Effect of Light & Colour on Shade Selection

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ABSTRACT

Now a day’s dental restoration is consolidated around three mainstays: The use of non-metallic materials, such as composite resins and ceramics; adhesion to dental structures; and achieving a natural cosmetic look. The colour and appearance of teeth is a complex phenomenon, depending on many factors such as lighting conditions, translucency, opacity, light scattering, gloss, the human eye and brain influencing the overall perception of tooth colour. The shade depends upon enamel-dentin thickness, surrounding colour structures and surfaces, type, quantity and intensity of light. The measurement of tooth colour is possible through a number of methods including visual assessment with shade guides, spectrophotometry, colorimetry and computer analysis of digital images. The first step to achieving clinical success in cosmetic dentistry will therefore be the correct identification of the tooth colour which we need to imitate and select material that most closely matches and / or to communicate this information to the laboratory if the restoration is to be fabricated out there. This is a summarisation of some important points to be considered during the shade selection of tooth coloured restorations.

Keywords: Colour, shade, lighting condition, tooth coloured restorations.

INTRODUCTION-

Accurate shade matching is one of the most challenging aspects of dental restorations and aesthetic dentistry. Due to great variety of natural tooth colour, achieving a close shade match of an artificial restoration with the natural dentition is a complex process. Practitioners require an understanding of colour, light and related characteristics of porcelain and resin, as well as the ability to clearly communicate instructions with laboratory technicians. (1)

In order to obtain a natural looking restoration, there are two crucial steps in everyday practice: the selection of a colour, through a shade guide, which will harmoniously integrate itself with the surrounding biological tissues and consequently the correct reproduction of this colour in the restoration. (1)

Understanding and correct analysis of the optical properties of the natural dentition such as colour and translucency and the differences between the natural teeth and restorative materials are very important in accurate and consistent shade selection and the proper use of restorative materials in order to achieve clinical success.
PHYSICS OF LIGHT AND COLOUR –
The physics of light is responsible for the perceived colour / shade of teeth and restorations. Light absorption, transmission, diffusion, refraction, reflection, and scattering all play a role. The right quality and quantity of light in a shade selection area is concerned with reflected light, not just colour pigments.
Still, the way we see and define colour is important to proper shade selection. Our goal is to choose colours that are in “harmony” with surrounding teeth and gingival tissues.

There are three dimensions to colour that help us define it:
• Hue
• Chroma
• Value

• Hue- Dominant colour of an object, e.g.- red, green, blue or it can be defined as the attribute of a colour by virtue of which it is discernible as red, green, etc., and which is dependent on its dominant wavelength and independent of intensity or lightness.

Chroma is the degree of saturation or purity of that hue (what would typically be thought of as the intensity or concentration of the colour). Chroma has been found to increase with age in both enamel and dentin, while hue and value do not, based on in vitro testing.

• Value is the degree of lightness or darkness of the colour or material and is dictated by the transmission of light through, and reflectance of light from, the material. Value ranges from black (value 0) to white (value 10) under the Munsell system.

• Fluorescence is the absorption of light by a material and the spontaneous emission of light in a longer wavelength. Teeth are fluorescent because they emit visible light when exposed to Ultra-Violet light.

• Opalescence is the ability of a translucent material to appear blue in reflected light and red-orange in transmitted light. The opalescent effect is based on the behaviour of translucency of natural teeth.

• Translucency is transmission and diffusion of light through an object so that definite image beyond the object cannot be seen.

So, it can be said that the degree of light transmission determines the translucency,
- with greater transmission resulting in greater translucency;
- the degree of light scattering influences the opalescence
- the degree of light absorption influences the opacity; and
- the degree of fluorescence influences the degree to which a material can absorb UV light and show it as visible light.

Translucency and opacity (the opposite of translucency) are important concepts for shade selection. If a shade is selected that does not mimic the translucency and opacity of the tooth, it will not blend in.
In general, thinner layers are more translucent. The ability of composite materials at a given thickness to provide opacity and translucency varies, some requiring a greater thickness than others to block out dark objects such as the oral cavity behind the teeth and a lesser thickness for translucency, such as would be required at incisal and proximo-incisal areas.

WHY SHADE SELECTION IS REQUIRED-
The Colours of Natural Teeth-
Natural teeth are complex to imitate because many colours are distributed through the enamel and dentin. Natural teeth also exhibit more than colour: opacity, surface texture and surface gloss all come into play. The opacity and translucency of teeth refers to their ability to transmit light. (Translucent vs. Opaque tooth).
Surface texture refers to the degree of smoothness vs. variations or ridges that occur on the tooth’s surface.
Surface gloss refers to the tooth’s ability to absorb or reflect light at the surface. Think of the difference between a matte finish paint and high gloss, enamel paint. They may be the same
colour, but when the surface texture and gloss are vastly different, the colour appears to change and there is no “match.” (5)

**Tooth vs. Porcelain**
- Prior to shade matching, the dentist must have an understanding that the human tooth and dental porcelain transmit light waves differently. It is their physical composition that determines the differences in light-wave transmission, absorption, reflection, refraction, scattering and surface gloss.
- A vital tooth is both naturally translucent and transparent. Enamel rods are transparent and therefore refract and reflect light. Light that strikes the incisal edges of an anterior tooth passes through with maximum transmission because of a high degree of translucency.
- Porcelain, however, is a heterogeneous material. It contains transparent properties and metallic oxides that act as opacifiers. These porcelains modify light by absorption, transmission and reflection. Absorption is largely responsible for colour. It occurs when light passes through the layers of the porcelain. Scattering occurs when light encounters interfaces between the materials (i.e., pigments and glass). The smaller the pigment size, the less light that is absorbed, resulting in less detectable colour. The larger the pigment size, the more reflection that occurs as light scatters at the particle surfaces. Scattering light is necessary in dental porcelains to simulate the prismatic effect of enamel. Yet, one must keep in mind that too much dispersed reflection through internal scattering will create an unnatural looking prosthesis. (6)

**FACTORS INFLUENCING SHADE SELECTION**
A shade matching method depends on the clinician’s colour perception, ambient light conditions and the background against which the tooth is compared; all of these factors may vary. Inconsistencies may result from uncontrolled factors such as fatigue, aging, emotions, previous eye exposure, differences in understanding, colour perception and the experience of the observer. Additionally, the inability of the human eye to perceive colour in a clear, concise and consistent manner is another important factor and colour perception varies from person to person. (3)

**The Influence of Dental Anatomy**
Dental anatomy and contour influence the colour of the teeth and esthetic restorations. The natural tooth’s shade varies with the age of the patient, region of the tooth, and whether enamel and/or dentin is exposed. (4)

**EFFECT OR RELATION WITH DENTIN AND ENAMEL**
The diversity of colours distributed between the enamel and dentin help explain why each natural tooth is unique. Dentin is the opaque and complex core of each tooth. The dentin imparts all of the colour of the tooth, with the exception of maverick colours, which usually are present within the enamel matrix. The dentin exhibits varying degrees of yellow, orange, and red tones. It is thickest at the gingival and middle thirds of the anterior teeth. A translucent, transparent, and opalescent shell called the enamel covers the dentin. (5) The enamel layer varies from translucent to nearly transparent. It often has a white or gray appearance. Enamel is thickest at the incisal edge of anterior teeth and thinnest in the cervical regions of the tooth. The enamel is a fiber optic structure that actually conducts light through rods and captures the colour of underlying dentin.

**AGE** - Age-related changes occur in the enamel and dentin (as well as the pulp) during an individual’s lifetime. There are also differences in colour and translucency in natural teeth that occur during the aging process or because of gender.
- In younger patients, enamel and dentin are thicker, and more opaque and less translucent, in the incisal area. In newly erupted permanent incisors, the mamelons...
are present and result in a dense, slightly darker, yellowish area at the incisal edges in some patients. This effect is due to counter-opalescence at the mamelons. For instance, young enamel is less transparent and obscures the dentin. Because youthful teeth display enamel of high value and minimum translucency, they have a bright appearance. (4)

- In young teeth, incisal edges of anterior teeth often appear violet, blue, or gray because there is little or no dentin present.
- As the patient ages, the mamelons are first ground down until the incisal edge is smooth (unless malocclusion precludes this from happening) and the incisal third gradually takes on a more translucent appearance. Dentin gives teeth a more opaque (dense) appearance than enamel.
- By the time a patient reaches middle age or later, a significant grey translucent area is typically present incisally as the dentin recedes and the enamel thins.
- Older patients typically exhibit a larger area of translucency at the incisal third and a darker, more opaque area in the cervical third of teeth. (4)
- Aged teeth have enamel of low value and maximum translucency. This can create a dull appearance as the translucent enamel allows the lower value dentin to come into view. (5)
- Older persons were more likely to have teeth with lower values (darker). Among those aged 60 and older, 85% had teeth in the medium and low range values compared with 17% of those younger than 31. (7)

SEX- Females generally have teeth that are more yellow and at a higher value than males. (5)

RELATION WITH COLOUR OF SKIN, EYE AND HAIR ???-

There is a controversy present regarding the relationship of skin colour, eye colour and hair colour with the tooth colour. Different authors have given different opinions. According to some authors shade of tooth depends on colour of skin, hair and to some extent to the colour. But it is significant in the shade selection of teeth in edentulous patients, it has little or no influences on selection of shade in esthetic tooth coloured restoration. (8,9,10,11)

Relationship of the tooth to its surrounding coloured structures and surfaces

- Tooth colour perceived by an observer is influenced by other coloured structures surrounding the tooth such as adjacent teeth, gingiva, lips, face skin, clothing of the patient and operatory walls. (12)
- Anterior teeth usually have slightly different colours according to their position within the arch e.g. maxillary central incisors are the lightest teeth whereas the canines are relatively redder, yellower and more saturated with colour. Likewise, maxillary anterior teeth are slightly yellower as compared to mandibular anterior teeth. These fine differences in colour of adjacent teeth can make selecting and finalizing tooth shade a testing procedure even for the experienced professionals. (12)
- Gums and lips form the soft tissues immediately adjacent to the teeth and can influence the apparent colour through the phenomenon of contrast. As has been reported, the subjects' perception of tooth whiteness, health and attractiveness is greatly influenced by the colour of the adjacent lips and gums. Lip colour can be altered through the use of lipstick. Presence of dark coloured lipstick creates the illusion of whiter teeth. (12)
- Clothing worn by the patient and colour of operatory walls can create contrast effects during the shade selection process. Therefore, it has been recommended to drape all bright coloured clothing prior to shade selection. (12,13,14)
The colour of the operatory can also affect shade selection. Colours should be kept at a low saturation level. Walls and cabinets should be glossy enough to maintain brightness without causing a glare. It is recommended that the colour of the walls and ceiling be white or off white. Some authors also say that the operatory walls should be painted in a neutral (pale gray-blue) colour.

The ceiling should be as white as possible and surrounding walls and cabinetry should be a neutral gray.\(^5\)

**How the Eye Perceives Colour**

Seeing colours is possible because all objects absorb certain parts of light and reflect other parts. The degree to which they absorb or reflect light determines the wavelength of the light and also the colour we perceive.\(^5\)

**Light and Colour Perception**

The anatomy of the eye is such that a sufficient amount of light is key to our colour perception. At the same time, as we age, our eyes are less able to allow light to enter the eye.

What this means in a dental office is:

1) **Younger eyes can see colour better** and
2) **Sufficient light is essential for the perception of colour**

**Accurate Shade Taking**

Accurate shade taking is best accomplished using natural daylight; a second source of light should also be used to see if the shade matches under both light conditions. This can also help avoid the problem of metamerism. Natural daylight also varies by time of day and direction,\(^15\) thereby altering perception when shade matching (with light at the middle of the day and from a northerly direction considered to be ideal). The literature suggests that various kinds of light may be acceptable during shade selection. It’s important to avoid light sources that give off colour, such as green fluorescents, and to make sure there is enough quantity of light to allow the eye to perform well.

The following are recommended types of light:

- Natural light when it is available through a window in sufficient quantity on bright days. Northern light at mid-morning is optimum.
- White light or a full-spectrum light source that is composed of all visible portions of the colour spectrum.

Sunlight has been standardized for shade selection purposes in the form of “northern daylight” i.e. sunlight around the noon hour on a bright day with slight overcast. It has a CRI of close to 100 and is also used as a normal standard for judging light from other sources. In spite of this standardization, the fact remains that sunlight is available only during the day time. Therefore, it is unreliable for dental shade selection purposes because that requires a stable light source in the form of an illuminant.\(^11\)
This is where the artificial light steps in. Artificial light is almost universally used in dental surgeries. It can be incandescent (which emits higher concentration of yellow light) or fluorescent (which emits higher concentrations of blue light waves). Neither of these is pure white light. The only artificial light suitable for reproducing the standardized northern daylight is a D65 light source. Unfortunately, the D65 lamps are very expensive and not readily manufactured on a commercial level. This leaves room for using fluorescent lighting in dental surgeries and laboratories. (11)

- The most commonly used cool white fluorescent tube lights have a CRI of between 50 and 80 and are not recommended for shade selection. The need is for a “colour-corrected” fluorescent lighting with a CRI of 90 or above, in line with the recommendations of the American Dental Association. Fortunately, this standard can be acceptably reached by using the newer cool white daylight energy saver lamps, which are cheaper and easily available. Findings of Azad et al. and Corcodel et al. favor these daylight lamps because they improve the shade selection ability of the observer. (11)

- Colour-corrected, daylight fluorescent bulbs with a colour rendering index (CRI) of 90 or more and a colour temperature of 5500 degrees K required for proper colour registration.

- **Quantity of Light**

  Enough bulbs should illuminate the operatory to provide 150-foot candles of light. If using fluorescent tubes, in a 100 square foot area with 8 foot ceilings, 12 four-foot color corrected tubes would distribute adequate lighting. Another option is the use of a light-correcting device, which was found in a recent study among 216 dental students to result in greater shade accuracy than natural daylight alone, with no statistical differences in results between males and females or first-year versus more-advanced students. (4)

  Use of the light-correcting device resulted in lower accuracy with Vita C shades compared to other shades in both natural light and using the light-correcting device. (16,15)

- **Dentists position**

  A tooth should be viewed along its normal axis (the line of sight perpendicular to the surface), using a diffuse light source. The dentist's eye should be at the level of the patient's tooth. Regarding shade matching distance, tooth and shade guide should be viewed from a distance 3-6 ft. Viewing distances should enables a viewing angle of not less than 2°. (17)

- **Tab placement**

  The shade tab should be placed parallel to the tooth 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. (17)

- **Time length and pauses**

  The first impression is frequently the best match and shade matching trials should be limited to 5 s, at a time to prevent eye fatigue and the recommendation to relax the eyes by observing a blue card between two trials. (17)

- **Patient position**

  Patient should be in the upright position when the shade is selected, so that the teeth may be viewed under the same conditions which they will be seen in business and social life.

- **Amount of lighting**

  The recommended minimal amount of room lighting for proper colour matching in the dental office is about 200 feet candles when measured at 30 inches above the floor. The level of lighting is approximately same as that from three ceiling fixture each containing four 48 tubes installed in a 10 ft / 10 ft room. Some authors also say that an illumination level of 200-250 foot candles is required for shade matching.

  Safura Anita Baharin et al. (2013) conducted a study on Anterior Tooth Shade Selection Procedure: Influence of Light Sources and Patient’s Position. They concluded that shade
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selection for anterior composite resin restoration was more accurate when the patient was in the upright position with dental chair light switched off. The patient’s position does influence the accuracy of the shade matching result under different lighting condition.

CONCLUSION
So, at the end of the discussion we can say that some points we should remember during the shade selection for perfect reproduction of the natural looking restoration.

1. The walls and cabinet of the clinics should be glossy enough to maintain the brightness without causing a glare. Colour of the walls and ceiling should be white / off white.
2. In operatory, 150-200 foot candles of light is required.
3. D65 light source is the only artificial light suitable for reproducing standardized northern day light.
4. Colour corrected, day light fluorescent bulbs with a colour rendering index (CRI) of 90 or more and a colour temperature of 5500 °K is required for proper colour registration.
5. Patient should be in upright position.
6. Tooth should be viewed along its normal axis, using a diffuse light source and dentist’s eye should be at the level of patient’s tooth, distance should be 3-6 ft and viewing angle not less than 2°.

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Fig-1 : Nature of light, how the eye perceives and brain interprets light as colour is important for successful shade selection.

Fig-2 : Shade matching
Fig-3 : A- Blended shade technique, B- layered shade technique

Fig-4 : Final Restoration