Total Color Replication Process for Fixed Prosthodontics

Multilayered, polychromatic, and translucent objects like teeth can make the color replication process challenging due to numerous optical characteristics and different contributing factors that directly impact outcome. It is vital for restorative dentists to understand the basics of the color replication process in order to enhance quality of care, particularly with the increased demand for esthetic dentistry.[1] This process is fundamentally divided into two main phases: the shade matching phase and the shade duplication phase.[2] Understanding this process allows clinicians to be able to clearly describe or illustrate what they are seeing chairside in order for the laboratory technicians to fabricate restorations that meet the desired esthetic outcome.

Shade Matching Phase

Teeth have different optical properties that may be divided into primary and secondary characteristics. The primary characteristics are generally reported based on the Munsell color system which describes the tooth in terms of hue, chroma, and value.[3] Hue refers to the actual perceived color, whereas chroma refers to the saturation or intensity of said color. Value reflects the lightness of the color based on white-grey scale. The VITA Classic shade guide uses this system to describe shade, whereby the letters represent hue, and the numbers represent chroma (e.g., A1). Secondary characteristics have a significant impact on the tooth shade. Examples include translucency, both inherent and incisal, iridescence, fluorescence, and surface morphology and gloss. Secondary optical properties are seen because the natural tooth color is produced by semi-translucent layers of enamel and dentin which can absorb, reflect, or transmit incident light.[3,4]

Visual Shade Selection

There are multiple methods of shade matching that restorative dentists may utilize. However, the most common method is visual shade selection with the aid of a shade guide.[5] The visual shade method is a subjective process, with many variables such as operator experience, gender, external light source, eye fatigue, and physiological factors such as color blindness often leading to inaccurate and inconsistent results.[4,5]

Light sources play a significant role in shade matching errors. Shade is impacted by factors that include color lux, color temperature, and the color rendering index (CRI). Ideal lighting conditions are important for shade selection—this includes a color temperature between 5500K- 6500K, a CRI greater than 90, and 1000 color lux.[2,6] Many dental operatories are not equipped with the appropriate lighting conditions to facilitate shade matching. As a result, different auxiliary devices have come to light to help assist with visual shading matching. Examples of these devices include polarizing filters and handheld color correctors that provide a balanced light source (e.g., Smile Lite by Smile Line, Rite-lite Pro by AdDent).

The choice of shade guide also impacts visual shade matching. There are various shade guides available for clinical use, the most popular of which are the VITA Classic and Toothguide 3D-Master guides (VITA Zahnfabrik, Bad Säckingen, Germany).While the VITA Classic shade guide may be simpler to use, shade matching against the VITA Toothguide 3D-Master shows significantly improved results.[7,8] VITA further introduced a more advanced shade guide, the VITA Linear 3D-Master, which shows

superior results to shade matching with both the Classic and 3D-Master shade guides. The Linear 3D-Master has been recommended for improved accuracy with visual shade matching.[9]

Shade Matching Instruments

Handheld spectrophotometers and colorimeters have been developed by different manufacturers to replace or supplement visual shade matching. Such devices include VITA EasyShade (VITA Zahnfabrik, Bad Säckingen, Germany), SpectroShade (MHT Optic Research AG; Zürich, Switzerland), and RayPlicker Quickshade (Borea Dental; Limoges, France) amongst others. Most available shade matching instruments show excellent reliability with shade matching (>90%).[10] However, shade accuracy ranges significantly depending on the instrument or device used (67-93%),[10] and caution is recommended when using handheld spectrophotometers as solo instruments for shade matching. Recently, SpectroShade showed highly promising results when compared to a verified, lab-mounted spectrophotometer, suggesting that it's use may result in clinically acceptable outcomes.[11] Updates in intraoral scanner software have enabled some scanners (e.g., TRIOS; 3Shape, Copenhagen, Denmark) to perform shade matching during impression making. While the reliability of intraoral scanners for shade matching is also high (>85%), accuracy is modest and their sole use for shade matching is not recommended.[8,12]

Transfer of Information to the Laboratory

The most basic method of transferring clinical findings of shade and characterization is through a hand-drawn color map. The advantage of utilizing shade matching instruments, however, is the ability to transfer quantifiable information to the dental laboratory. Some devices also provide a complete shade map. Photography is another tool that may be used to transfer clinical information to the laboratory. Selection of the shade tab to be photographed, however, remains operator dependent and relies on visual shade matching. Photography is therefore not only subjective due to visual shade selection but is also subject to external influences such as reflections and over/under exposure. However, utilizing polarizing filters and white balance gray cards to create controlled conditions may provide accurate transfer of information to the laboratory.[13,14]

It is important to remember that capturing and transferring of digital images for shade matching will inevitability result in alteration to the color of the image.[13] However, a recent systematic review and meta-analysis showed that color discrepancy was still reduced when digital cameras were employed for shade matching, regardless of the color alterations that may occur.[14]

Shade Duplication Phase

After the clinician performs the shade match process, information is transferred to the dental laboratory. The dental technician then uses that information to attempt to match the restoration to the shades provided by the clinician. A common problem with transferring shade is the variation within the different porcelains between manufacturers, and the differences observed between fired porcelains and the shade tabs.[15,16] Furthermore, it was shown that color reproduction varied significantly between commercial laboratories despite the use of a uniform shade guide system.[17]

The choice of restorative material will also directly impact the outcome of the shade matching process. Porcelain fused to metal restorations, feldspar, and layered lithium disilicate require an artistic eye, and are subject to sources of error such as layer thickness, glazing, powder to liquid ratio, firing temperature and others.[18]

The final outcome is also influenced by the characteristics of the restorative material. For example, the lack of inherent translucency of yttria-stabilized zirconia impacts transmission of light and its scatter throughout the restoration. Consequently, restorations may appear more opaque and do not replicate the translucency of natural teeth.[18]

To assist with overcoming material limitations and replicating natural tooth characteristics, laboratories may employ the use of staining. The use of stains allows laboratory technicians not only to achieve the desired color, but also to accentuate the secondary anatomy. Staining of dental ceramics can be intrinsic or extrinsic in nature. Intrinsic staining is described as the application of tints and stains between the different ceramic layers. This is usually done with feldspathic or porcelain-fused-to-metal crowns, where the application of different layers allows for the incorporation of such stains. With monolithic materials and ceramics, external staining is utilized. This process can be described as the superficial application of stains to the outermost layers of the restoration.[19] While staining, particularly external staining, may aid with shade matching of more complex restorations, clinicians must be aware of their limitations such as degradation and wear over time.[19]

Conclusion

In summary, it is the position of the American College of Prosthodontists that understanding the process of color replication is vital for success of restorative dental procedures. Clinicians must understand the importance of adjusting their practice settings to allow for ideal conditions for visual shade matching. With advancements in digital technology, various shade matching devices are now available on the market to assist with shade selection. However, restorative dentists must understand the limitations of those devices to ensure that the shade selection process is not compromised by depending solely on such devices. Current literature agrees that the key to ideal shade matching is using a combination of currently available methods.

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Authors

Mohammed A. Akl, DDS, MS
Alvin G. Wee, DDS, BDS, MS, MPH, PhD

Date

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