Review Article

Importance of color in Dentistry : A Review

Abstract:

Replicating and reproducing the color of natural tooth with restorative material is a challenge. Color matching is influenced by several factors , mismatch in which gives unsatisfactory results. Shade selection play a important role in obtaining good esthetic restoration.

The purpose of this review was to discuss about dimensions of color, age related color changes in tooth , different shade selection methods like visual and digital, standard shade taking protocol using accurate, precise methods and devices.

Keywords- Shade matching, Intraoral scanner, Spectrophotometer, Shade guide**,** Colorimeters

INTRODUCTION

Gaining the color match between natural teeth and restoration is very important to the patient for acceptance of restoration. Demand for composites and ceramics has increased due to increased demand for esthetics.[1]

Polychromatic nature of natural teeth makes shade selection more challenging. Composite resins have been developed commercially in multiple enamel and dentin shade of differing translucencies and opacities and measured according to vita classic guide shade.[2]

The discoloration of tooth can be classified as intrinsic , extrinsic or combination of both.Intrinsic tooth color is associated with light scattering and absorption properties of enamel and dentin(tetracycline stains). Extrinsic color is associated with the absorption of materials (eg- Tea, Chlorhexidine , Red wine) onto the surface of enamel.[3]

Without light , color doesn't exist. When light interact with object some wavelength is reflected which are perceived by receptor cells in eye and specific color recognized by brain.[3]

The way in which we perceive color is influenced by many factors like environmental (physical surrounding) and viewer centric (physiological) which includes lighting conditions, background effect, color blindness,binocular differences , eye fatigue , age and other physiological factors[4].In order for color to exist 3 elements must be present- light, an object and a viewer. Without interaction of all 3, color doesn't exist.[4]

UNDER PEER REVIEW

IMPORTANCE OF COLOR IN DENTISTRY

The study of color is very important part of esthetic dentistry. If there is slight change in color of restoration the mistake can be very evident by which the patient will be unhappy.Process of color perception and reproduction can be applied to dentistry , specifically to shade matching are pigment colors and dimensions of color.[4]

Pigment colors

Pigment color contribute to hue of an object. It is very important to understand color in dentistry because they are inherent in dental restorative materials like composite and ceramics.

To achieve accurate and esthetic shades understanding the primary , secondary and the complementary color is important(fig-1).[4]

Primary colors- Red, Yellow, Blue

Red is perceived when green is absorbed; yellow is perceived when blue is absorbed; and blue is perceived when red is absorbed.[4]

Secondary colors: orange, green , violet - They are formed by combination of 2 primary colors

Complementary colors- when they are combined in equal proportions they form a dull gray that absorbs and reflects all the wavelength in equal amount. This has a clinical significance because complementary colors can be combined to lower the value of excessively bright restorations.[3]

DIMENSIONS OF COLOR

Hue- It describes the pigment of tooth or dental restorations(red, blue or yellow)

Value- measures the brightness of hue. Value is 0 for pure black and value 10 for pure white.

Chroma – defined as saturation of hue. The chroma and value are inversely related. As chroma increases the value decreases.[4]

COLOR CHANGES OF TOOTH RELATED TO AGE-

The influence of age on tooth color could be due to multiple factors,

1. Gradual reduction in pulp chamber with compensatory deposition of secondary dentin.
2. The secondary dentin is harder, darker in color and less porous.

UNDER PEER REVIEW

3. Darker dentin color results from the gradual reduction of enamel thickness caused by wear and tear The progressive loss of enamel thickness due to wear and tear lead to darker dentin color.
4. It has been noted that dentine enamel junctions with amorphous organic and inorganic pigment deposition have more saturated dentine chroma.

DIFFERENT METHODS OF SHADE MATCHING

VISUAL METHOD

Visual methods of shade selection employ dental shade guides, which are sets of tooth color physical samples, to assess the shade of teeth or restorations. The physical samples (shade tabs) are placed close to the tooth in the same plane and ensuring incisal alignment.

Then, for the fabrication of a restoration, the shade that is most similar to the shade of the tooth and the shade of the surrounding teeth and restorations is chosen.Shade guides should express specific characteristics such as proper distribution in color space, rational arrangement, ease of manipulation, and acceptable accuracy and precision.[3,5]

DENTAL SHADE GUIDES

Dental shade guides can be classified based on their shape (strip, disk, or toothshaped), material (ceramic, composite resin or acrylic resin), fabrication type (custom or stock)and concept (theoretical, empirical, evidence-based). No shade matching accuracy differences exist between disks and tabs.

Shade guide has been made of materials such as ceramics, denture teeth, and composite resins. Moreover, manufacturers have produced their original guides for their products because different materials and brands show different colors and optical properties. The fabrication of shade guides with the actual restorative material has been suggested, otherwise the shade and optical properties of the restorative material may differ from shade guides. Using actual ceramic shade guides rather than nonhomogeneous shade guides induces more acceptable color matching in ceramic restorations.[3,5]

Effective factors and conditions related to visual method

Three factors affect how an observer perceives the object color including the light source, the object and the observer. A **light** source releases electromagnetic radiation which can be specified by the color temperature. The color temperature of a light source is the temperature of an ideal black-body radiator that emits light of a color similar to that of the light source.

UNDER PEER REVIEW

The **object** properties affect shade taking results. Teeth should be wet when assessing shade and translucency, otherwise all color attributes including value, hue, and chroma may be influenced.

A dehydrated tooth indicates more lightness and less chroma and translucency, and therefore, using a medium-viscosity clear glaze liquid is suggested for wetting both teeth and shade tabs. This can also neutralize effects of tooth surface texture and morphology on shade selection. Thus, shade selection should be done at the appointment's beginning within the first minute and before tooth dehydration due to restorative procedures or isolation.

The effectiveness of shade selection depends on the **observer's** ability to match shades. This ability may be affected by age, gender, experience, type of shade guide, training, color perception potentials, and diseases. Although gender has been recognized as a crucial factor by stating the superiority of females over males in color perception.

Professional experience can positively influence the observer accuracy/precision. Intra observer and inter observer precisions are critical for shade discrimination. The intraobserver precision of visual method for experienced prosthodontists is higher than that for experienced general practitioners. The interobserver precision for observers without color vision deficiency has been reported from 22.5% to 55%, while the intra observer precision has been estimated from 11% to 64%. The use of VITA 3D-Master (Fig-2)rather than VITA classical may reduce the interobserver color matching differences, while controversially one study reported a decrease in the intra observer precision from 64% to 48% and the interobserver precision from 55% to 43% when using VITA 3D-Master.[3,5]

VITA 3D-Master -Instructions for use:

STEP 1- Determining the lightness level (value)

Hold shade guide at arm’s length to the patient’s mouth

Select group 0, 1, 2, 3, 4 or 5

Start selection with darkest group first

Step -2 Selecting the chroma

On the basis of the determinedlightness level, choose the middlehue group (M) to determine the chromaand spread the samples out like a fan

• Select one of the three shade samples

STEP-3 Determining the hue. Check whether the natural toothis more reddish or more yellowish ascompared to the shade sample selected

UNDER PEER REVIEW

Factors Affecting Clinical Shade Selection:

Shade-matching devices are also called shade guides. The order of shade selection is first selecting the value,chroma, and lastly hue.

Color matching should be done in a systematic way that ensures accuracy,uniformity, predictable results which are absolutely important in esthetic dentistry

i.OPERATING SITE LIGHTING-Sunlight in the middle of the day is considered optimal for shade selection, as this exposure contains an almost equal blend of all wavelengths of light compared to morning and evening exposures, which are richerin reddish and yellow wavelengths.

ii.ENVIRONMENT

Bright-colored surroundings should be avoided as they interfere with proper color matching by influencingthe colors in the reflected light. A drape can be used to mask undesirable colors in the patient's clothing andjewelry.

Lipstick should be removed so that it does not affect color perception.

Make your selection quickly. In case of doubt, trust your initial decision as the eye already tires after approx. 5 - 7 seconds

iii. CONDITION OF THE TEETH

The tooth of interest and its adjacent teeth should be free of plaque and other deposits and surface stains.

The tooth should be moist with saliva as dehydration results in a whiter appearance.

The tooth becomesdryer after application of the rubber dam, and therefore, color matching should be performed beforeapplying it.

iv. DISTANCE OF THE OPERATOR FROM THE TOOTH, POSITION OF THE PATIENT

A distance of 61 cm (2 feet) to 183 cm (6 feet) distance from the oral cavity is considered ideal for shadematching. The patient should be positioned in the dental chair such that the patient’s teeth are at thelevel of the operator's eyes.

DIGITAL METHODS

UNDER PEER REVIEW

Dentalshadeselectionincluding digitalcameras,colorimeters, spectrophotometers,and intraoral scanners. A color-measuring device shouldhave requirements such as shock proof, easy control, rapid measurement,acceptable working life, proper light source, reasonable price,and most of all acceptable accuracy and precision.

1.COLORIMETERS

A colorimeter is an optical device that can read the visible spectrum by using filtered photodetectors. Initially, three glass filters (red, green, and blue), whose transmittance spectra imitated the CIE color matching functions, were used to simulate response of the average human visual system.

Later on, a filter bank was employed to upgrade the device accuracy. In fact, colorimeterssensors assess the sum of different wavelength spectra reflectedfrom the object to indicate the object color.The technology of sensors has been improved to an accurate level for assessingeven opaque objects.

Dental colorimeters have been introduced to help with shade selection. These simple, less expensive devices take data, transform it into color parameters, and determine the shade of teeth by analyzing reflecting light.

As visual methods are not able to quantify the color, colorimeters raise the accuracy by error reduction.

Effective factors and conditions related to colorimeters

The disparities between colorimeters may be related to color variabilityamong the same nominal shade tabs, complexity in reading translucentobjects, and dissimilar algorithms for assessing color values.Correct measurement is possible with standard positioning, constant distance between the device and the tooth, and an effective specimen port opening size.

Furthermore, colorimetry seems most consistent in the middle region of labial tooth surface

Accuracy- the camera and colorimeter outputs showed only 30% CIELab similarities,due to differences in L* and b* values regardless of close a* values. Reports on the accuracy and precision of colorimeters have been questionable. While the colorimeter showed 10–20% lower precision and lighter shades compared to the spectrophotometer.

2.SPECTROPHOTOMETERS

Spectrophotometers can measure the color by assessing the spectralreflectanceor transmittance curve of objects. A spectrophotometerhas a tungsten-filament bulb or LED

UNDER PEER REVIEW

lamp as a white light source tocreate a light output with the wavelength between 400 and 700 nm.The light is depressed by a prism into a spectrum of wavelength bandsbetween 10 and 20 nm, reaches the object, and may then reflect,passor scatter. The amount of light emitted from or transmittedthrough the object is assessed for each wavelength band in the visiblespectrum. A handheld spectrophotometer should have shockproofability, easy control, rapid measurement, acceptable working life,appropriate light source, reasonable price, and high accuracy and precision.Some types of dental spectrophotometers can isolate the oralcavity from external light using a mouthpiece eliminating effects ofambient light on color measurements VITA Easyshadespectrophotometer[Fig 3] measures CIELab/CIELChvalues and determines the tooth shade based on VITA 3D-Master andVITA classical.

SpectroShade is another dental spectrophotometer which is accurate,fast, and easy to use and one of the most representative.SpectroShade Micro [Fig 4] combinesdigital color imaging with spectrophotometrybased on a LED technology. This instrument benefits from alinear polarized filter which excludes reflections caused by gloss. Variousshade guides data are saved in the device memory and capturedimages can be compared with different shades. Its software can dofine and coarse color mapping, send data to laboratories with e-mailand overlap the tooth image with the restoration image to allow forvirtual examination. SpectroShade Micro can compare two color measurementsallowing evaluations before and after treatment, checkingthat the restoration is a faithful copy of the original tooth,and enabling to map inhomogeneities of the tooth surface.

Position of the tooth impacts spectrophotometric results.Both repeatabilityand reproducibility of SpectroShade are affected by the toothtype (posterior teeth, lower incisors) and the tooth surface (mesial ordistal areas). Thus, caution should be taken when measuring thecolor of curved surfaces of posterior teeth and labial surfaces of lowerincisors. Handling conditions(standardized or freehand) definitelyimpact the outcomes. In this regard, using custom-made acrylic jigsis proposed for preventing the effect of probe angulation and alsomeasuring similar tooth areas.

Dental spectrophotometers present remarkable precision ratherthan excellent accuracy. However, considering their accuracy(from 66.8% to 92.6%) and precision (from 87.4% to 99.0%,).[3,5]

3.INTRAORAL SCANNERS

UNDER PEER REVIEW

Although intraoral scanners have been initially used for digital impression,a tool for dental shade measurement has been added to somescanners. The tool uses a high definition camera included into a handhelddigital scanner. After scanning of the tooth with LED light, thetooth color is estimated with software and shown according to VITAshades rather than color parameters.

The selected shade and the digitalimpression are utilized for the restoration fabrication.

Effective factors and conditions related tointraoral scanners

Color imaging and data processing are two major requirements forintraoral scanners to be considered as a viable means for shade selection.Though intraoral scanners can measure the tooth color and collectthree-dimensional tooth surface data, their color matching abilitymay be affected by some factors emerging some deficiencies. Intraoral scanners display the color results based on dental shadeguides. Benefiting from a highdefinitioncamera, LED light, color analyzing software and VITA shadeguides as references. Newer scanners such as TRIOS 3 [Fig 5] show notonly superiority over the visual method,but also comparableresults to spectrophotometer.

In contrast to spectrophotometers, shade determination byintraoral scanners using VITA classical or 3D-Master mode can beaffected by different lighting conditions.

Thus, the use of an additional instrument is suggested forshade assessment.

The accuracy/precision of TRIOS 3 is greaterwhen the color is registered as VITA 3D-Master shades (53.3% foraccuracy, 90.3% for precision) rather than VITA classical shades(27.5% for accuracy, 87.2% for precision).Moreover, the shaderesults of an intraoral scanner do not exactly match those of a spectrophotometer. In general, shade selection using scanners isinfluenced by elements such as ambient light, image capture, coloranalyzing software and the shade guide mode used.

ACCURACY AND PRECISION OF INTRAORAL SCANNERS:

TRIOS 3 has a lower shade matching accuracy compared toSpectroShade Micro, SpectroShade, VITA Easyshade, and VITAEasyshade Advance 4.0. The precision of TRIOS 3 seems acceptable(>85%) but the accuracy of this device is less than that of a validatedspectrophotometer.

Intraoral scanners and spectrophotometers are more precise thanvisual methods using shade guides by expert clinicians with or withouta light-correcting device. Although some

UNDER PEER REVIEW

investigators advocatethe use of an intraoral scanner as an alternative to a spectrophotometerfor shade taking, others conclude unacceptable shade matchingaccuracy for a scanner such as CEREC Omnicam.

The color measuringprecision of TRIOS may be up to 86.66%, while the precisionof TRIOS 3 is estimated from 87.17% to 90.33%.The accuracy was 78% for Easyshade V, 66%for TRIOS, 57% for Omnicam, and 63% for Primescan, while the precisionranged between 44.3% (Easyshade V) and 51.9% (Omnicam).Scannersmay report lighter shades compared to spectrophotometers and visualmethods due to their unpolarized light source.

CONCLUSION

Each individual perceives color differently. So it is very important to understand basics of colour and factors that can influence the dental professional's color assessment. When using traditional shade-matching techniques, there are several variables that the dental professional should consider. When tooth shade is selected properly, it gives efficient results and satisfaction to dentists and patients both.Tooth shade selection is a complicated task fundamentally affecting esthetic outcomes of restorative treatments. To improve the accuracy and precision of shade determination, successful efforts have been made to make a shift from subjective visual methods to objective digital methods.

Clinical Relevance-

This article discusses various methods of shade selection and the factors that affect the shade matching process. It also covers the changes in tooth shade that occur with age and the reasons behind them. Shade matching is a crucial aspect of clinical situations, and this article provides information on how to approach shade selection using the Vita 3D Master, which is widely used as a reference for shade matching in most clinics.

UNDER PEER REVIEW

References

1.Igiel C, Lehmann KM, Ghinea R, Weyhrauch M, Hangx Y, Scheller H, Paravina RD. Reliability of visual and instrumental color matching. Journal of Esthetic and Restorative Dentistry. 2017 Sep;29(5):303-8.

2Iyer RS, Babani VR, Yaman P, Dennison J. Color match using instrumental and visual methods for single, group, and multi- shade composite resins. Journal of Esthetic and Restorative Dentistry. 2021 Mar;33(2):394-400.

3. Agrawal V, Kapoor S. Color and shade management in esthetic dentistry. Univers Res J Dent. 2013 Dec 1;3(3):120-7.

4.Chu S, Zamzok J, Mieleszko A. The Art and Science of Shade Matching in Esthetic Implant Dentistry. Fundamentals of Esthetic Implant Dentistry. 2007 Sep 1:275-99.

5.Tabatabaian F, Beyabanaki E, Alirezaei P, Epakchi S. Visual and digital tooth shade selection methods, related effective factors and conditions, and their accuracy and precision: A literature review. Journal of Esthetic and Restorative Dentistry. 2021 Dec;33(8):1084-104.

6.Makhloota M,KorogluA,Turhan BA Review of Color Matching in Dentistry. Med Records 2021;3(1):44-9

7.Ristic I, Stankovic S, Paravina RD. Influence of color education and training on shade matching skills. Journal of Esthetic and Restorative Dentistry. 2016 Sep;28(5):287-94.

8.Hardan L, Bourgi R, Cuevas-Suárez CE, Lukomska-Szymanska M, Monjarás-Ávila AJ, Zarow M, Jakubowicz N, Jorquera G, Ashi T, Mancino D, Kharouf N. Novel trends in dental color match using different shade selection methods: a systematic review and meta-analysis. Materials. 2022 Jan 8;15(2):468.

9. Dede DÖ, Sahin O, Özdemir OS, Yilmaz B, Celik E, Köroğlu A. Influence of the color of composite resin foundation and luting cement on the final color of lithium disilicate ceramic systems. The Journal of prosthetic dentistry. 2017 Jan 1;117(1):138-43.

10. Vadher R, Parmar G, Kanodia S, Chaudhary A, Kaur M, Savadhariya T. Basics of color in dentistry: A review. IOSR-JDMS. 2014 Sep;13:78-85.

11. Ragain JC. A review of color science in dentistry: The process of color vision. J Dent Oral Disord Ther. 2015;3(01):1-4.

UNDER PEER REVIEW

Fig 1 The primary pigment colors are referred to as red, yellow, and blue. The secondary pigment colors—orange, green, and violet—are formed when two primary colors are added together. When complementary colors are added together, they neutralize each other and form gray.

Fig-2- VITA 3D MASTER Shade guide

Fig3: VITA Easyshade Spectrophotometer

Fig 4- Spectro shade Micro Spectrophotometer

Fig -5 – TRIOS intraoral scanner

PEER REVIEW