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Shade Matching in Prosthodontics

[1]Dr. Hari Haran V M, Postgraduate Student, Department of Prosthodontics, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research (Deemed To Be University), Chennai, Tamil Nadu, India.

[2]Bhavani Roopan Vijayakumar, MDS, Assistant Professor, Department of Prosthodontics, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

[3]Devi Parameswari B, MDS, PhD, Professor, Department of Prosthodontics, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

[4]Krithika Anbalgan, MDS, Assistant Professor, Department of Department of Periodontics, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

[5]Annapoorni Hariharan, MDS, PhD, Professor and Head, Department of Prosthodontics, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

[6]Pinky A, Postgraduate student, Department of Prosthodontics, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

Corresponding Author: Bhavani Roopan Vijayakumar, MDS, Assistant Professor, Department of Prosthodontics, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research (Deemed to be University), Chennai, Tamil Nadu, India.

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Abstract

Shade matching in prosthodontics is crucial for achieving aesthetically pleasing dental restorations like crowns, bridges, veneers, and dentures. Accurate replication of tooth colour, translucency, and texture directly impacts the success and satisfaction of these

restorations. As colour is a complex phenomenon influenced by science, culture, and perception, mastering shade matching requires both a scientific understanding of colour dimensions—hue, chroma, and value—and keen observational skills. Traditionally, visual methods and shade guides based on systems like Munsell's have been widely used. However, these methods face limitations such as inconsistency and inadequate shade range. Digital technologies, including colorimeters, digital cameras, spectrophotometers, and intraoral scanners, offer more precise, objective, and consistent shade matching by quantifying colour parameters. Despite their advantages, these technologies also present challenges like calibration requirements, cost, and sensitivity to lighting conditions. Thus, achieving optimal shade matching in prosthodontics often requires a balanced integration of both traditional and digital methods, ensuring restorations that harmonize with the patient's natural dentition while meeting aesthetic demands.

Keywords: Shade Matching, Visual Guide, Intra Oral Scanner, Spectrophotometer, Digital Camera

Introduction

Shade matching in prosthodontics is a critical process aimed at replicating the natural appearance of teeth when fabricating dental restorations, such as crowns, bridges, veneers, and dentures. Achieving an accurate match in colour, translucency, and surface texture is essential to the overall success and patient satisfaction with these restorations.[1]

Shade matching is an important procedure to provide patients with an aesthetic restoration that harmoniously blends to the patient's existing dentition. Shade matching has gained wide importance over the last few years among both dental practitioners and patients. Success in shade matching not only impacts aesthetics but also contributes to the patient's confidence and satisfaction.[2]

In Prosthodontics, shade matching serves as a pivotal foundation for achieving optimal aesthetics, with tooth shades varying under different lighting conditions. Factors such as enamel and dentin properties, along with gingival colour, intricately influence the final tooth colour. Thus, replicating the natural appearance of teeth poses a significant challenge for prosthodontist.[3] This review article discusses about the various methods used in shade matching in Prosthodontics.

Colour

Colour is a highly complex phenomenon which encompasses nature, science and culture. Colour can turn everything, even the unsightly into a visual pleasure and vice- versa. For shade matching of colour, one must be a good observer. The science of colour can be understood well by learning about the nature of colours, how they work together.[3]

Billmeyer and Saltzman defined colour as the result of the physical modification of the light by colorants as observed by the human eye and interpreted by the brain.[4]

In the 1930s, Bruce E. Clark emphasized the importance of understanding colour as a three-dimensional concept, which was essential for creating aesthetically pleasing dental restorations. Three dimensions of color are Hue, Chroma, and Value.[5]

Hue: Refers to the actual color or shade, such as red, yellow, or blue. In dentistry, hue is associated with the basic color of the teeth.[5]

Chroma: Describes the intensity or saturation of a color. In teeth, chroma relates to how vivid or muted the shade appears.[5]

Value: Indicates the lightness or darkness of a color. This dimension is often considered the most critical in

shade matching because the human eye is more sensitive to differences in value than to hue or chroma.[5]

Shade Matching System

The three attributes of color can be expressed as a three-dimensional sphere. By using this color space, the color of an object can be expressed numerically in a variety of color-ordering systems. The method for evaluating the color of tooth can be divided into two main categories: Visual Matching and Instrumental Matching.[6]

Visual Matching

Visual colour determination by comparison of a patient's tooth with a colour standard is the most frequently applied method in clinical dentistry. Munsell color order system falls under this category.

Dental Shade Guides

Dental shade guides are the aids to help in selection of the most acceptable color and shade matching with the tooth or the teeth to be restored. These devices have been designed to aid clinicians and technicians in the specification and control of tooth color. A shade guide is composed of a set of shade tabs intended to cover the range of colors present in human dentition. Shade guides are primarily based on Munsell Color Order System.[1]

Types of Shade Guides

1. Clark Tooth Color System.
2. Vitapan Classic Shade Guide
3. Vita 3D Master Shade Guide
4. Chromascope Guide
5. Vintage Halo NCC Shade Guide

Munsell Colour Order System

The Munsell Colour Order System is a colour classification system developed by Albert H. Munsell in the early 20th century. Munsell Color Order System is the system of choice for color matching in dentistry because of its worldwide recognition, consistency, flexibility, and simplicity. It is widely recognized for its scientific approach to organizing colours based on three dimensions: **hue**, **chroma**, and **value**

The Munsell Color Tree

The three-dimensional organization of colors in the Munsell system is often visualized as a "color tree"

- The vertical axis represents value (lightness/darkness).
- Around this axis, colors are arranged according to **hue** in a circular manner.
- Extending horizontally from the axis is the chroma scale, with colors increasing in saturation as they move outward.[7]

Application of the Munsell System in Dentistry

In Prosthodontics, the Munsell colour system is used to guide shade matching for dental restorations. The system's structured and scientific approach helps professionals accurately select and communicate the colour of teeth and prosthetic materials. By considering the hue, chroma, and value, dentists and lab technicians can better replicate natural tooth color in restorations.[7]

Limitations of Visual Examination

As the shade guides commonly serve as color standards with which the color of a tooth is matched, still there are three distinct disadvantages:[8]

- Range of available shades inthe shade guides is inadequate.
- Shades are not logically distributed.
- Shade guides are not constructed to match natural teeth.
- Shade guides do not match other shade guides.
- Lack of consistency among and within individual dentists in matching tooth colors
- Inability to translate the results obtained into C.I.E color specifications.

- Inconsistencies from uncontrolled factors like ageing, fatigue, light conditions, metamerism and contrast.
- Difference in color perception among different age groups, color defects.

Instrumental Matching

Instrumental color analysis, on the other hand, offers a potential advantage over visual color determination because instrumental readings are objective, can be quantified and are more rapidly obtained

Cie Lab Color System and Color Space

The Commission Internationale de I'Eclairage (CIE), defined a color space, CIE Lab, which supports the accepted theory of color perception based on three separate color receptors (red, green, blue) in the eye.[9]

The CIE color space represents a uniform color space, with equal distances corresponding to equal perceived color differences. The basic concept of the CIE Lab color system revolves around the idea that all colors can be produced by mixing different amounts of three primary light colors: red (X), green (Y), and blue (Z). The amounts of these primary colors needed to match a specific color are represented numerically by X, Y, and Z, which are referred to as tristimulus values. These tristimulus values serve as the standardized units of color measurement within the CIE color-order system.[10]

In the CIE Lab system, colors are represented within a three-dimensional color space with axes labeled as L*, a*, and b*:[9]

- **L*** represents the lightness of a color, with a scale ranging from 0 (perfect black) to 100 (perfect white).
- **a*** indicates the color's position on the red-green axis, where positive a* values signify redness and negative a* values signify greenness.
- **b*** measures the color's position on the yellow-blue axis, where positive b* values indicate yellowness and negative b* values indicate blueness.

The CIE Lab system's advantage is its ability to express color differences in a way that aligns with human visual perception and clinical relevance. By comparing the L*, a*, and b* values of two colors, the color difference (ΔE) can be calculated mathematically using a specific formula.[9]

Current Instrumental Matching Systems

Instrumental colour analysis used to obtain quantitative values for the shade matching. These devices have been designed to aid clinicians and technicians in the specification and control of tooth color. All colour measuring devices consist of a detector, signal conditioner, and software that processes the signal in a manner that makes the data usable in the dental laboratory.[11]

Colorimeters

A colorimeter is a digital device used in dentistry to measure and analyze the colour of teeth accurately. It provides an objective method for shade matching, making it a valuable tool in ensuring that dental restorations, such as crowns, veneers, and bridges, match the natural colour of a patient's teeth. Unlike the traditional visual shade-matching methods that rely on shade guides and the human eye, colorimeters offer a more consistent and reliable approach by eliminating subjectivity and potential errors. As digital technology continues to evolve, colorimeters will likely become an even more integral part of dental practice.[12]

Digital Cameras

The newest devices used for dental shade matching are based on digital camera technology. Digital cameras have become valuable tools in modern dentistry, particularly in the shade-matching process. They offer a

reliable, accurate, and efficient way to capture the colour of teeth for dental restorations.[13] While traditionally shade matching relied on visual comparison using shade guides, digital cameras provide a more objective and consistent approach, enhancing the precision of the final restoration. Many digital cameras are integrated with shade-matching software that can analyze images and suggest shades based on pre-programmed color databases. The software enhances accuracy by allowing the dentist to zoom in on specific areas of the tooth and analyze the color at a granular level.[13]

Spectrophotometers

Spectrophotometers are advanced instruments used in dentistry to measure the color of teeth with high precision, making them a critical tool for shade matching in dental restorations. Spectrophotometers provide objective and reproducible data, minimizing errors and ensuring a closer match between the restoration and natural teeth.[14]

Intraoral Scanners

Intraoral scanners (IOS) are advanced digital tools that have transformed shade matching in dentistry. Traditionally used for capturing 3D impressions of the oral cavity, many intraoral scanners now include shade detection features. These devices capture both the geometry and color of teeth, offering a comprehensive solution for shade matching in aesthetic restorations.[15]

Limitations of Digital Shade Selection

While digital shade matching offers several advantages, such as precision and consistency, it also comes with certain limitations.[1] These include:

- Influence of Tooth Surface Conditions
- Calibration Requirements
- Cost and Accessibility
- Variations Across Devices
- Lighting Conditions
- Metamerism

Shade Matching Sequence

Shade matching needs few requirements and follows a sequential order to achieve the perfect shade match.[16] They are:

1. Shade selection should be completed before preparation as teeth can become dehydrated and result in higher values.
2. Ensure that surroundings are of neutral colour so that there is no colour cast onto the teeth.
3. Remove lipstick; ask patients not to wear lurid clothing or any items that may distract the attention of the teeth.
4. Make sure teeth are clean and unstained before attempting shade matching.
5. Patient should be in an upright position at a level similar to the operator and the shade guide should be at arm length. This ensures that the most colour sensitive part of the retina will be used.
6. Observations should be made quickly (5 seconds) to avoid fatiguing the cones of the eyes. If longer than this, the eye cannot discriminate, and the cones become sensitized to complement the observed colour.
7. Fatigue can accentuate yellow sensitivity so dentists can look at a blue object, bib, etc, while resting the eyes.
8. Choose basic shade at the middle of the tooth - using the Vita System 3D-Master technique of value, chroma then hue.
9. Viewing tabs through half-closed eyes can decrease ability to discriminate colour but increases the ability to match value.
10. Examine tooth for translucency and any characterizations, e.g. craze line, hyopcalcification etc.

11. Create a shade/chromatic map – divided into different sections to ensure correct placement of different effects, characterizations and shades.[31]
12. Check for metamerism by evaluating selected shade under different light sources (e.g. colour corrected, incandescent, and fluorescent and daylight.
13. Compare shade selection under varying conditions like wet versus dry, lip retracted versus lip down, light sources at different angles.

Problems in Standard Shade Matching

The pitfalls of the standard shade matching are:[1]

1. Differences of color vision
2. Viewing conditions for shade matching procedure
3. Shade guides
4. Shade matching procedure
5. Glare
6. Veiling reflections
7. Communication between dental practice and laboratory
8. Color reproduction

Conclusion

Shade matching in prosthodontics is a delicate blend of art and science, crucial for achieving restorations that seamlessly mimic natural teeth. While traditional visual methods have laid the foundation for shade selection, they often fall short in consistency and accuracy. The integration of digital tools like colorimeters, spectrophotometers, and intraoral scanners has significantly improved the precision of shade matching by providing objective, quantifiable data. However, each method, whether visual or digital, has its limitations, and successful shade matching often depends on the clinician's ability to combine these approaches effectively. Understanding the principles of color science—hue, chroma, and value—and recognizing factors such as lighting, surface conditions, and metamerism are essential for achieving optimal results. As technology advances, the potential for even more accurate and reliable shade matching grows, promising better aesthetic outcomes and increased patient satisfaction in prosthodontic treatments.

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