

# VITA Easyshade<sup>®</sup>

**The principles of use of a spectrophotometer  
and its application in the measurement of  
dental shades**

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## OVERVIEW

The Vita Easyshade intraoral dental spectrophotometer is a self contained, easy to use, portable, dental shade matching device. The Vita Easyshade consists of a base unit and hand piece with a six foot PVC stainless steel monocoil fiberoptic cable assembly connecting the hand piece and base unit. The hand piece contains a fiberoptic probe assembly for illuminating and receiving light from a tooth, multiple spectrometers and a microprocessor for communications with the base unit. Communication between the handpiece and base unit is via USB. The base unit contains a lamp assembly, CPU, vacuum fluorescent display with touch screen and a removable calibration block assembly. There are both (RS232) and USB ports (terminal) for interfacing to external computers. Custom made, disposable, polyurethane barriers are utilized to prevent patient cross contamination.

### Spectrophotometers

A spectrophotometer is an instrument that consists of 3 principle elements: a light source; a means to direct the light source to an object and receive the light reflected or otherwise returned from the object; and a spectrometer that determines the intensity of received light as a function of wavelength. Additionally, Easyshade has a CPU to analyze the spectrometer data, determine a shade match to current Vita Classical and 3D shades and output and display the results.

### Light Source

Easyshade utilizes a 20 Watt halogen stabilized tungsten filament lamp. It has a color temperature of 3350K and is a continuous light source over the full visible and near infrared spectrums. Average life of the lamp is 100 hours. It requires 15 seconds to warm and stabilize. The lamp is mounted in an assembly in the base unit with a shutter that is activated for each measurement.

### Spectrometer

A spectrometer is a device that measures light in distinct bands. Traditionally, spectrometers utilize a diffraction grating and a linear CCD detector. Easyshade's spectrometers are a custom design by JIL Technologies LLC and utilize interference filters in combination with light to frequency converters (silicon photodiode array). The advantages of this design is small size, mechanical stability and a gray scale output (of each band) that is very stable, linear over a wide intensity range, and has high resolution (over 64,000 levels of gray). The spectral resolution is 25 nanometers over the visible light range from 400 – 700 nanometers. The spectrometer makes up to 50 measurements per second (its rate is variable and adjusts itself to operational conditions).

The Easyshade handpiece contains 3 separate spectrometers. One spectrometer continuously monitors the output of the lamp during the calibration and measurement process. The other two spectrometers are utilized to analyze the light that is internally scattered (not absorbed) by the tooth structure. The spectrometers have separate receiver elements spaced at different distances

from the light source and effectively measure the color of a material (tooth or ceramic) at different depths.

### **Infection control barrier**

Patient cross contamination is controlled with a polyurethane barrier, in the form of a pouch, that is stretched taut over the end of the probe. Polyurethane is a material that is very strong, has no known allergic toxicity, can be stretched approximately 800% without tearing, is optically neutral (little chroma distortion), and impervious to bacterial penetration. It's utilized widely in medical invasive surgery as infection control barriers. The infection control tip is easy to install, low cost, disposable and is placed on the instrument prior to calibration and removed when tooth color data has been collected.



Fig. 1 Easyshade probe tip with infection control barrier

### **Calibration**

All color measurement determination is a comparative process. To calibrate an instrument, one needs to measure one or more reference materials. The spectrometers in Easyshade are very linear, thus only one sample is required for calibration. A ceramic block of known color is utilized for calibration and is located over a switch which is used to detect when the instrument is in the calibration mode.

An infection control barrier is placed over the probe tip and the probe is placed into the calibration holder and a small amount of pressure is applied which activates the calibration switch. A series of spectrometer measurements are made. The first measurements are with the lamp shutter closed, the next series are with the lamp shutter opened (calibration block is illuminated). Both “dark” levels and “white” levels are recorded and the three spectrometers are normalized. The lamp spectrometer is normalized to a white (artificial) light standard. The two sample spectrometers are normalized to the known color of the calibration block. This process permits all color variables in the system to be calibrated away including ageing of the lamp (red shifting), the thickness and color variation of the infection control barrier, twisting of the fiber optic cable and aging of the spectrometer sensors and fiber optics in the handpiece probe.

The color of the calibration block is determined in the factory and is stored in each Easyshade system. If a calibration block requires replacing, the calibration information for the new block can be entered into Easyshade via one of the serial ports and a computer or can be entered by hand via the display and touch screen. It's important to care for the calibration block and insure it is not contaminated or gets dirty in any manner. It can be removed for cleaning or autoclaving.

### **Measuring Teeth and Dental Materials**

Following calibration, Easyshade is ready to measure teeth or dental materials. The type of material to be measured is selected from a menu on the display via the touch screen. Shade tabs may also be measured to insure the accuracy of Easyshade and as a measurement learning procedure. It is not necessary to re-calibrate Easyshade when switching from one material to another and it is not necessary to re-calibrate between measurements. It is only necessary to recalibrate after replacing the infection control barrier between patients.

A measurement proceeds by placing the probe on an area of a tooth and pressing the probe switch. A series of "dark" level measurements are made and recorded followed by opening the lamp shutter and making a series of "white" level measurements. The "dark" level measurements include any stray background light which is subtracted from the "white" level measurements to obtain only the light provided by Easyshade. The spectrum of the lamp is compared to the spectrum during calibration and if the lamp has drifted (unlikely) or if the optical cable is twisted the lamp color and intensity are compensated for any drift.

The probe has additional sensors utilized to measure angle and motion. If the probe is moving during a measurement the "white" measurement is delayed until the probe is stabilized. Additionally, if the probe is held at an awkward angle or is too near an edge of the tooth the measurement may be adjusted for the angle or rejected. It's a simple process to re-measure the tooth.

## **TRADITIONAL COLOR MEASUREMENT METHODS**

Teeth are complicated, layered, translucent materials and can not be measured with conventional color measurement techniques. One of the more challenging aspects is the fact that teeth are in a mouth, making it difficult to reach them. The Easyshade probe is designed specifically for teeth and other translucent dental materials and is not applicable for opaque objects.

There are several factors that affect measuring the color of materials. The first is to control the light source to light receiver geometry. Traditionally this is done with an integrating sphere which directs a light source on an object and collects virtually all the reflected light from the object with a spherical cavity that is totally diffuse and very white. The importance of the sphere is three fold. Firstly, it controls the distance of the light source and receiver from the sample. Secondly, it collects all the light reflected from the sample in a proportion nearly equal to the light reflected from a reference sample. Third, it provides for diffuse illumination of the sample. The accuracy of the integrating sphere is entirely dependent upon the sample having the same reflection characteristics as the standard. If the sample reflects light in a different pattern than the reference sample errors can occur. To minimize the errors, integrating spheres are designed

as large as possible to have the largest internal surface area relative to the area of the sample. (Of course, as the sample area relative to the sphere area decreases, the sensitivity of the system spectrometer must correspondingly increase.) Thus integrating spheres are usually 6'' (152mm) in diameter and have sample openings of approximately 0.5'' diameter (quite impracticable for making measurements in a mouth). An additional problem is edge loss. When a translucent material is measured, light can exit the material through the edges of the material outside the sphere rendering the color measurement to be too dark. Although it is possible to calibrate a sphere with a sample material of the same size and translucency (or use a series of standards) for calibration to reduce the effect of edge loss the impracticality of the sphere's size renders it unusable for insitu measurements of teeth.

The most important aspect of a sphere is that it both controls the light source to sample distance and that it collects all the light reflected (or as much as possible) from the sample, independent of the sample surface. While it may be possible to control the light source and the manner in which light is directed to a tooth, it is impossible to control the angles that light will be returned from a tooth. If a camera is utilized for example, the light source (usually a strobe) directs light in a controlled manner to the tooth, but the light reflected back from the tooth may or may not be directed back to the camera lens. Thus the intensity of light received will vary over a large range rendering an accurate color measurement very difficult and not very repeatable.

The advantage of an integrating sphere is that it collects all the light returned from the sample. To simulate the sphere, it's important to have the light receiver as close as possible to the sample and to collect as much light as possible from the sample independent of surface characteristics or angle.

Teeth are both translucent and glossy and when illuminated light can both be reflected from their surface and can penetrate the tooth and be scattered back. Light reflected from a surface is referred to as specular reflection; light that penetrates a material and is reflected back is referred to as diffuse reflection (at an atomic level all reflections are specular). The principal difference of specular reflection (from the surface) and diffuse reflection is that for non-metallic materials the specular reflected light contains little or no color information. This is particularly important for teeth or any translucent material. The appearance of color occurs because the reflected or otherwise returned light has been partially absorbed, refracted or scattered within the bulk of the material. If the light simply reflects from the surface, little or no absorption will occur and the reflected light is the same color as the light source. If the light penetrates only a short distance into the enamel a minimal amount is absorbed and although it may be possible to quantify the hue (or tint) of the tooth, the chromacity will be too low and the value too high. The returned light will be "too white" and not representative of the true base color of the tooth. It's necessary to have light penetrate a tooth to the dentin level, travel through the enamel, and exit some distance away to obtain the proper degree of absorption and scattering inside the tooth. Otherwise, one is only measuring "hot spots" from the surface and obtaining false colors.

## EASYSHADE METHOD

Easyshade's measurement technique utilizes large diameter fiber optics arranged in a specific pattern in a stainless steel probe to illuminate a tooth and receive light that is internally scattered by the enamel layer and reflected from the dentin layer of the tooth. Separate fiber optics are utilized to transmit light to the tooth (source fibers) and receive light (receiver fibers) reflected from the tooth. Specular reflection (light that is reflected from the tooth surface) is not received by the receiver fibers. All measurements are specular excluded measurements.

The Easyshade probe (see fig 2) consists of nineteen 1 mm diameter fiber optics arranged in a stainless steel ferrule that holds the fibers in precise alignment. The outer ring of fibers are utilized to illuminate the tooth. An inner ring of fibers consists of three fibers for one spectrometer and three fibers that serve as angle/motion detection sensors. The angle/ motion fibers determine if the probe is being held steady and perpendicular to the tooth surface. The inner fiber is connected to a second spectrometer.

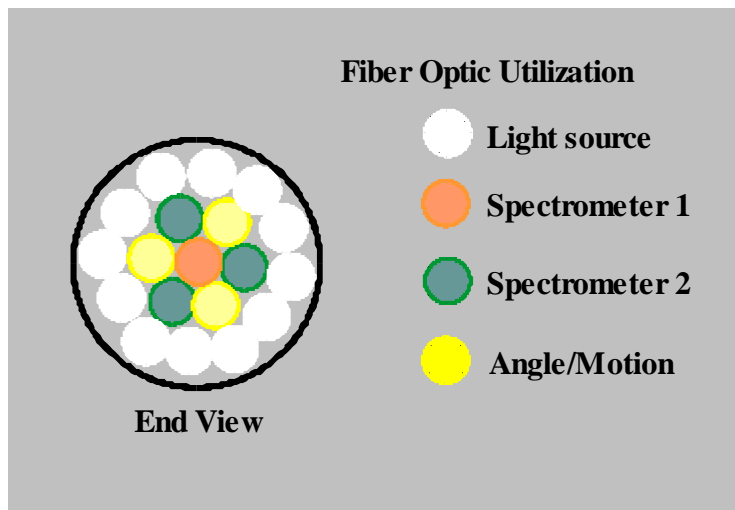


Fig. 2 – End view of Easyshade probe

The geometry of the probe is a pseudo 0/0 circular design (source and receiver fiber optics are parallel but are spatially separated). Due to the arrangement of the fiber optics in the probe (as explained in greater detail in the fiber optic technology section) all measurements are specular excluded. The probe illuminates a 5 mm diameter area on the tooth surface (angles of illumination are from 0 – 30 degrees) and due to the scattering properties of enamel, the light diffusely illuminates the underlying dentinal layer. The 5mm diameter of the probe covers the middle 1/3 and cervical 1/3 of most teeth well and requires an underlying dentinal layer to reflect light back into the probe. The incisal and marginal ridges of teeth should not be included in the measuring area of the probe because the light will travel through the enamel and into the oral cavity resulting in a lower L\* value measurement (light is lost to the receiver).

## Basics of Fiber optics

In order to better understand the measurement technique of Easyshade, it is necessary to understand certain fundamental principles of fiber optics (see Fig. 3). Fiber optics consist of an outer cladding material and an inner core material. The core and cladding material have different indexes of refraction. This produces a numerical aperture (NA) for the fiber optic, which is:

$$NA = \sin(\alpha) = \{(n_0)^2 - (n_1)^2\}^{1/2}$$

where:  $n_0$ = index of refraction of the core

And  $n_1$ = index of refraction of the cladding

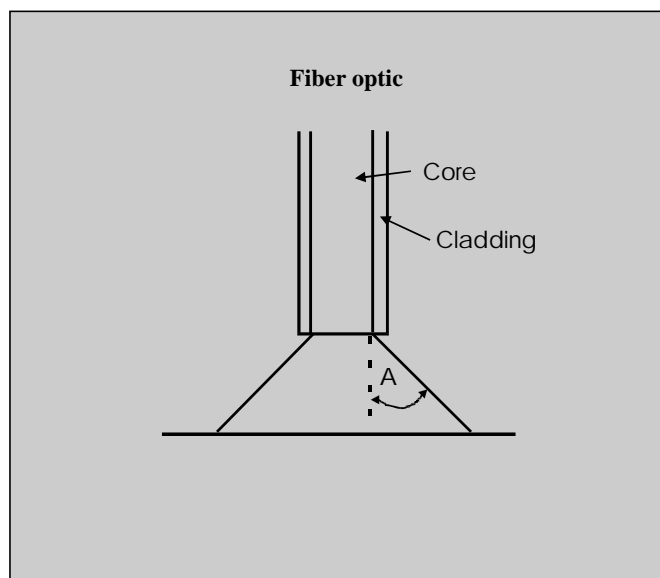


Fig. 3. Single fiber Optic Illuminating a Surface

In order for light to enter and be propagated by a fiber optic, the light ray must be within the acceptance angle of the fiber optic. Light rays outside the acceptance angle exit the fiber optic and are lost. In general, as light travels through a fiber optic, the angle of incidence to the end of the fiber is preserved and the light will exit the fiber optic at the same angle as it entered the fiber optic (unless the fiber optic is severely bent).

If we now consider two fiber optics parallel to each other (see Fig. 4), where one is transmitting light to a surface (illumination fiber optic) and the second fiber is receiving light (receiver fiber optic) reflected from the surface. The only light that will enter the receiver fiber optic is light that is reflected from the surface in the area of intersection of the two fiber optic's acceptance cones. This results in a critical height ( $C_h$ ) which is the minimum height that two fiber optics must be above a surface for light to reflect from the surface and be able to be received by the receiver fiber optic. The critical height is a function of the fiber optics NA and the separation between the two fiber optics.

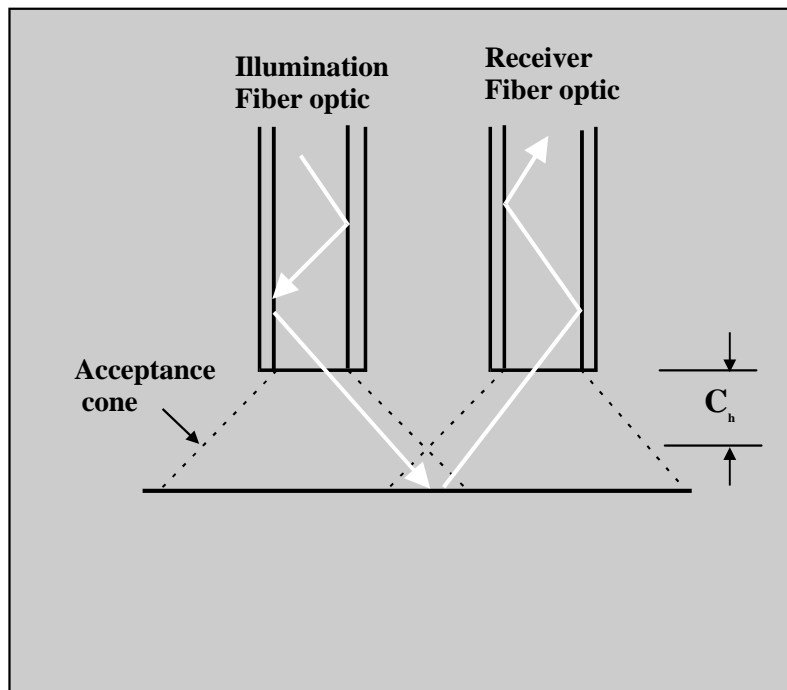


Fig. 4 –Source and Receiver fiber optics above a surface

For teeth, as long as the Easyshade probe is touching the tooth surface, or is at a distance less than the critical height away from the tooth surface, no light that reflects off the tooth surface (specular reflection) can be received and transmitted to the spectrometers in the Easyshade hand piece and adversely effect the color measurement (see Fig. 5). This includes light that is reflected from the inner surface of the infection control barrier. As long as the infection control barrier is stretched tightly over the end of the probe and as long as the barrier thickness is much less than the critical height, it is invisible to the probe. This principle allows Easyshade to utilize a true infection control barrier.

Refer to Fig. 5. Ray  $R_1$  (specular reflected light ray) is not detected by the receiver. Light Ray  $R_2$  which both penetrates the tooth, reflects from the dentin layer, travels transversely through the enamel of the tooth, and emerges from the tooth in the acceptance cone of the receiver fiber optic is measured.

Since no light reflected from the surface of the tooth is received by the receiver fiber, the Easyshade probe is insensitive to both surface irregularities and to the angle of the probe relative to the tooth provided it is held to within approximately  $15^\circ$  of vertical.

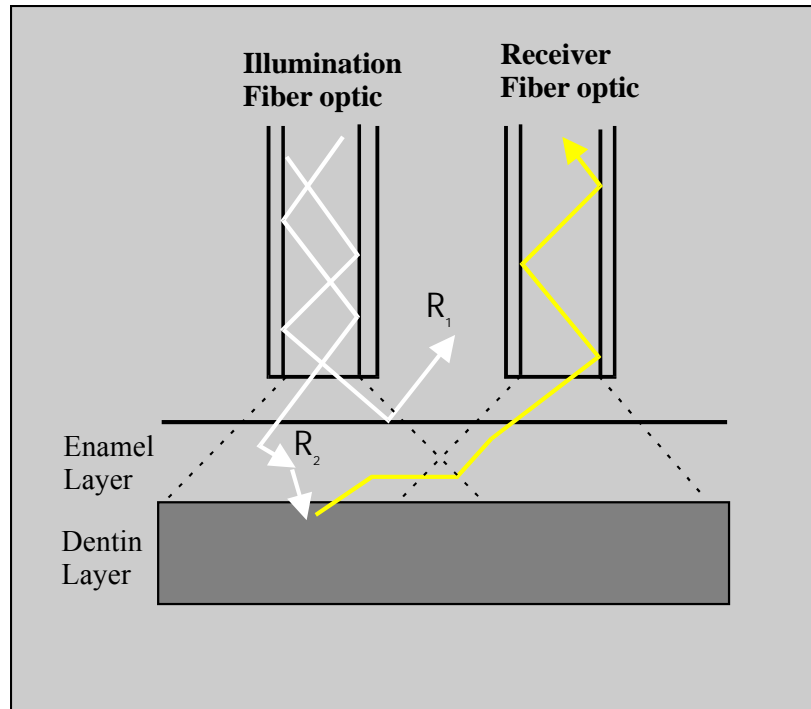


Fig. 5 –Source and receiver fiber optic above a tooth surface

As shown in Fig 2, the Easyshade probe contains multiple receiver fiber optics spaced at different distances from the light source, coupled to two spectrometers, which varies the effective depth of the color measurement within a tooth or ceramic restoration. As a result, the path lengths of the light rays are different for the two spectrometers. Ceramic restorations are generally less than 1.5 mm in thickness and the color layers (dentin and opaque) are from .2- .4 mm under the enamel porcelain layer. With teeth, the dentin layer is generally 1.0- 1.5 mm from the outer surface. Easyshade’s probe design is material dependent and the user is required to select different measuring modes based on the type of material: natural tooth; ceramic or shade tabs. The spectrums from the two spectrometers are mathematically combined dependent upon the material to produce a “principle” spectrum representative of the material.

### Calculating Color and Tristimulus Values

The Easyshade instrument contains an internal CPU and a display to analyze and output the measurement result. The output of the spectrometer is converted into a spectral reflectance curve (see Fig. 6) by the CPU. A spectral reflectance curve indicates at a specific wavelength the percentage of light that is absorbed or reflected by a material and it defines the color properties of a material. A spectral reflectance curve is independent of the illuminant (light source) or observer. The CPU converts the spectral reflectance curve into color space nomenclature, such as CIE  $L^*a^*b^*$  based on a specific illuminate and observer. Easyshade’s CIE  $L^*a^*b^*$  output is based on a D65 illuminant and a 2 degree standard observer. To be technically accurate, when reporting  $L^*a^*b^*$  results, the illuminate and observer should be included with the results, such as: D65 2 degree  $L^*a^*b^*$ . In addition, it is also appropriate to include the instruments

measuring geometry with the data results. In general, there is not great correlation between different manufacturer's instruments. This is due to differences in measuring area sizes, viewing angles and illumination angles.

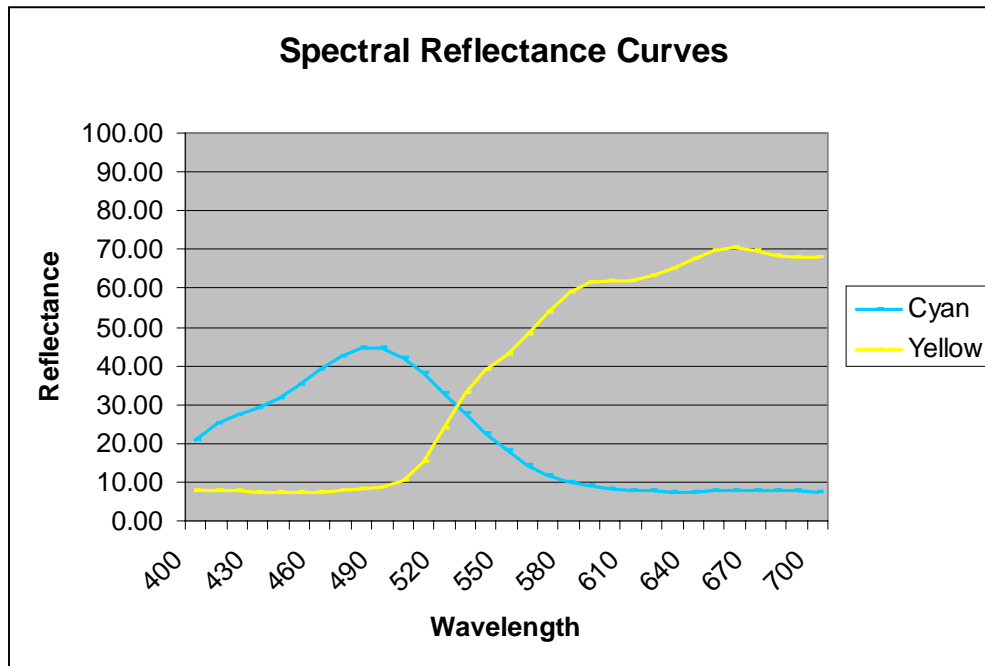


Fig. 6 Typical spectral reflectance curves.

## Translucency

The Easyshade probe must be in contact with a tooth or dental material to make a measurement and thus can only measure translucent materials. Additionally, if a dental material is too thin or if a tooth is too opaque the value and chroma may be reported too low. Easyshade is designed and optimized for dental materials that are minimally 0.7mm thick and for most translucency ranges of teeth. The translucency of a tooth is determined by analysis of translucent-dependent measurements made as a part of the Easyshade system's measurement process.

## COLOR PERCEPTION TUTORIAL

The perception of color involves three elements: a light source, an object (which in this discussion is a tooth) and an observer. Although gloss, translucency and opalescence all affect the appearance of a tooth, this overview will be restricted to color measurement.

To begin, it is important to understand that the terms "light source" and illuminant have precise and different meanings. "Light source" is a general term for an emitter of visible electromagnetic radiation, such as a candle, incandescent bulb or the sun. Since the perceived

color of some objects changes with different light sources, specifying the color of an object requires that the light source be defined. An “Illuminant” is a specification of a particular light source. Common illuminants include:

<b>Illuminant</b>	<b>Description</b>	<b>Color Temperature (Kelvin)</b>
A	Tungsten lamp (typical)	2,856
B	Direct sunlight	4,870
C	Average daylight light from an overcast sky	6,770
D65	A 'non-real' standard - mathematical construct	6,500
D55	A 'non-real' standard - mathematical construct	5,500

Easyshade uses the D65 (6,500 °K) illuminant for shade matching. This Illuminant is a mathematical construct that cannot be physically realized as a light source, but is close to average northern sky daylight.

### **Specular Light**

Specular light, commonly referred to as “glare”, is reflected off the surface of an object and, with the exception of metals, contains no color information about the object. Color measurement instruments therefore must indicate whether a measurement is made with specular light included or excluded. Specular light is an important consideration with respect to the shade-matching of teeth.

When an examiner looks at a tooth, there are often “hot-spots” of specular light present. To match the shade accurately, the examiner will shift the line of vision to eliminate hot-spots from consideration. Hot-spots also are present for camera-based shade-matching systems, and if eliminated from consideration during the shade-matching calculation, they compromise the accuracy of the calculated shade.

### **Color Space**

A device-independent color space is required for measuring and quantifying color that is independent of the measuring device. Several such systems have been developed to be true representations of colors as perceived by the human eye. The most commonly used color space is based upon the three colors red, green and blue (also referred to as X, Y and Z). The Commission Internationale d'Eclairage (CIE) is an international standards organization with respect to the measurement and reporting of color. The CIE L\*a\*b\* color space has a vertical axis that indicates relative lightness or darkness. The two horizontal axes represent the amounts of red/green and yellow/blue. In the L\*a\*b\* color space:

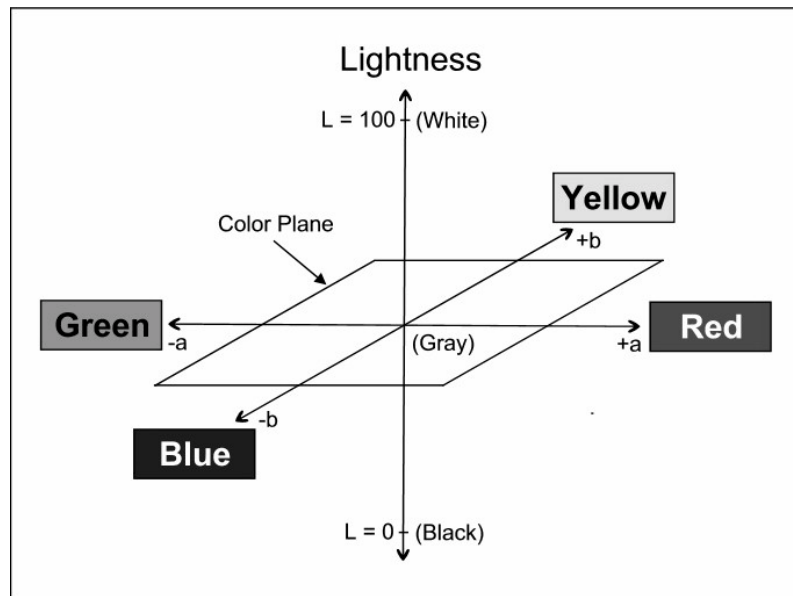


Fig. 7 CIE L\*a\*b\* color space

“L” is a measure of the Lightness of an object, ranging from 0 (Black) to 100 (White).

“a” is a measure of redness ( $a > 0$ ) or greenness ( $a < 0$ ).

“b” is a measure of yellowness ( $b > 0$ ) or blueness ( $b < 0$ ).

The L\*a\*b\* color space is shown in Fig. 7. Along the vertical axis (the “neutral” axis), between black ( $L=0$ ) and white ( $L=100$ ) is a continuous range of gray shades.

The CIE L\*C\*h\* system is a cylindrical coordinate representation of the L\*a\*b\* color space. In any horizontal color plane in the L\*a\*b\* color space, “C” (or Chroma) is measured as the distance from the vertical (neutral or gray) axis, and “h” (or Hue) is the angle of displacement as measured from the red/green axis. This is shown in the color plane below, which is a horizontal slice (a region of constant L) from Fig. 7.

The axes for the L\*C\*h\* color space are the same as for the L\*a\*b\* color space. The difference between the systems is that the L\*C\*h\* color space (often referred to simply as “LCh”) uses cylindrical coordinates, while the L\*a\*b\* color space (often referred to as “CIE Lab” or simply “Lab”) uses Cartesian coordinates.

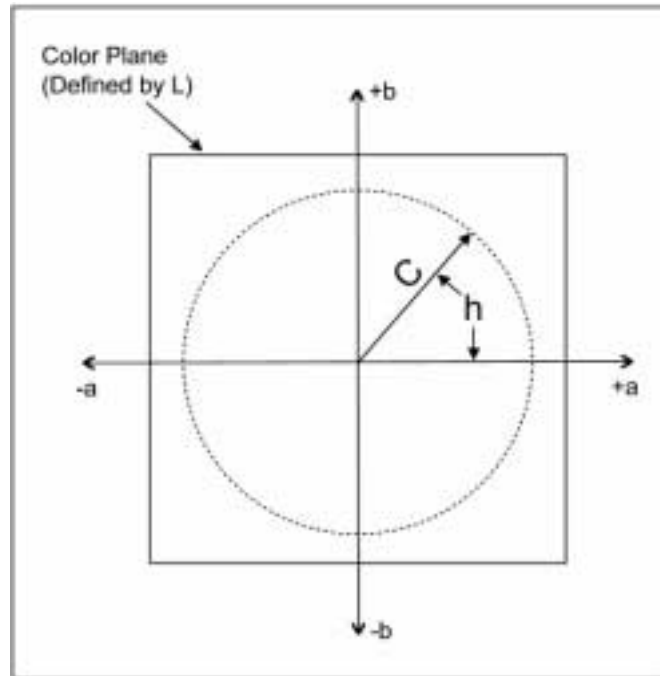


Fig. 8. Chroma (C) and Hue (h)

The LCh system defines the three visual aspects that are most often used to define a color:

**L – Value** is the brightness of the color. It is the degree of lightness or darkness of a color relative to a series of grays ranging from white (L=100) to black (L=0).

**C – Chroma** is the saturation or strength of a color. It is the difference between the color and a gray having the same brightness, measured as the distance from the neutral axis. It is sometimes referred to as the purity of the color.

**h – Hue** is what we commonly call color (red, yellow, green, blue or some other color). It corresponds to the physical wavelength of light. It is represented as an angle ranging from 0° to 360°. Angles that range from 0° to 90° are reds, oranges and yellows; 90° to 180° are yellows, yellow-greens and greens; 180° to 270° are greens, cyans (blue-greens) and blues; 270° to 360° are blues, purples, and magentas, returning again to red at 360° (the same as 0°).

## The VITA 3D-Master System

In the VITA 3D-Master system, the range of normal Lightness for human teeth is represented by Value Groups ranging from 0 (the lightest) to 5 (the darkest). Within a given Value Group, the Chroma is represented by a number ranging from 1 to 3. Also within a given Value Group, Hue is represented by L (slightly green), M (neutral), or R (slightly red).

## The Observer

In addition to the light source and the object, the third element in the perception of color is the Observer. For color to be measured and reported on a device-independent basis, the perceptual characteristics of the observer must be defined. The  $L^*a^*b^*$  and  $L^*C^*h^*$  systems are both based upon a model for human color perception (an “Observer”) that was published in 1931 by the CIE, and updated in 1964. The  $L^*a^*b^*$  color space (CIE Lab), developed in 1976, improves upon the XYZ color space and chromaticity diagram developed in 1931 in that the  $L^*a^*b^*$  color space is more perceptually uniform.

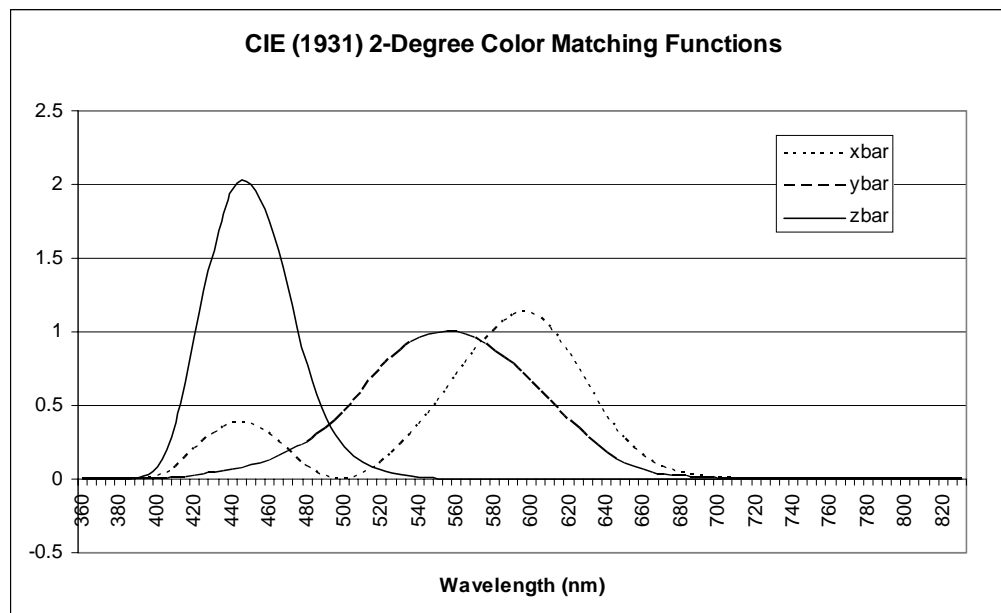


Fig. 9. Color matching functions for the 2-Degree Observer

The standard observer is based upon the experimentally determined sensitivities of the human eye over the range of visible light from 380 nm to 720 nm. Depending on the relative size of the area being viewed, the perception of color can change slightly. This is because the color sensing cells in the eye (cones) are concentrated in a central area of the retina called the fovea centralis. Cells that are very sensitive to lightness, but not color (rods) are distributed throughout the retina, outside of the fovea centralis. In 1931 the CIE defined color matching functions for a 2°

field of view (the “2° Observer”) and in 1964 they published color matching functions for a 10° field of view (the “10° Observer”). For determining the color of an object the size of tooth, the 2° Observer is the appropriate choice for color matching functions.

The 1931 and 1964 color matching functions are shown in Fig. 9 and Fig. 10.

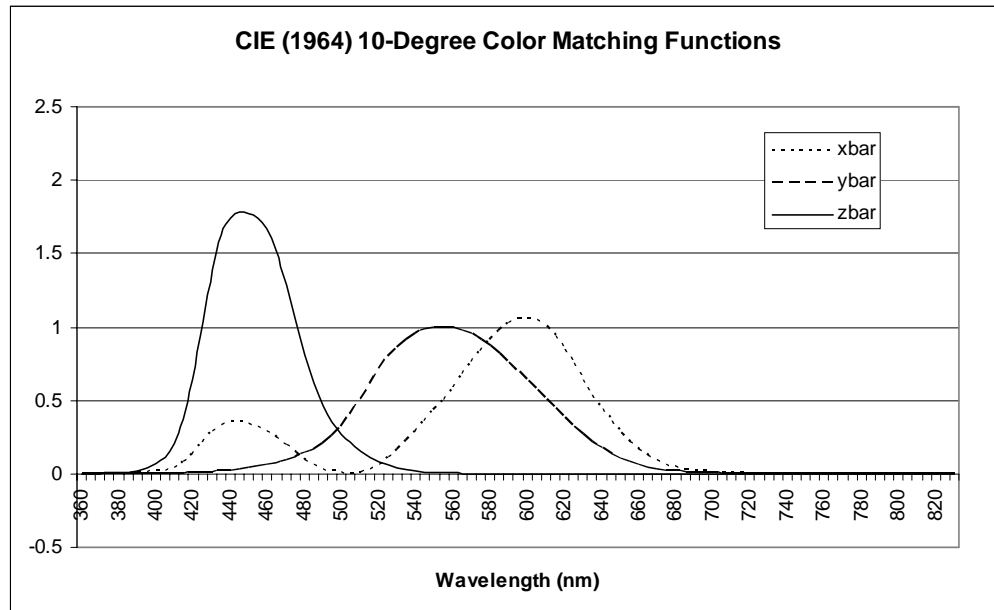


Fig. 10. Color matching functions for the 10-Degree Observer

### Color Measurement Instruments

For measuring the color of teeth, two basic types of instruments are used. A Colorimeter uses three filters corresponding to the peaks in the three color matching functions. A colorimeter directly measures the XYZ tristimulus values (corresponding to the three color-matching functions, xbar, ybar and zbar) for the sample under the illuminant, from which the  $L^*a^*b^*$  and  $L^*C^*h^*$  values for that illuminant may be calculated. Since a colorimeter does not capture full spectral data, the resulting information cannot be accurately transformed to show the effects on  $L^*a^*b^*$  and  $L^*C^*h^*$  of different illuminants.

In contrast, a visible-range spectrophotometer (such as Easyshade) captures the full spectrum in the (typical) range 400nm to 700nm. From this spectrum, using the color matching functions of the standard observer and the spectrum of the illuminant, the XYZ tristimulus functions and subsequently the  $L^*a^*b^*$  and  $L^*C^*h^*$  values are calculated. By changing the spectrum of the illuminant,  $L^*a^*b^*$  and  $L^*C^*h^*$  values may be calculated to show the impact on perceived color of changing the light source. This is an important distinction between a colorimeter and a spectrophotometer.

## Color Differences

The L\*a\*b\* color space provides a three-dimensional representation for the perception of color. If two points in space, representing two measurements, are coincident then the color difference between the two is zero. As the distance in color space between two points ( $L^*_1, a^*_1, b^*_1$  and  $L^*_2, a^*_2, b^*_2$ ) increases it is reasonable to assume that the perceived color difference between the stimuli that the two points represented increases accordingly. One common measure of color difference is therefore the Euclidean distance between the two points in the three-dimensional space, referred to as “ $\Delta E$ ”. The term  $\Delta E$  is derived from the German word for sensation *Empfindung*.  $\Delta E$  therefore literally means difference in sensation. A superscript asterisk is sometimes used to denote a CIE Lab difference thus,  $\Delta E^*$ .

Unfortunately several evaluations of CIE Lab have shown that  $\Delta E$  is not a particularly good measure of the magnitude of perceptual color difference.  $\Delta E_{CMC}$ ,  $\Delta E_{94}$ , and  $\Delta E_{2000}$  all improve upon the original  $\Delta E$  by adding corrections for the color-difference non-uniformity of L\*a\*b\* color space.

Easyshade reports a  $\Delta L$ ,  $\Delta a$ ,  $\Delta b$ ,  $\Delta C$ ,  $\Delta h$ , and for general purposes of comparison,  $\Delta E$  and  $\Delta E_{LC}$ , which is  $\Delta E$  calculated excluding h.

## References

Richard S. Hunter and Richard W. Harold, The Measurement of Appearance, John Wiley & Sons, 1987.

Fred W. Billmeyer, Jr. and Max Saltzman, Principles of Color Technology, John Wiley & Sons, 1981.

Anni Berger-Schunn, Practical Color Measurement, John Wiley & Sons, 1994

## INTERPOLATED 3D-MASTER SHADES

The 29 VITA 3D-Master shades are shown in **bold** in the following tables. Also shown are 52 interpolated shades that are achieved by equally mixing the appropriate 3D-Master porcelains. Easyshade measures teeth and restorations to the nearest 3D-Master interpolated shade.

### "M" Shades

<b>0M1</b>	0.5M1	<b>1M1</b>	1.5M1	<b>2M1</b>	2.5M1	<b>3M1</b>	3.5M1	<b>4M1</b>	4.5M1	<b>5M1</b>
0M1.5	0.5M1.5	1M1.5	1.5M1.5	2M1.5	2.5M1.5	3M1.5	3.5M1.5	4M1.5	4.5M1.5	5M1.5
<b>0M2</b>	0.5M2	<b>1M2</b>	1.5M2	<b>2M2</b>	2.5M2	<b>3M2</b>	3.5M2	<b>4M2</b>	4.5M2	<b>5M2</b>
0M2.5	0.5M2.5		1.5M2.5	2M2.5	2.5M2.5	3M2.5	3.5M2.5	4M2.5	4.5M2.5	5M2.5
<b>0M3</b>				<b>2M3</b>	2.5M3	<b>3M3</b>	3.5M3	<b>4M3</b>	4.5M3	<b>5M3</b>

### "L" Shades

<b>2L1.5</b>	2.5L1.5	<b>3L1.5</b>	3.5L1.5	<b>4L1.5</b>
2L2.0	2.5L2.0	3L2.0	3.5L2.0	4L2.0
2L2.5	2.5L2.5	<b>3L2.5</b>	3.5L2.5	<b>4L2.5</b>

### "R" Shades

<b>2R1.5</b>	2.5R1.5	<b>3R1.5</b>	3.5R1.5	<b>4R1.5</b>
2R2.0	2.5R2.0	3R2.0	3.5R2.0	4R2.0
2R2.5	2.5R2.5	<b>3R2.5</b>	3.5R2.5	<b>4R2.5</b>

**TECHNICAL SPECIFICATIONS**

Height	7" (17.8 cm)
Width	11" (29.9 cm)
Depth	9" (22.9 cm)
Weight	3 lbs (1.4 Kg)
Illuminant	D65
Observer	2°
Spectral range	400nm – 700nm
Spectral resolution	25 nm
Measurement mode	Specular Excluded
Measurement area	Illumination: 5mm diameter Spectrometer 2: 3mm diameter ave Spectrometer 1: 1mm diameter
Lamp estimated life	Average operational life 100 hours
Power	110-240 VAC, 50/60 Hz, 1.0 A
Classification	UL 2601-1 Class I Equipment Type B Applied Part IPX0 Equipment not suitable for use in presence of flammable anesthetic mixture
Temperature Range	0°C to 40°C

**PATENTS AND TRADEMARKS**

VITA Easyshade™ is powered by the Pocket Spectrometer™ Engine and Shaderite™ System.

VITA Easyshade is covered by one or more of the following US Patents: 6,249,348; 6,249,340; 6,249,339; 6,246,479; 6,246,471; 6,239,868; 6,233,047; 6,222,620; 6,188,471; 6,127,673; 6,118,521; 6,040,902; 6,038,016; 5,966,205; 5,926,262; 5,883,708; 5,880,826; 5,871,351; 5,851,113; 5,759,030; 5,745,229; 6,254,385; 6,264,470; 6,271,913, and other U.S. and Foreign Patents Pending.

VITA Easyshade is manufactured for Vident by JJI Technologies LLC.

Pocket Spectrometer, Shaderite and ChromIdent are Trademarks of JJI Technologies LLC.

Other trademarks shown herein are the property of their respective owners.

**GLOSSARY**

<b>3D-Master Shades</b>	Refers to the 26 natural tooth shades and optional 3 bleached shades found in the VITA 3D-Master tooth guide system.
<b>Chroma</b>	The saturation (strength or vividness) of a color. It is the difference between the color and a gray having the same brightness, measured as the distance from the neutral axis. It is sometimes referred to as the purity of the color.
<b>Classical Shades</b>	Refers to the 16 original VITA shades found on the Classical shade guide, which was originally called the Lumin Vacuum shade guide.
<b>Colorimeter</b>	A color measurement device that measures colors using the tristimulus method, similar to the human eye, and expresses colors in numerical form using internationally recognized color systems (XYZ tristimulus, L*a*b color space, L*C*h color space and Yxy color space)
<b>Hue</b>	What we commonly call color (red, yellow, green, blue or some other color). It corresponds to the physical wavelength of light. In the L*C*h* system it is represented as an angle ranging from 0° to 360°. Angles that range from 0° to 90° are reds, oranges and yellows; 90° to 180° are yellows, yellow-greens and greens; 180° to 270° are greens, cyans (blue-greens) and blues; 270° to 360° are blues, purples, and magentas, returning again to red at 360° (the same as 0°).
<b>Interpolated</b>	The mixture of two or more shades of porcelain to achieve an intermediate shade. For example, 3M2 can be mixed with 3M3 to achieve the shade 3M2.5.
<b>Metamerism</b>	The phenomenon of having two samples match under one light condition but not under other light sources. Samples of this type will have the same color coordinates but different spectral reflectance curves for the matching light sources.
<b>Spectrophotometer</b>	An instrument for color measurement that measures the spectral reflectance of a color and converts it into a tristimulus value, or internationally accepted numerical form. It can also display spectral data, providing a highly detailed definition of the color measured.
<b>Value</b>	The luminance of the color. It is the lightness or darkness of a color relative to a series of grays ranging from white (L = 100) to black (L = 0).