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Dental Esthetics in Practice: Part 3 - Understanding Color & Shade Selection

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One aspect of clinical dentistry that offers clinicians almost limitless and exciting challenges is esthetic dentistry. In a culture where the emphasis on beauty is growing rather than diminishing, patients of all ages, races, and genders are apt to ask you, the dental professional, how they can improve their appearance by enhancing their smile. Whether the motive is personal improvement or is driven by the belief that appearance influences professional success, patients have become aware of their smile, what changes they might like to see, and how those alternations might come about.

This is part 3 of a 5-part series called **Dental Esthetics in Practice**. From the fundamentals of color to digital imaging analysis, this course reviews the practical application of color and shade in dental esthetics.

Conflict of Interest Disclosure Statement

- Dr. Goodacre reports no conflicts of interest associated with this work.
- Mr. Sagel is a full-time employee of the Procter & Gamble Company.

Overview

Now that you've reviewed principles of esthetic dentistry related to the patient and the dental practice, it's time to move on to the clinical elements of esthetic and restorative dentistry. Understanding color and shade is one of the most challenging aspects of esthetic dentistry, but it's one of the most important factors to deliver successful outcomes. From the basics of color to digital imaging, this module will teach the practical application of color and shade in dental esthetics.

Learning Objectives

Upon the completion of this course, the dental professional should be able to:

- Understand the basics of color.
- Apply the basics of color to human teeth and dental restorations.
- Understand how shade guides and digital imaging are used to assess tooth color and shade.

Course Contents

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The Basics of Color

The color of an object is determined by a light source and visible light that it reflects or emits. In other words, the color of an object is determined by the light that enters the human eye from that object. So there are essentially three elements of color:

1. A light source.
2. The object that absorbs, transmits, reflects, or scatters the light from this source.
3. The interpretation of the result by the human visual system. This aspect also includes the interaction between the observer and the light source.

Figure 1. The individual colors of the visible spectrum.

Light is a form of visible energy that is part of the electromagnetic spectrum. Specific wavelengths of radiant energy may be used to identify the type of energy. The visible spectrum ranges from about 380 to 780 nanometers (nm). When daylight passes through a prism, it is refracted (bent), and each wavelength changes direction by a different amount. This separates the various wavelengths, and the individual colors of the visible spectrum are seen (Figure 1). Because passing these individual colors through other prisms doesn't produce further change, we can demonstrate that daylight is composed of all the colors of the visible spectrum and that "white" light is produced when all of these colors are combined.[1,2,3]

Color Mixing

Three large bands of color (red, green, and blue) are observed in the visible light spectrum (Figure 2). These are the primary, or basic, colors of the spectrum. They can be combined to make all the other spectral colors but cannot be produced by mixing of other colored lights. These are termed the *light-mixture primary colors*.[4,5]

Mixing of two of the light-mixture primary colors produces a *secondary color*; for example, mixing

Figure 2. The light-mixture color system.

Figure 3. The pigment-mixture color system.

Figure 4. The color wheel.

red and green produces yellow. The other secondary colors are cyan, which is formed by combining green and blue, and magenta, which is produced by mixing red and blue. This type of mixing has been termed the *light-mixture*, or *additive, color mixing system* and applies only to combining lights or illuminants.[4,5]

Another related color network used in fields such as painting and printing is the pigment-mixture system, which is also called the *subtractive color mixing system*. The secondary colors in the additive color mixing system are the primary colors in the subtractive color system. Thus, the primary colors in the subtractive, or pigment-mixture, color system are yellow, cyan, and magenta, and these form the basis for the derivation of the other colors in the pigment-mixture system (Figure 3). Mixing two of the subtractive primary colors results in the formation of a secondary color; for example, green is produced by mixing cyan and yellow.[4,5]

In esthetic dental procedures that involve shade selection for resin materials, and ceramic restorations, both additive and subtractive color concepts are used.

Color Wheel

The primary and secondary colors can be arranged in the form of a wheel in which the individual colors form parts of the rim of the wheel (Figure 4). This arrangement has been called the color wheel or color circle. It is produced by bending the spectrum of light into a circle.

Colors directly opposite each other on the color wheel are termed complementary colors. For example, the secondary color blue is opposite the primary color yellow and is thus the complementary color of yellow in the subtractive color system. The result of mixing a color with its complementary color is achromatic (colorless). Mixing of the three primary colors also produces an achromatic result.

While the color wheel provides a basis for understanding the mixing of colors, it does not allow an accurate description of color. Color has three dimensions and without the use of these measurements, it is not possible to adequately describe color.

Munsell Color Order System

Albert Henry Munsell, while teaching color composition and artistic anatomy, felt a need to describe the colors of his sketches in definite terms to his students. This led to the development of the *Munsell Color System* in the early 1900s, which remains a widely used visual color order system based on three dimensions of color.[6]

These three dimensions were defined as hue, value, and chroma. It is possible to vary each of these qualities without disturbing the other. The ability to understand each of these dimensions and separate them from one another is fundamental to an understanding of color as it relates to dental ceramics.

- ***Hue***
  Hue is that quality by which we distinguish one color family from another, as red from yellow, or green from blue or purple. It is the family name we apply to a group of colors. There are ten hue families in the Munsell Color Order System, and they are designated by the following upper-case letters: **R** for red, **YR** for yellow-red, **Y** for yellow, **GY** for green-yellow, **G** for green, **BG** for blue-green, **B** for blue, **PB** for purple-blue, **P** for purple, and **RP** for red-purple (Figure 5). Each of these ten hues is further subdivided into ten numbered segments. For example, the middle red would be 5R.
- ***Value***
  Value is that quality by which we distinguish a light color from a dark one. In other words, this is a colorless distinction. The possible range of values used in describing the lightness or darkness of a surface in the Munsell Color System extends from zero to ten. Black is zero and white is ten with a range of grays between (Figure 6). The value of a color is determined by which one of the grays it matches on the scale. Colors with low value numbers are termed dark colors, and one with high value numbers are called light colors. To compare the color match between a restoration and tooth, value is generally considered the most challenging of the three dimensions of color. One reason is that value differences are readily detected, even by an untrained eye, and restorations with improper value are frequently described by patients as being too dark or too white. In addition, value differences are more easily detected both close-up and at a distance, whereas differences in hue and chroma become less noticeable as the viewing distance increases.
- ***Chroma***
  Chroma is that quality of color by which we distinguish a strong color from a weak one; the degree of departure of a color sensation from that of white or gray; the intensity of a distinctive hue; color intensity.

  The chroma scale starts from zero, or achromatic, with increasing numeric values indicating stronger colors. In terms of chroma, color is defined by Munsell as weak, moderate, and strong. A strong chroma would be in the range of seven to ten. There are standards for very strong chromas above ten.

Figure 5. The ten hue families in the Munsell Color Order System.

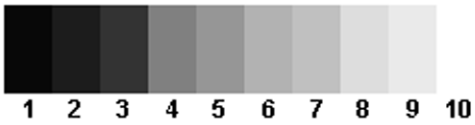

Figure 6. The range of values in the Munsell Color Order System.

Figure 7. Different chromas of a particular color are arranged from those of least purity on the left to those of greatest purity on the right.

Different chromas of a particular color are arranged from those of least purity or intensity on the left to those of greatest purity on the right. Figure 7 shows six reds arranged in ascending order from a weak one (grayish) on the left to a strong one on the right.

The significance of the three dimensions of color is not fully realized until they are related to each other three-dimensionally as was done by Munsell when he formulated his Color Order System.

The Munsell color solid can be described as follows. The hues are uniformly spaced around the central axis of the color wheel. The center of the wheel – or axle – is the achromatic or value

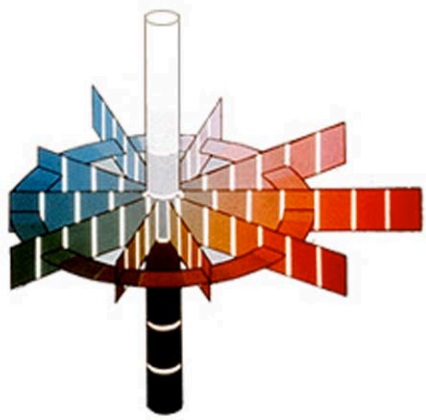

Figure 8. A wheel with the hues designated around the periphery of the wheel, the center value axle, and the spokes representing increased chroma going from the center of the wheel toward the rim.

Figure 9. The three-dimensional color solid is not complete unless there are wheels representing each value level stacked on top of each other.

Figure 10. Sectioning of the solid vertically allows the relationships between hue, value, and chroma to be viewed.

portion. Each spoke of the wheel represents the gradations in chroma occurring within a hue. Figure 8 demonstrates one wheel with the hues designated around the periphery of the wheel, the center value axle, and the spokes representing increased chroma going from the center of the wheel toward the rim. The three-dimensional color solid is not complete unless there are wheels representing each value level stacked on top of each other (Figure 9). The wheels on the top of the stack have a higher value than those on the bottom of the stack. The wheels are not the same size because it is not possible to achieve the same degree of color purity, or chroma for all hues. Sectioning of the solid vertically allows the relationships between hue, value, and chroma to be viewed and aids in an understanding of the three dimensions of color (Figure 10).

The designation of a particular color located in the Munsell solid is provided by the notation H V/C, where H stands for hue, V for value, and C for chroma. The notation 5R 4/6 would mean the hue is medium red, the value level is four, and the chroma is six. A color differing only in value and being lighter would be directly above the previous sample.

CIELAB Color System

Color research continued to evolve based on the Munsell color model. In 1976, The Commission Internationale de l'Eclairage (CIE), an international color research group founded in 1931, published the CIELAB color system. In this 3-dimensional color system, L* refers to brightness (0 to 100), a* represents red (+a*) vs. green (-a*) and b* indicates yellow (+b*) vs. blue (-b*). When a* and b* are zero, the L value represents the continuum of black to white.[7,8,9]

The CIELAB model offers some advantages over other color models. The L*a*b* color space was designed to correlate with perceptions of color. This allows the CIELAB system to measure color differences that are meaningful in industrial applications.

Since the development of the original 1976 CIELAB color system, several refinements have been made to make the color space more visually uniform. These versions are known as the $CIELAB_{94}$ and $CIEDE_{2000}$ models.

Throughout the years, CIELAB models have become some the most broadly used frameworks to measure color.

Color Differences

CIELAB is often used to measure changes in color, including changes in tooth color from use of whitening products. Color difference equations are used to quantify the color change. ΔL^*, the change in brightness, is calculated as $L^*_2 - L^*_1$ w here L^*_1 represents the initial L* value and L^*_2 is the end of treatment measure. The change in a* and b* is calculated similarly.

ΔE^* represents overall color change. ΔE^* is defined as $(\Delta L^{*2} + \Delta b^{*2} + \Delta a^{*2})^{1/2}$. Extreme care must be used when interpreting ΔE^* because it gives no information about the quality or direction of color change. For example, a unit negative change in L* ($-\Delta L^*$) means a sample became darker while a unit positive change in L* means a sample became brighter. Both situations, however, yield the same value for a change in E*.

Color of Human Teeth

The color of teeth encompasses only a small portion of the total color space. The color ranges of human teeth have been measured by different researchers at different times and using different methods and color notation systems. Using the Munsell color notation system, Dr. E. B. Clark, a dentist, produced the first data in 1931.10 He indicated the Hue ranged from 6 YR (yellow-red) to 9.3 Y (yellow), the Value ranged from 4 to 8, and the Chroma ranged from 0 to 7. Lemire and Burk found a Hue range from 8.9 YR to 3.3 Y, a Value range of 5.8 to 8, and a Chroma range from 0.8 to 3.4.3 Goodkind and Schwabacher identified the Hue range as 4.5 YR to 2.6 Y, the Value range as 5.7 to 8.5, and the Chroma range from 1.1 to 5.[11] There are several other studies that used spectrophotometers and the findings were expressed in different color notation systems. However, all of the studies indicate that human teeth are in the yellow-red to yellow portion of the spectrum, they are relatively high in Value (light or bright), and they have a relatively low Chroma (not too much color intensity).

Measuring Tooth Color

As described earlier, three factors determine the color of teeth: the light that strikes the tooth, the tooth itself and the visual system of the person viewing the tooth. Tooth enamel is translucent, allowing light to pass through and reflect off the dentin. The degree of discoloration in the enamel and dentin, which generally increases with age, affects the color of the tooth.

Measurement of tooth color is generally classified into two categories – subjective color matching and objective instrument measurement. The first attempt to accurately describe the color of human teeth was by a dentist named Dr. E. B. Clark in 1931 using a subjective analysis. He reported his color data from a visual analysis of 6,000 teeth from 1,000 of his patients over an eight-year period. He found a hue range from 6 YR to 9.3 Y. This range can be exactly located on the Munsell color wheel by using the ten subdivisions of each hue on the wheel. He found the value range to be 4/ to 8/ and the chroma range from /0 to /7.[10]

Tooth color has also been characterized using objective methods. Measurements made by a spectrophotometer show that the hue range of teeth lies in the yellow-red to red portion of the color wheel. The value range of teeth is toward the lighter portion of the scale, and the chroma range is toward the lower portion of the chroma scale.

Objective measurements of tooth color have also been performed using the CIELAB system under Daylight 5000K lighting. Values for L*, where 0=black and 100=white, typically fall in the 60-95 range. On the b* scale, which measures yellow-blue, tooth values typically range from 8 to 25. Finally, standard values range from -2 to 10 on the red-green scale (a*). The CIELAB colorspace is also used to characterize changes in tooth color. For example, when teeth are whitened with hydrogen peroxide, the teeth become brighter (L* increases), less red (a* decreases) and less yellow (b* decreases).

The following section provides more details about common subjective and objective tools used to assess tooth color and their application in the operatory and clinical research.

Dental Shade Guides

Shade guides are examples of the various color combinations available from manufacturers of denture teeth, restorative resins, and porcelain. Clinical shade selection involves direct visual

comparison of the different color samples that are present in a shade guide with the natural teeth and determination of which one best matches the teeth.

The VITAPAN Classical shade guide (Figure 11), introduced in 1956, has been, and still is widely used for shade matching in dentistry, however it is not the most appropriate tool for measuring color changes due to use of whitening treatments. Today, there are three main shade guide designs in use:

1. The VITAPAN Classical design and other manufacturer's shade guides that are based on the shade designations and organization of this shade guide. Criticism of the empirical design of these shade guides, the logic of its structure, and the color distribution let to the development of the 3D-MASTER.
2. The VITA 3D-MASTER shade guide with a more logical order and wider color distribution.
3. Other shade guide systems with proprietary designs and organizational structures.

Since the 3-D MASTER shade guide is relatively new and is continuing to grow in its popularity, it is important to have an understanding of the organizational design.

Designs of the VITA 3-D MASTER Shade Guides

There are three VITA 3-D MASTER shade guides: Toothguide, Linearguide and Bleachedguide. The 3D-MASTER was developed based on research and according to the literature, it has the smallest coverage error compared to natural teeth. The 3D-master tabs are marked using a number-letter-number combination. The first number designates Value, from 0 – the lightest, to 5 – the darkest. The middle letter designates Hue with the L, M, and R corresponding to yellowish, medium and reddish Hue. The second number designates Chroma, from the least Chromatic – 1, to the most Chromatic – 3.

Toothguide

The color samples in the toothguide shade guide (Figure 12) are divided into one of six groups, based on Value: group 0 (3 tabs); group 1 (2 tabs); groups 2, 3 and 4 (7 tabs each); and group 5 (3 tabs). Within the groups, tabs of different Chroma are available. Hue variations are available only in groups 2, 3 and 4.

Figure 11. VITAPAN Classical Shade Guide.

Figure 12. VITA 3D-Master Toothguide..

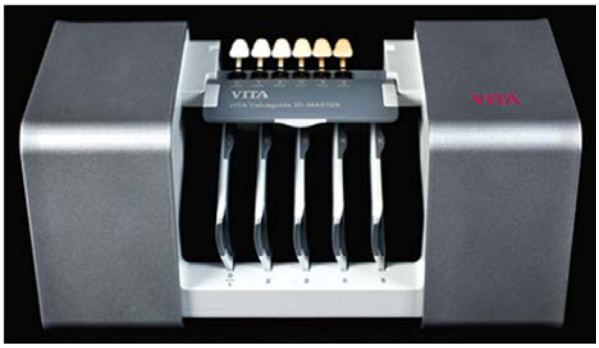

Figure 13. VITA 3D-Master Linearguide.

Linearguide

The Linearguide shade guide (Figure 13) has the same 29 tabs as the Toothguide but its organizational structure is different and shade matching is thereby reduced to two steps. There is a dark-gray base holding 6 shade tabs and it is labeled as the VITA Valueguide 3-D MASTER and is designed for selecting Value. The linear tab arrangement and small number of tabs (6) greatly simplifies the selection of Value. There are 5 other small shade guides, labeled as VITA Chroma/Hue guides. The Chroma/Hue guide to be used is determined by the previously completed Value choice. Using the appropriate Chroma/Hue guide, the second step is completed by selecting the best Chroma and Hue. While this

Figure 14. VITA Bleachedguide 3D-Master.

guide is called Linearguide, it does not represent a linear ruler-like spacing of tooth colors. Like all other shade guides, it is not particularly useful for assessing product effects.

Bleachedguide

The bleachedguide shade guide (Figure 14) is the only shade guide developed specifically for shade matching of teeth which have been previously bleached and not matched with other shade guides. Bleachedguide exhibits a wider color range than earlier shade guides.

No single shade guide or combination of guides includes all of the color combinations that may be encountered in clinical practice. As a result, exact matches are not common. While the use of shade guides is common for matching restorations, they are of limited value in measuring color changes resulting from tooth bleaching procedures. This is due to the non-uniform spacing of the shades throughout 3-dimensional color space. No techniques exist to eliminate the subjective nature of shade guides. However, careful attention to the environmental conditions will help optimize matches.

- Ensure the lighting in the room is appropriate for shade matching. The light source, color temperature of light, amount of lighting, and location of lighting must be appropriate for color matching.[12,13]
- Ensure the color environment is suitable for shade selection (e.g., color of operatory walls, patient's clothing, use of lipstick, etc.).[14,15]
- Put the patient in an upright position so the teeth will be viewed in the operatory under the same conditions under which they will be seen.
- Ensure the tooth condition is appropriate (e.g. clean, hydrated) for matching.[16,17] (Figure 15)
- Select the proper shade guide system.[18]

Figure 15A. Dehydrated Teeth.

Figure 15B. Teeth that are clean and hydrated, ready for matching.

- Evaluate the patient's natural teeth to determine their color characteristics (yellow, red, gray, and so forth) by looking at the cervical aspect of the teeth. Then only the properly pigmented shade guide specimens need to be used, reducing the number of choices and making the selection process easier. Modern shade guides, like the Vita 3D-Master shade guide, recommend selecting the value first, then selecting the chroma and finally the hue.
- Evaluate prospective shade guide specimens one at a time by holding them next to the tooth being matched (Figure 16). Holding the entire shade guide adjacent to the teeth can cause confusion, and difficulty may be encountered in determining the best specimen from such a large group of samples.
- Align the shade guide so that light reflects off the shade guide specimen in a manner similar to that of the natural tooth.
- Consider the selection distance. A selection made at one to three feet is generally more useful than one made in close proximity to the teeth.[19]
- Use a short-duration glance, resting the eyes on a blue card between glances. Compare the

Figure 16. Evaluate prospective shade guide specimens one at a time by holding them next to the tooth being matched.

color of the cervical portion of the shade guide specimen with the natural tooth by covering the incisal half of the tooth and shade guide specimen, which allows the comparison to be made without distraction. Other samples are observed in the same manner until a decision is made regarding the best cervical color match.[19]

- Restrict light to the eye if needed. Squinting can be helpful to assess value differences.[19]
- For many teeth, one cervical shade selection is all that is required. However, certain teeth exhibit different zones of dentin coloration, and the shade selection must be performed cervically and repeated for other areas of the tooth, since one dentin color does not provide the multiple color characteristics present in the tooth.
- A diagram showing zones of discoloration, form and extent of translucency and other tooth characteristics should be considered for the laboratory technician.
- Verification of the shade should be made on more than one occasion (e.g., initial visit and the subsequent appointment) without reference to the initial reading. A second opinion from another staff member is recommended.
- It is best to avoid unnecessary involvement of the patient. If the patient wants to be involved in the treatment process, the final selection can be shown to the patient for approval, or the patient can be given the two best possibilities and allowed to decide.
- Adequate time for selection must be available. Shade selection should not be rushed at the end of an appointment.[19]

While shade guides are commonly used in dental practices, they have several limitations both in the operatory and in clinical trials. First, the subjective nature of shade matching increases the odds of variability. Two dental professionals may select different shades under the same set of conditions (intergrader variability). Moreover, the same dental professional may select different shades when assessing the same patient under the same conditions on two separate visits (intragrader variability). Finally, research indicates that the order of certain shade tab systems does not correspond with consumer perception of whiteness ranking and the change in brightness from tab to tab varies.

An additional drawback to the use of shade guides in clinical research concerns the different systems. The number of shade tabs varies across systems, so a claim of “7-shade change” has little meaning unless one knows which shade tab system was used in the research study. A 7-shade change on one system does not necessarily reflect a 7-shade change on a different system.

A small percentage of dentists have deficient color vision (anomalous color vision) and it has been determined[20] that these individuals make more errors in the chromatic aspects of color (Hue and Chroma). Dentists with color deficiencies need to be aware of their condition and make corrections by enlisting the help of other office personnel with normal color vision to assist them in the shade selection process as it relates to Hue and Chroma.

Instruments Used for Measurement of Tooth Color - Digital Shade Selection

While shade guides are commonly used in restorative dentistry, there are various human errors associated with the use of commercial shade guides. Some of the problems associated with the use of shade guides stem from the fact that the teeth do not match the shade guides to which they are being compared. The shade guide tabs are 4-5 mm thick with a metal backing compared to the thin 1.5 mm piece of porcelain used for the restoration and the fluorescence of shade guides is different from that of natural teeth. Eye fatigue and improper room illumination magnify the chances for improper shade selection.

The limitations of the shade guides have led to the development of objective measurement

Figure 17. VITA Easyshade Compact Shade Measurement System.

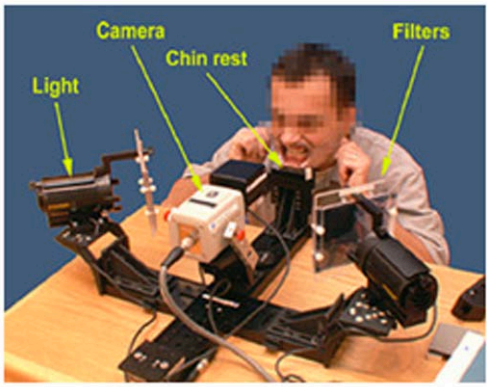

Figure 18. A typical imaging system is comprised of a 3-chip CCD camera, a d50 polarized lighting setup, computer and fixed positioning of the patient.

tools, which are generally more reliable and reproducible. The popularity and use of digital color matching devices has increased in the last decade due to introduction of several more accurate, more affordable, and user friendly hand-held color measuring devices (Figure 17).

Color-matching instruments now consist of a handpiece and a base unit. They are compact, have their own light source, and incorporate means for electronic storage and transfer of recorded information. Some are cordless.

These devices are useful. They can help achieve a better esthetic result, and may increase a patient's self-confidence in their dentist. However, the role of the dental professional is still an important factor affecting the final color match since no electronic device is currently available that is capable of recording all the fine details and subtle color and translucency variations present in human teeth.

Digital Cameras

A preferred method for measuring tooth color is a high-end digital camera with an appropriate lighting system and calibration methods – often referred to as digital imaging. The camera has the capability of capturing the entire tooth surface. This provides much more information about the color of the tooth and the color distribution across the tooth surface. Importantly, capturing color with a camera is much easier than a spectrophotometer.

Digital imaging has been used extensively to measure tooth color changes associated with bleaching products. The system is based on the CIELAB color space. Tooth luminosity (L*), yellow-blue (b*) and red-green (a*) color components are calculated. Measures of overall color change (DeltaE) are derived from these values.

A typical imaging system is comprised of a 3-chip CCD camera, a D50 (Daylight at 500K color temperature) polarized (polarization eliminates glare) lighting setup, computer and fixed positioning of the patient (Figure 18). It is important to use a camera that does not have automatic color correction features or the feature can be turned off. Most consumer cameras are designed to produce aesthetically pleasing pictures rather than correct measurements of color. Typically this requires a high-end camera such as the Fuji HC series cameras or the JVC KY-75U camera. A single click captures the entire dentition, whereas spectrophotometers and radiometers are more cumbersome to use. These higher end digital imaging systems are custom built and typically not available in dental offices.

o use the system, subjects place their chin in the chin rest and use cheek retractors to expose maxillary and mandibular dentition. An image of the teeth is captured and sent to the personal computer. Image analysis software measures the color of each pixel, so the system assesses total tooth color, not just one point on the tooth.

A critical aspect of digital imaging analysis is the hourly calibration. This ensures the results are accurate and reproducible.

Digital imaging analysis is a measurement tool used in more than a hundred of clinical trials to assess tooth color. The objective system is particularly useful in clinical trials as it limits variability and bias seen with subjective methods. The archival quality image produced can also be used to track long-term response. Published data shows a correlation between objective and subjective responses seen with L*a*b* analysis.[21]

In addition to clinical research, digital images can be very useful in practice. They can be used to show the laboratory technician the extent of translucency and the magnitude and location of surface characteristics, particularly if the laboratory and clinical environments are comparably illuminated and the digital image viewing environments have been calibrated.

Conclusion

From the previous information, it becomes apparent that accurately assessing color and shade is a critical component of esthetic dentistry. This process requires knowledge of the dimensions of color, the tools used to assess color and shade, and clinical experience.

This skill cannot be thoroughly mastered in the absence of scientific knowledge, nor can it be fully grasped by merely memorizing facts about color. Together, knowledge and experience provide rewarding solutions to this challenging aspect of dentistry.

Course Test Preview

To receive Continuing Education credit for this course, you must complete the online test. Please go to www.dentalcare.com and find this course in the Continuing Education section.

1. An element of color is _____.

a. a light source
b. an object that absorbs, transmits, reflects, or scatters a light source
c. the interpretation of the result of a light source and an object by the human visual system
d. All of the above.

2. The light-mixture primary colors can be produced by mixing colors.

a. True
b. False

3. Which is one of the primary colors in the subtractive color system?

a. Red
b. Green
c. Yellow
d. Blue

4. In esthetic dental procedures that involve shade selection, resin materials, and ceramic restorations, which color concept(s) is used?

a. Additive
b. Subtractive
c. Both additive and subtractive.
d. Neither additive and subtractive.

5. "Complementary colors" is the term used to describe colors that have what kind of relationship on the color wheel?

a. Colors next to each other.
b. Colors with one other color between them.
c. Colors with two other colors between them.
d. Colors directly opposite each other.

6. The three dimensions of color used in the Munsell Color System are hue, value and chroma.

a. True
b. False

7. The value of a color describes _____.

a. the family name applied to a group of colors (red vs. yellow)
b. colorless distinction (distinguish light color from dark one)
c. color intensity (distinguish strong color from weak one)
d. None of the above.

8. The CIELAB system is often used to measure changes in tooth color from use of whitening products.

a. True
b. False

9. One goal of tooth whitening is to decrease the b* value (CIELAB system) which represents _____.

a. reduction in yellowness
b. lighter tooth
c. decrease in blue
d. None of the above.

10. Which is a guideline to follow to help mitigate the subjective nature of shade matching?

a. Make sure the patient is lying back in the chair.
b. Ask the patient to wear lipstick.
c. Ensure the tooth is clean and hydrated.
d. Be sure to make the selection when standing within inches of the patient's teeth.

11. What type of artificial light source is recommended for color matching procedures?

a. Incandescent lighting
b. Color-corrected fluorescent lamps
c. Cool white fluorescent lighting
d. All of the above.

12. Digital imaging analysis of tooth color _____.

a. provides objective results
b. provides archival data
c. limits variability and bias
d. All of the above.

13. When comparing the color of a porcelain sample with that of a tooth, it is recommended that glances of how many seconds are followed by periods of rest?

a. 5
b. 10
c. 15
d. 20

14. Hand-held color measuring devices _____.

a. are compact, consisting of a handpiece and base unit
b. do not have their own light source
c. do not incorporate means for electronic storage and transfer of recorded information
d. None of the above.

15. Elements of a digital imaging system include a _____.

a. 3-chip CCD camera
b. d50 polarized lighting setup to eliminate glare
c. computer
d. All of the above.

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