KNOWLEDGE – International Journal
Vol.30.4
March, 2019

# CONTEMPORARY METHODS FOR EVALUATION AND COLOR SELECTION FOR CERAMIC PROSTHETIC CONSTRUCTIONS

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**Abstract:** Digital technologies are more commonly used in dental prosthetics, especially in the field of aesthetics and in determining the color of future prosthetic restoration. The color actually represents the interaction between the object and its illumination. Optical display of teeth and color determination is different in relation to other objects, because it depends on their chemical composition and on the layout of several different building layers. Natural teeth have an inner opaque dentine layer which is concealed with a translucent layer of enamel substance. The tooth has a rounded surface that further increases the effect of light scattering from hydroxyapatite crystals. Hence, teeth in humans differ considerably in their opacities, translucency and fluorescence. Determining the color of natural teeth and its reproduction is sometimes a difficult and complicated process and the transfer of color information to the dental technician also.

The aim of the paper is to describe the procedures for determining the color of natural teeth in prosthetics and to point out their advantages and disadvantages. This process, even today, in everyday clinical practice, is based on the subjective visual method for color evaluation by successive comparison with color keys, under the most appropriate environmental conditions. The disadvantages and inconsistency of this procedure are the reason for the emergence of instrumental determinations with the aid of appliances-colorimeters and spectrophotometers. Spectrophotometers are easy to operate, and the selection process with them is objective and accurate. In their surroundings and light sources should not be influential factors. Of course, certain problems arise in the instrument selection of the color, especially in the devices that determine the color of one tooth point with an area of 3 mm square, so the instruments that make the chromatic map and measure on a larger surface are more reliable in the results. Today, various digital software programs are more commonly used, they digitally display the tooth (obtained by a digital or mobile camera) process and give color value which can be sent in real time in the dental laboratory. Digital display can also be obtained with the help of high resolution cameras installed on mobile phones, and the software applications can determine the color of the teeth on the photos. The color is compared with familiar, previously entered color keys, with the possibility to install additional. A detailed map of the tooth is made and the color and the transcription are determined. The improvement of mobile phones by incorporating high quality digital cameras and the possibility of installing software programs is the reason that mobile applications for determining the color with the possibility of data transfer to the dental laboratory are used more frequently in the last years. Chromatcher, T Shade, Tooth Shade Recognition, VITA Shade Assist and Tooth Configurator can determine the color and shape of the teeth, and they are some of the most common applications that allow doctor / patient / dental technician interaction.

Color determination with smartphone applications and comparison with existing color systems is a procedure that could be of great benefit, primarily because of availability, ease of use and high resolution cameras, but further testing should be carried out. When the doctor and the technician succeed in mastering the language of the color, the procedure improves and the final result is successful construction and satisfied patients.

**Keywords:** spectrophotometer, digital, mobile applications, color communication

## 1. INTRODUCTION

Digital technologies are more commonly used in dental prosthetics, especially in the field of aesthetics and in determination of color of the future prosthetic restoration. The color actually represents the interaction between the object and its illumination. Optical display of teeth and color determination is different in relation to other objects, because it depends on their chemical composition and on the layout of several different building layers [1]. In prosthetic the color of the dental restorations is most important for final esthetic outcome. Several factors influence color matching and all three parts are involved- patient, doctor and technician [2].

Color is a key element that helps us perceive our surroundings. Color is complex, and possesses primary and secondary components. Primary components of the color are hue, chroma or saturation, and value or brightness [3], [4]. The hue is the main component of color, and it comes from the three main or primary colors: red, yellow, and blue. Chroma refers to the saturation of the color. High chroma is color that is intense and low chroma is color that appears faded. Value refers to the lightness or darkness of the color (Figure 1).

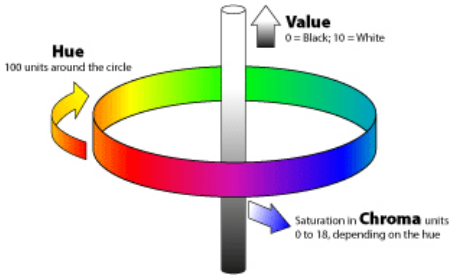


***Fig. 1 Color components (hue, value and chroma)***

Another color aspect is the optical properties of the object, its ability to absorb, reflect or allow the light to pass through. Secondary color components are translucency, opacity, surface gloss and fluorescence. Translucency is the most important of the secondary color components. [5] The translucency of human enamel and dentin is measured by total transmittance of wavelengths from 400 to 700 nm. The transmittance coefficient ($t_c$) of enamel is 0.481mm-1 at 525 nm, and is increased with the increase of the light wavelength.

Light is a form of electromagnetic radiation. The human eye is sensitive to a narrow range of this form of radiation called "visible light". Each light source is characterized by the set of wavelengths it emits. Therefore color perception by the same observer of the same object could be different under different light sources. Metamerism is the phenomenon of two objects appearing to match in color under one condition but showing apparent differences under another. [6]

Natural teeth have multilayer structure. Enamel and dentin have different optical properties. Dentine as an inner, opaque layer is high in value, chroma, and fluorescence. It is concealed with a translucent layer of enamel substance, which is low in chroma and value. Enamel allows light to pass through and then it hits the dentin where dentin will reflect, absorb, or refract it. (Figure 2) Therefore the color of a tooth is affected by both of these two structures but predominantly by dentin [7]. The tooth has a rounded surface that further increases the effect of light scattering from hydroxyapatite crystals. Hence, teeth in humans differ considerably in their opacities, translucency and fluorescence. Therefor determining the color of natural teeth and its reproduction is sometimes a difficult and complicated process. [8]

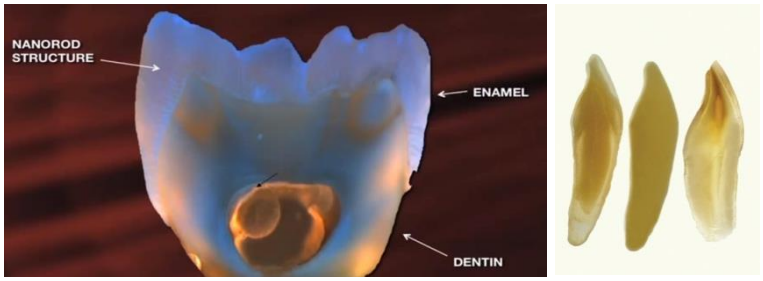


***Fig. 2 Multilayered natural tooth structure***

The process of color evaluation even today, in everyday clinical practice, is based on the subjective visual method by successive comparison with color keys, under the most appropriate environmental conditions. This procedure is inconsistent and very often varies under subjectivity of the person that performs, the light under it is performed, and from the color of the surroundings like gingiva, lipstick or color of the clothes. [9]

Age is also one of the factors that influence the color of the teeth. Several changes that happen during aging starting at 35, are shrinkage of the pulp, reduction of the blood supply, deposition of secondary and tertiary dentine, or reduced enamel thickness due to wear, are all responsible for darkening of teeth with age. [10] Older people usually have reddish or yellowish color of the teeth, which is more saturated.

Even position of the teeth in the dental arches or upper or lower jaw impact the color. The maxillary anterior teeth are yellower than the mandibular anterior teeth, with the exception of the middle third of the maxillary canines where they were redder than that of the mandibular canines. If we compare the individual teeth canines are darker,

less yellow, and more saturated than the corresponding incisors. [11] When the patient's sex is considered, women's teeth are slightly yellower, lighter, and less saturated.

In everyday clinical practice evaluation of the teeth color is quite difficult, so sometimes it is useful to use color-measuring instruments which provide constant values in any condition. Colorimeters and spectrophotometers are easy to use, have high sensitivity, and allow color communication between technicians and dentists [12].

High resolution cameras installed on mobile phones, and the software applications can determine the color of the teeth on the photos. The color is compared with familiar, previously entered color keys, with the possibility to install additional. The improvement of mobile phones by incorporating high quality digital cameras and the possibility of installing software programs is the reason that mobile applications for determining the color with the possibility of data transfer to the dental laboratory are used more frequently in the last years. [13]

The aim of the paper is to describe the procedures for determining the color of natural teeth in prosthetics and to point out their advantages and disadvantages.

## 2. MATERIALS AND METHODS

### Evaluation of color for ceramic prosthetic constructions

Ceramic materials provide excellent esthetic mimicking the natural tooth color. Since its first use in 1774, the ceramic went through rapid development and today it can accurately reproduce the appearance of a natural tooth, considering the patterns of reflection and absorption of the light [14]. Dental ceramics present very big group which can be classified by the melting temperature, composition and manufacturing process. Physical characteristics of dental ceramics are: color stability, translucency, opacity, fluorescence, opalescence and counter-opalescence. The lower the degree of porosity evidenced by a ceramic after laboratory processing, the higher is color stability. There is no ceramic which can display characteristics of opacity and translucency in one material. There are ceramics for infrastructure building, opaque ceramic coverage for the construction of the dentin and translucent glaze for layer technique.

In order to mimic the translucency of the dentine, some ceramics exhibit fluorescent characteristics similar to teeth in order to create an effect of luminosity. Rare earth metals (europium, terbium, cerium and ytterbium) have been used as luminophor agents in the composition of ceramic powders, because they show an intense blue-white and yellow fluorescence. Behavior of color in dental ceramics depends on optical influence of the illuminant, substrate, material thickness, material composition and manufacturing process. [15] The light source is one of the factors that influence the choice of color most. The type of light source, its intensity and inclination are some of the variables. When we choose the color in order to avoid metamerism, it is necessary to use fluorescent and incandescent light sources and not the daylight. The thickness of the material depends on the amount of reduced dentine during preparation. A deeper preparation can improve the ability of a ceramic to hide the substrate, as increasing the thickness of a ceramic material decreases the degree of translucency. Based on the variety of ceramics available, it is important to understand that the composition and manufacturing process directly influence the optical outcome.

### Methods of color selecting

There are several methods for color selection: visual, instrumental and digital. Visual color selection is still most common, but subjective method based on standardized scales samples of the average of the colors present in the human dentition. VITA classic and Vitapan 3D-Master are the most widely used shade guides in dental practice and the laboratory. The scaled shade guides (Figure 3.) allow visual comparison with natural teeth and the results depend on age, light exposure, individual skills or metamerism [16].


***Figure 3. Visual color selection with Vitapan master***

Instrumental methods are objective, and they intend to overcome mistakes during visual color selection by devices with standardized illumination without environmental influence. Spectrophotometers and colorimeters are instruments which measure the amount of light energy reflected from an object at 1–25 nm intervals along the visible spectrum. For optimal results the teeth have to be clean, dry, without plaque and saliva. Digital shade selection is based on two types of measurements: spot measurement and complete tooth measurements. The instruments are placed on tooth surface, and minimum three measurements have to be done in incisal, middle and cervical thirds. Complete tooth measurement measure entire tooth surface and provide complete shade mapping, but the sensors size limit their use to frontal teeth.[17]

CIE (Commission Internationale de l'Eclairage) developed color system for shade selection with three values (L, a and b) and this system is used by digital devices. The L value measures the lightness of an object, a measures the redness (positive value) or greenness (negative value), and the b measures yellowness (positive value).

Spectrophotometers are accurate and simple to handle and use devices which measure the spectral reflectance or transmittance curve of an object. It is consisted of the source of optic radiation, photodiode detector and monochromator which convert light to signal for analyzing (Figure 4). Usually they come with PC software concept with user-oriented operating interface. There are several spectrophotometers available: Vita Easyshade compact (Vita Zahnfabrik, Germany), Shade-X (X-Rite, Grandville, MI), SpectroShade Micro (MHT Optic Research, Switzerland), Crystal eye (Olympus, Tokyo,Japan), but they all are with complex design and quite expensive. [18]

***Figure 4. Spectrophotometer for shade selection***

Digital cameras are devices which make digital images of the teeth and analyze them in Adobe Photoshop CS5.1 or some other software, and they can be used as cost effective alternative to spectrophotometers. A shade-matching protocol comprises of digital cameras, a grey card, and Photoshop software (Figure 4). Digital photo colorimetric (PCM) method for shade matching may provide the entire spectrum of color for natural teeth. The shades are compared with known referenced shades from the software. To calibrate the digital color signal, a black and white standard and a shade tab must be included in each photograph.

***Figure 5. Shade matching digital procedure***

It is recommended to take several pictures, at least three, before the preparation, because the teeth are still hydrated. The processed images with color chosen can be easily transferred to dental laboratory for best esthetic outcome. Distance gauges are available with some software programs (Clear Match), for 25 cm is recommended distance between camera and the patient.

Last years some companies developed cameras special for dental use. The EyeSpecial C-II camera (Shofu ) is especially developed for the use in the dental surgery or laboratory and meets all demands of dental photography. It presents ergonomically designed camera, ultra-light, with eight preset shooting modes for good image quality from any angle [19].

**Mobile phone applications for color selecting**

The improvement of mobile phones by incorporating high quality digital cameras and the possibility of installing software programs is the reason that mobile applications for determining the color with the possibility of data transfer to the dental laboratory are used more frequently in the last years. Chromatcher, T Shade, Tooth Shade Recognition, VITA Shade Assist and Tooth Configurator can determine the color and shape of the teeth, and they are some of the most common applications that allow doctor / patient / dental technician interaction (Figure 5).


***Figure 6. DMP Chromecatcher mobile phone color application***

The DMP Dental Chromatcher, which is one of first mobile shade guide application, was designed to enable dentists or technicians to accomplish restorations effortlessly. Users can determine a patient's tooth shade by taking a photo of the desired tooth area and matching it with DMP's shade system for restorative materials. The user will then know the required shade immediately, avoiding the need to use conventional shade guides. This process applies for all aesthetic restorations using DMP's restorative materials. Available for use with the iPhone, iPad, and iPod touch. The Chromatcher application can be downloaded from the App Store for free.[20]

T Shade is an assistant application for matching the shade of teeth with sample tabs. It is easy to use, functional and not very expensive. The photo has to be taken under uniform light preferable the classic 5500 ° K without shadows. First the calibration must be done on the tooth of the patient (generally the upper incisor). Then the red square can easily select sample area of the tooth. When the calibration is completed, the text on the bottom left will turn green, and a box will appear for a short time with the values L, a, b (CIELab color space).

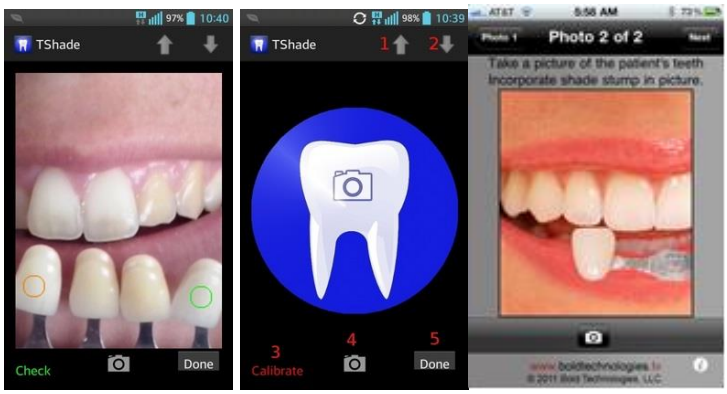


***Figure 7. Mobile phone color application***

After evaluation two circles appears in the image, corresponding to the best match and to the second best match. The first one will be green, the second one will be orange (Figure 6).

Created in partnership with Bold Technologies, an innovative mobile application marks the next step for Styledent Technologies in finding more solutions in new technologies with the goal of improving communication between dentists and technicians.

Dental Rx allows the practitioner to send by email to the laboratory of its choice his prescription and photos for a patient's case in just one step. More and more dentists are taking pictures of their patients face and smile in the office, given that these photos are necessary for the success of their lab cases, especially when aesthetics are considered. The occlusal plane, the midline, dentin color, final shade and any other information is often forgotten in the prescription, or pictures are not sent immediately which can delay or compromise the success of lab cases. Dental Rx assures dentists and labs that all the necessary information for their cases will be transmitted with the auto-fill form that also acts as a reminder (Figure 6).

## CONCLUSION

Shade determination is rapidly evolving toward a more objective standard. The clinical importance of correct shade selection in aesthetic dentistry cannot be overemphasized. Unless an appropriate shade is selected, the most careful attention to the material, structure, and other aspects of the restoration will not produce an optimal final result. Dentists and technicians from all around the world are looking for tools that will allow them to better communicate and maximize the final results of their aesthetic cases. The clinical use of colorimeters and spectrophotometers to determine the best match of dental material shade is on the increase in the practice of restorative dentistry. Color determination with smartphone applications and comparison with existing color systems is a procedure that could be of great benefit, primarily because of availability, ease of use and high resolution cameras, but further testing should be carried out.

When the doctor and the technician succeed in mastering the language of the color, the procedure improves and the final result is successful construction and satisfied patients.

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