of 26 tabs divided into 5 groups according to lightness. The numbers (1, 2,3,4,5) in front of the letters indicate group number and lightness level; a lower number means higher lightness. The number (1, 1.5, 2, 2.5, and 3) below the group number designates chroma level- the more chromatic tabs have higher number. Three bleaching shades (0M1, 0M2, 0M3) introduced indicating high lightness, three levels of chroma and middle hue.

Advantages of Vitapan 3D master shade guide over Vitapan classical shade guide:

- Wider lightness range
- More chromatic tabs are included
- The hue range is extended toward reddish spectra part
- The shade tabs are more uniformly spaced
- Group division is better

Other shade guides: Bioform, Bioblend, New Hue, Imperial Guide, Trubyte bioform series, Unitek and Chromoscope shade guide (Ivoclar Vivadent).

Custom Shade guide
Standard shade guide do not cover the entire hue-chroma-value area of the human teeth range. They are useful to the extent of nearly 85% of color selection; however, the remaining 15% requires modification or fabrication of custom made shade tabs. Custom made shade guides are made of composite resin, ceramic or acrylic. Modification in the shade guide can be brought about with the help of surface colorants or by abrading the surface using aluminum oxide. Colored pencils and fine line markers can be used in sketching the finer aspect of transition between shades, relative translucency and characterizing colors. [21]

**Extended shade guides**

Extended shade guide, which contain the tabs of all materials used for the restoration could also be used to enlarge the choice of shades. [22]

**Characteristics of an ideal shade matching method [23–29]**

**Preliminary procedures**

Some things (e.g. large jewelry, lipstick, eyeglasses, heavy rouge, facial makeup) may interfere with shade matching, so if appropriate, patient should be asked to remove these things. Proper cleaning should be done to re-move plaque, stains and accretions of concerned tooth. After cleaning, all traces of prophylaxis paste should be removed as well. Drape the patient with a neutral colored cover if the patient is wearing bright colored clothing.

**Time of doing color matching**

Shade matching should be performed at the beginning of the appointment for following reasons.

- Preparation of the tooth could cause accumulation of a debris layer on its surface. The dentist’s eyes get fatigued during the appointment, which results in reduced shade matching ability.

- Tooth dehydration could occur during the appointment because of the long time spent with the mouth open. This results in alteration of tooth lightness and chroma; more than 24 hours is needed to regain normal tooth coloration. Accordingly, a rubber dam should not be placed and the tooth should not be dried too much before shade matching is performed.

**Patient’s & Dentist’s position**

1. Patient is seated in an upright position. Position of dentist should be between the patient and the light source. Concerned tooth should be viewed along its normal axis (the line of sight perpendicular to the surface). Level of dentist eye should be maintained on the level of the patient’s tooth. A proper working distance of 25-33 cm should be there between dentist’s eyes and concerned tooth. Viewing angle should not be less than 20.

**Shade guide selection**

Use the shade guide that matches the porcelain of the dental technician. Every porcelain is different, and the best results are obtained if one use the same guide the manufacturer used in designating the colors of the product.

**Shade tab placement**

Tab should be placed parallel with the tooth whose shade is being matched, and with the same relative edge position. If possible, it should be in the same plane with the tooth-not in front of it or it will appear lighter and not behind it, or it will appear darker.

**Time length & pauses**

Time period for shade matching should not be more than 5 second, after this eyes should be relaxed by observing a blue card between two shade matching trials. (Because blue and yellow are complimentary colors, staring would cause blue fatigue and increased eye sensitivity to yellow color)

**Chromatic induction effect**

According to S. Westland, rather than blue card gray or neutral card should be stared in between shade selection as it is probably right that relaxing the L- and M- cones (by staring at a blue card) will increase sensitivity to yellow but looking at blue fatigues the short wave (or S) cones to some extent, so that subsequently a neutral field may appear slightly yellow.

**Other consideration [24, 26, 29]**

- Magnification of at least x 3.5 to 4.5 (4 teeth in focus) is essential so the practitioner can focus on 1/3rd section of a tooth.

- Grind off the necks of the shade tabs, which have heavy extrinsic coloring and may distract shade determination.

- Assess value level by squinting. Half closed eyes decrease the amount of light entering the eye to inactivate the cones and allow peripherally located rods of the retina to discriminate lightness and darkness.

- Compare shade selection under varying conditions (for example, wet versus dry, lip retracted versus lip down, and light sources at different angles).

- Place the patient under different lighting conditions because the spectral reflectance from the natural, incandescent, fluorescent, or halogen light will be relatively different between the porcelain and the tooth, to avoid metamerism and thus accurate shade selection. One must be aware of vertical and horizontal transitions in color and the other appearance attributes in human dentition.

- Vertical color transition in a single tooth, the cervical or incisal color should be carefully observed and recorded. Shade tab can be corrected accordingly for accurate communication.

- Horizontal color transition of a single tooth, among middle and proximal thirds, among different teeth and tooth groups in the same jaw, should also be taken into consideration as well. E.g. mandibular incisors are one chroma level lower than maxillary incisors. Canines are two chroma levels higher than maxillary incisors.
Factors affecting the final shade of ceramo-metal restoration

• Select a shade that is of lower chroma and higher value if not able to precisely match a shade, because it is easy to increase chroma and decrease value.
• Color perception and overall appearance are influenced by other attributes like translucency, gloss, surface roughness of the tooth and the tab so these should be taken into consideration. It is useful to compare tooth and shade tab both relatively dry and wet conditions.

Effect of firing & firing temperature [30]

According to Hammad et al a significant increase in hue and decrease in value and no change in chroma when firing temperature was increased. Opalescence is created using low fusing ceramics (for e.g. Duceram- LFC). During subsequent firings, however, the fusing particles and the loss of the opalescent effect. This effect can be suppressed by ad direing Zirconium oxide particles which are dissociated at temperature over 700 °C. A phenomena called counter-opalescence effect is seen in metal ceramic bridges due to over firing of opaque, as a result incisal edge appears bluish whereas proximal edges look dark and mainly orange-yellow as light get reflected because of opacity, and the transmitted light will give the tooth an orange shade.

Effect of repeated firing [31]

On Hue
Hue and chroma are not significantly affected by the number of firing. Clark felt that hue differences were so unimportant that his tooth color indicator contained only the yellow hue. Hue ranges should extend into the yellow red region to give a larger selection for the more discriminating clinician.

On Value
Value consistently increased (become less gray) with increasing thickness. With increasing thickness, the restoration becomes less affected by the graying (lower value) effect of the opaque layer. With increasing thickness, the effect of the porcelains translucency becomes greater.

Color measuring instruments
Color specification and color difference evaluation can be done using electronic color measuring instruments. They are:

• Colorimeters
• Spectroradiometers
• Spectrophotometers
• Digital cameras [21]

Colorimeters
Colorimeter can measure color only in terms of Tristimulus values under a fix set of illuminant and observer condition. The key optical elements include a light source, an integrating sphere, and a detector (three or four filter). [32]

Spectrophotometer
Spectrophotometers are most widely used for measuring surface colors. The optical elements consist of a light source, a monochromator and a detector. They can also evaluate metamerism. Spectrophotometers are quite stable over time and accurate. [33]

Digital imaging and shade analysis

Based on digital color imaging a newest device is introduced with accurate colorimetric assessment, it provides the technician with a detailed image of the tooth surface as well as useful color mapping. The ShadeScan (Cynovad), Shade Vision system (X-Rite) is hand held with LCD screen and illumination is by halogen light source. There is flash card which record all memories and also allow voice comments to be recorded which can be sent directly to the laboratory without the use of a computer with the work authorization. The data can also be downloaded to a computer for simple shade and translucency mapping. [34]

Hybrid devices
SpectroShade (MHT Optic research)- Combines digital imaging with spectrophotometric analysis. ClearMatch system (Smart technology)- Hardware-independent product designed to be used on any windows-platform personal computer with almost any digital camera. [35]

2 SUMMARY

An understanding of the science of color and color perception is important if success is to be attained in the ever-expanding field of esthetic restorative dentistry. Although limitation in materials & techniques may make a perfect color match impossible, a harmonious restoration can almost always be achieved.

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