Machnaking an artificial restoration with natural teeth can be one of the most challenging procedures in restorative dentistry.

Dental professionals such as general dentists, prosthodontists and dental technicians regularly perform shade-matching procedures during restorative procedures. This article will give the reader a better understanding of the factors that influence shade-matching and the importance of considering the use of modern methods such as light-correcting devices due to its reported benefits.

**Bases of aesthetic dentistry**

Aesthetic outcomes in dentistry are essential to meet patients’ expectations and positively impact their self-esteem. This could be achieved by using restorative materials that exactly match the patient’s remaining natural teeth in terms of shape and colour. Pleasant restorative and prosthodontic outcomes begin with a consistent shape and silhouette of the buccal surface of a tooth as it determines the amount of light reflected back. The colour we perceive of natural teeth depends on the nature of the light source illuminating them, which is crucial to appreciate their translucency, opalescence and fluorescence.

The dentist’s skills, type of shade guide system used and lighting conditions are essential criteria for precise shade-matching.

**Clinical applications of shade-matching**

Selection of the appropriate colour is recommended for tooth whitening and the restoration of a tooth with porcelain or composite, acrylic teeth of a denture and even gingival prosthetic components.

**Essentials of colour concepts**

According to the Glossary of Prosthodontic terms, colour can be defined as “the quality of an object or substance with respect to light reflected or transmitted by it. Colour is usually determined visually by measurement of hue, saturation and luminous reflectance of the reflected light.”

The three components of colour:
- Light source (illuminator)
- Object (reflects, absorbs or transmits the incident light to the observer)
- Observer (perceives the reflected light).

Therefore, the clinician who discusses the primary tooth shade characteristics of hue, chroma and value provide essential information to a technician who produces restorations that correspond with the remaining dental structure.
Natural teeth exhibit translucency, fluorescence and opalescence, which should be mimicked by restorative materials to succeed clinically.

**Hue:** The quality of sensation according to which an observer is aware of the varying wavelengths of radiant energy (red, yellow, green, blue, purple).\(^{10}\) Approximately 80% of the natural dentition belong to the A hue range.\(^{16-17}\)

**Chroma:** The purity of a colour or its departure from white or gray and describes the strength or saturation of the hue.\(^{19}\)

**Value (lightness or brightness):** The quality by which a light colour is distinguished from a dark one.\(^{10}\) Value is the most important dimension of shade rendering.\(^{18-20}\)

Translucency: The gradient between transparent and opaque,\(^{8}\) the quality of allowing light to pass diffusely.\(^{8}\)

Fluorescence: The absorption of light of short wavelength by a material and the spontaneous emission of light in a longer wavelength.\(^{21}\)

Opalescence: When a material seems to be of one colour when observed from the light reflected upon it but becomes another colour when light is transmitted through it.\(^{22}\)

**Tools for transmission of tooth shade**

The most commonly used technique is performed by visually matching the shade of the natural teeth with the tabs of a shade guide system. The shade guides available on the market are the standard instruments for determining tooth shades.\(^{23-24}\) The computerised shade determination devices use quantification of colour, which generally provides more accurate colour-matching outcomes. However, 35 years ago, these spectrophotometer and colourimeter devices were primarily used in research rather than in dental offices due to high cost.\(^{15, 25-26}\)

**Operator’s factors affecting shade-matching**

It has been stated that shade-matching varies due to experience, age and individual degree of colour perception due to the decline in functional ganglion cell density and abnormalities in the eyes’ rod and cone photoreceptor morphology.\(^{27-28}\) For instance, images are perceived more yellowish and brownish as our eyes age. Therefore, human physiology mostly determines colour perception along with individual variations.

- **Gender.** In dental symposia, we have heard that men are
less likely to get the colour right than women. However, there are at least seven studies in dentistry showing no gender differences in shade-matching.29-35

- Experience. It is still controversial whether the accuracy of shade-matching can be attributed as an innate or acquired/learnt skill. However, there is also enough evidence contradicting experience as influential in shade-matching.30-33, 35-39

- Eye colour. Brown eyes absorb wavelengths better due to the greater presence of melanin,40 which may influence sight – but not colour perception.

- Astigmatism, hypermetropia and myopia. An insignificant influence may be expected upon shade-matching ability even when these refractive errors are corrected with eyeglasses or contact lenses.41 Therefore, corrected refractive error cannot be associated with a poorer shade-matching skill.

Light source evolution

“The most important factor in shade-matching is the lighting condition.”
– Dr. Afrashtehfar and Dr. Freedman

The correct light source allows the clinician to get the shade right the first time and avoid remakes, extra appointments and increase in cost. Since natural light conditions vary, recommendations for shade-matching include proper colour temperature that come up to 5500k and a colour-rendering index (CRI) greater than 93 for dental professionals.42-43 The CRI measures the equal balance of all the visible wavelengths, and viewing teeth under diffuse illumination will minimise the distortion of the reflected light.21 A low light intensity will make the clinician miss the fine details and complicate hue perception. The value guide should be used first,18-20, 44 preferably with low light levels, even if the operator has to squint, since it is the best for value evaluation.7, 19 There is strong and reliable evidence that supports the use of a light-correcting source during tooth shade-matching. On the contrary, there is no evidence in literature contradicting this fact.29-33, 35, 43, 45

In the United Kingdom, clinician scientists combined the use of colour-correcting and digital recording devices showing an improved ability to match dental shades when compared to the digital device alone under normal light conditions.29 Another study showed that, in order to standardise light conditions, a daylight lamp may be a useful aid to significantly improve the ability to match colours when compared to natural daylight.45 Shade-matching was also much better under a light-correcting source when compared to natural or clinical light.32 Even when light conditions are improved by using a low temperature illuminator, there is a notable improvement in colour vision-deficient individuals.46-47 In another Irish study, the overall results indicated that the most beneficial factor for shade-taking was the light-correcting source.43 The closer the spectral reflectance curves (optical properties) of the two materials to be matched, the more successful the colour matches will be, thereby minimising metamerism.48-49

Ideally, the clinician and technician should have balanced full-spectrum lighting conditions. The superiority of a correcting light is a fact and could also be seen as convenient since it is portable, wireless and readily available as it is often found in the dental market industry.

Rite-Lite 2 shade-matching instrument: A proper light-correcting source

This portable and wireless light-correcting device has been designed to aid in shade-matching (Fig. 1). Clad in satin-finished aluminium and weighing 184.3g, the round top has an external diameter of 5.3cm and 12 LEDs. The inner window-hole for viewing patient’s teeth has a diameter of 3cm. The patient side of the round top section illuminates the dentition from all directions to avoid glare or distortions by direct reflections. The bottom section is a cylindrical handle that is 9.6cm long with a diameter of 2cm. The device is capable of notifying the user when the batteries (two conventional AA) lose power and need to be replaced in order to emit a constant light intensity.

Three setting choices of colour temperature:

• 5500k (colour rendering index of 92.2): The closest to natural daylight and considered a standard in shade measurements. This light is produced by six LEDs with one push of the activation button.

• 3200k: Simulates incandescent light. This light is produced by the other six LEDs when the activation button is pushed twice.

• 3900k: A combination of incandescent and fluorescent indoor lighting. This light is produced by all 12 LEDs when the activation button is pushed thrice.
Benefits of Tri-Spectra LED technology

For the clinician:
- Daylight mode: Initial shade determination.
- Room and ambient light modes: Shade verification to avoid metamerism (when a restoration matches the natural shade under one light condition but displays a different colour in another.50)

Shade-taking may be performed efficiently with the patient not having to leave the chair (Fig. 2).

For the ceramist:
- Verification of the fired ceramic during build-up. (The restoration can be verified in the model as a quality control measurement before sending the case to the clinician.)

Considering the ambience

Clinicians are advised to use the ideal background colour – neutral gray50-53 – during shade-matching since it has no complementary colour and is restful to the retinal cones in our eyes (Fig. 3).52 Pink, also shown in Fig. 3, is also considered an ideal colour reference.65

For female patients, lipstick must be removed or covered. For instance, if the patient is wearing red lipstick and it is adjacent to the tooth under evaluation, the red receptors in the clinician’s eyes become fatigued while the blue and green receptors remain fresh with full potential to be stimulated. This eventually leads to tooth perception that is more blue-green than in reality. Another recommendation is the use of a gray bib to cover the patient’s clothes.54 Contrast aids our visual system; an excess would cause glare. A brilliant object against a dark background or differently-coloured items can affect the shade-taker’s perception.9, 55

Ideal time for shade-matching

Due to several factors such as different daylight conditions (due to varying directions of light rays), amount and size of windows, month/season of the year, weather conditions, geographical region and the like,24, 51 proper timing would not be as reliable.

Ideal appointment time for shade-matching

Shade selection should be done before treatment as value increases and chroma and translucency decrease as the teeth dry out during treatment.56 Shade selection is contraindicated after using a dental unit light.

Eye fatigue awareness

The high intensity (brightness) of the dental unit light can cause glare and result in fatigue to the eyes. Shade selection should be done prior to turning on the dental unit light.57 Eye fatigue can also be reduced by having a correcting daylight lamp around while shade-matching is conducted.32, 58

During shade selection, the operator should not stare at the teeth for more than five seconds to prevent hue accommodation. Therefore, first impressions are better.19

To rest the shade-taker’s eyes, they can also look at a blue plaque.51

Another recommendation for rooms where shade-matching takes place is to paint the walls gray and place two correcting daylight lamps.58

Photographic considerations

It is suggested to take photos of the following:
- A full face;
- A natural smile;
- Retracted lips and cheeks and;
- "The selected shade tab adjacent to the remaining natural teeth.

If these are not possible, the last suggestion* must at least be taken.59

The only moment teeth should be dry is when its value, translucency, surface, texture and degree of lustre are
When choosing the hue with a shade tab, the clinician should pay attention to the mid-buccal surface of the tooth.\(^{61,62}\)

- Shades should be evaluated by viewing the tooth at different angles (vectoring) due to the curved translucent surfaces found on teeth, the anisotropic properties of enamel and the complex layering of the tooth structure.\(^{50,52,57}\)
- Shade-matching should be delayed for at least one month after bleaching due to enamel rehydration and colour stability.\(^{63-64}\)

**Conclusion**

Given the available extensive literature, it seems safe enough to state that the use of standard light sources with full spectrum is strongly recommended to carry out a favourable shade selection, matched with the appropriate clinic environment. An accurate shade selection positively influences the patient’s aesthetic appearance and self-esteem, making the restoration a success.

Regardless of any factor stated (gender, experience or training), shade-matching would be significantly improved when a light-correcting device is used in the clinical practice or dental laboratory instead of merely relying on conventional light conditions.

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**Dental laboratory prescription**

This prescription should be a three-dimensional drawing of the shade map, ideally from several views (vectoring). The labial face of the crown can be divided into 9 to 16 zones (Fig. 5). The surface texture and lustre should be described as heavy, moderate and light, since these have an impact on the optical properties of the tooth.\(^{40}\)

**Additional recommendations**

- While performing shade-matching, it is advised to use a standard light source with full spectrum under the appropriate conditions.
- The shade tabs should remain on the shade guide rather than out of it while performing shade-matching as it significantly increases accuracy (Fig. 6).\(^{37}\)
- Holding the shade tab incisal edge against the incisal edges of the teeth avoids the reflection against each other, thereby reducing afterimages (Fig. 7).\(^{40}\)
- When choosing the hue with a shade tab, the clinician should evaluate. Teeth can be wet for hue and chroma evaluation to limit the influence of surface morphology.

Shade-matching with photography serves as a communication tool between the clinician and technician; however, proper shade tabs still need to be selected with appropriate special lighting (Fig. 4).

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**References**
