Color is an essential ingredient in our environment and is associated with certain feelings, emotions and meanings. These associations are defined by the culture we live in as well as our personal experiences. Color communicates emotions, creates visual mood and affects energy; color has an emotional impact that can delight or distress. It is almost impossible to separate the seeing of color from the “feeling of color” because so much of what is seen is based on what is felt. Not surprisingly, these factors and influences have infiltrated into the oral healthcare environment with patients having a high expectation of a natural aesthetic result, both in the anterior and posterior dentition.

Although color as an entity should be regarded as only one of the many building blocks necessary in the achievement of an aesthetic result, nevertheless a discordant color scheme can probably be more devastating to the overall effect than many of the other factors present. It is for this reason that so much time, research and expense has gone into the “color matching” properties of contemporary aesthetic restorative materials.

Color matching and shade taking continues to provide oral health clinicians and technicians with one of the great and important challenges of their respective professions. Yet, despite the importance of color matching, this area still remains largely and universally untaught in most teaching institutions (Figure 1). A viable reason for color matching not to be part of a healthcare curriculum could well be the fact that all areas involved in healthcare, it occupies the unique position of requiring three equal elements for understanding and implementation. These elements could be defined and classified as scientific aspects, objective reasoning and subjective response.

Scientific aspects would involve understanding of the basic properties of light, and color, and an understanding of the physical and chemical properties of natural color as well as those of the object being studied. In dental healthcare this would involve the understanding of the anatomy and physiology of the various structures that make up the oral environment. A knowledge of the anatomy and physiology of the eye would be required, as well as a thorough understanding of color and image interpretation by the brain (Figures 2 & 6).

Objective reasoning would involve the understanding of the effects that various colors have on society generally and the individual specifically. There would be a scientific basis in that such an objective reasoning forms a part of psychophysics, psychology, philosophy and the morays and ethics of our contemporary religions. Although these aspects can be culturally and socially diverse, a unified pattern could nevertheless be established and reasoned, predictable “findings” applied.

Subjective response is probably the least scientific of the three elements, yet possibly occupies the most dominant position. In order to achieve as near perfect color matching as possible, the subjective response needs to be disciplined in a positive and constructive fashion. In the fabrication of a single ceramic crown for example, three individuals are involved: the clinician, ceramist and the patient. Each individual will interpret color differently and success will be determined by achieving a consensus of approval for a particular shade. Attaining this consensus can often be a difficult and painstaking procedure, with possible remakes of the restoration commonplace. The scientific literature describes sexual and age differences in response to color stimulation, as well as cultural and ethnic differences. The manufacturers of aesthetic restorative materials have also inadvertently added to the challenge of accurate color matching. Although producing wonderful aesthetic materials, there still remains a lack of total standardization within the productive process and separate batches of the same material often display completely different color properties. The shade guide remains the traditional method of recording color matching, and for the most part this is totally inadequate as the guide is not unique to the chosen material.

The objective of this article is to present an understanding of the nature of color and to provide a simple roadmap technique that hopefully eliminates much of the uncertainty of color matching (Figures 4 & 5).
Color Temperature

Color is intimately related to temperature. Color T° is expressed in Kelvin. The higher the color T°, the closer to blue the color is; the lower the color T°, the closer the color is to red. The sun at noon is 5,800 Kelvin (Figures 9 & 10).

Describing Color

Color can be described in at least three different ways:

• Spectrophotometry describes the physical characteristics of a color (eg, the spectral reflectance of a surface at different wavelengths).
• Colorimetry describes what a color matches with. The Munsell system describes what the color looks like.

The Munsell Color System

This system was proposed by the American Al Munsell in 1905 and revised in 1945. The system defines three attributes of color:

• H (hue), C (chroma), and V (value).
• Color matching in dentistry is based on this system. Munsell established numerical scales with visually uniform steps for each of these attributes.
• Hue is that attribute of a color by which we distinguished red from green, blue from yellow etc.
• Munsell called red, yellow, green, blue and purple principal hues and placed them at equal intervals around a circle. He inserted five intermediate hues:
  • Red-yellow
  • Yellow
  • Green-yellow
  • Blue-green
  • Purple-blue
  • Red-purple

This makes ten hues in all.

Hue indicates the lightness of a color. The scale of value ranges from 0 for pure black to 10 for pure white. Black, white and the grays between them are called neutral colors. They have no hue.

Colors that have a hue are called chromatic colors (Figure 11).

Chroma is the degree of departure of a color from the neutral color of the same value. Colors of low chroma are times called weak, while those of high chroma are said to be highly saturated, strong or vivid (Figure 12).

Munsell Color Space

Hue, value and chroma can be varied independently and the colors can be arranged in a three-dimensional space. The neutral colors are arranged in the vertical line called the neutral axis. Black is at the bottom, white at the top and all grays are in between. Hues are displayed at various angles around the neutral axis and chroma arranged perpendicular to the axis increasing outward (Figure 15).

In 1951 the CIE developed the XYZ color system, also called the “norm color system”. Red components of a color are called along the X (horizontal) axis and green components along the Y (vertical) axis. Every color is assigned a particular point and the spectral purity of colors decreases as you move left along the coordinate plane. What is not taken into consideration in this model is brightness.

CIE L*a*b*

A three-dimensional model with the color differences perceived corresponding to distances when measured colorimetrically. The a-axis extends from green (-a) to red (+a), b-axis from blue (-b) to yellow (+b). Brightness (I) increases from the bottom to top (Figure 14).

Chromatic & Achromatic colors

Achromatic colors are white, black and grey in between. They lack the attributes of hue and saturation. Chromatic colors are everything else, except for “having color”; everything other than white, black or grey.

Color of the Natural Tooth

In describing the color of a natural tooth we find there are two additional attributes. In addition to hue, chroma and value, we discover the attributes of opalescence and fluorescence.

The definitions of the first three attributes are identical to those defined by Munsell, but each can be qualified further:

Hue: The primary source of color is dentine and the hue of a vital, healthy tooth is in the yellow to yellow-red range.

Chroma: In natural teeth the chroma is dictated primarily by dentine but is influenced by the translucency and thickness of enamel. The thinner the enamel, the greater the optical effects resulting in a higher value. Thick, dense, opaque dentine has the effect of lowering the enamel value (Figures 15, 16 & 17).

Opalescence: In a natural tooth, this is an effect produced in enamel and is due to different refractive indices of the various organic and inorganic components of enamel as well as the ability of hydroxyapatite crystal to scatter incident light. The result is that the long wavelengths are transmitted through the tooth whilst the short wavelengths are reflected, producing a bluish gleam. The effects vary from blue to grey to white gleaming areas (Figure 18).

Fluorescence: This effect occurs when a body absorbs luminescent energy and then diffuses it back to the visible spectrum. In nature this is caused by ultraviolet light striking pigments in the dentine enamel interface resulting in light emission range.