The shade-matching tools that most dental practitioners use to identify and communicate color and shade information with others are called color reference standards or, simply, shade guides. Presently, dentists use shade guides for describing tooth shades, prepared teeth (dentin/stump guides), gingival tissues, and even human skin.

**BRIEF HISTORICAL BACKGROUND**

**Hue-Based and Value-Based Shade Guides**

Tooth shade guides were first developed in the late 1920s in response to the acceptance of Munsell’s color theory and the development of dental ceramics intended for artificial porcelain teeth and customized dental restorations. The individual shade tabs of those early guides were empirically developed, based on the availability and popularity of commercially available porcelain shades. The best-known and most popular guide worldwide is the VITA Classical Shade Guide (Figure 1). Introduced in 1927, this guide is still manufactured by VITA Zahnfabrik in Bad Säckingen, Germany. Surprisingly, the manufacturer never used a logical arrangement, systematic, or scientific approach based on range of known human tooth shades to develop this guide. In fact, the 16 shades of the VITA Classic Shade Guide have been reported to cover only 6% of the color range of human teeth. Anyone who has ever struggled to find a match to one of those 16 tabs can attest to this limitation. The Vitapan 3D Master Guide (VITA), which was introduced in 1998, has 26 shades and has been systematically arranged and designed to address some shortcomings of earlier guides (Figure 2). It has a superior range of coverage but still only approximates 25% of tooth color range. According to Paravina et al, the actual coverage for each guide is somewhat higher, and when the range of the 2 shade guides are combined, can be as high as 52%. Other popular guides fall somewhat in between the range of these 2 guides.

In addition to having a limited shade range, the vast majority of tooth shade guides are hue-based and not value-based. Value represents the optical brightness (or luminosity) of the color, according to Munsell. Detecting the value of objects is the function of the rod cells, one of the 2 main photoreceptors of the eye. The cone cells, which are sensitive to color, are the other. There are approximately 120 million rod cells and 6 to 7 million cones in the human eye. Comparing the relative number of rods to cones means that humans are incredibly more sensitive to the value of an object than its hue. Even small differences between the value of a restoration and the tooth being matched can be readily detected and may appear to be a mismatch in shade. This why achieving a good value match is much more important than a perfect hue match.

Despite its popularity, the VITA Classic Shade Guide is hue-based. Its tabs are subdivided into the following 4 major hue groups: A = reddish brown, B = reddish yellow, C = gray, and D = reddish gray. Each of those primary hue groups is further broken down into 3 to 5 variations of the same hue with increasing chroma (ie, for the A hue group, the variations are A1, A2, A3, A3.5, and A4, and for the B group, the variations are B1, B2, B3, and B4). Of course, each of the individual tabs does possess a specific value and may be arranged from lightest to darkest. The Chromascop Shade Guide (Ivoclar Vivadent) is also hue-based. It has 20 possible shades in the following 5 hue groups: Group 100 = white, Group 200 = yellow, Group 300 = light,

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**Figure 1.** VITA Classical Shade Guide (VITA) has 16 shade tabs arranged by 4 standard hue groups.

**Figure 2.** VITA Tooth Guide 3D Master (VITA) has 26 regular shade tabs and is currently the only “value-based” shade guide.
brown, Group 400 = gray, and Group 500 = dark brown (Figure 3). Each hue group has 4 shade variations of increasing chroma (i.e., Group 100 = 110, 120, 130, and 140).

Another popular guide, the Trubyte Bioform Color Ordered Shade Guide (DENTSPLY Trubyte) has 24 shades that are based more directly on Munsell’s work2 rather than on commercial factors. Its shade tabs are broken down into the following 4 hues: reddish brown, yellow, gray, and reddish gray. The guide may be purchased in 2 different materials—plastic and porcelain—and 2 different versions—Style A, where all 24 tabs are ordered by value from lightest to darkest, and Style B, where the tabs are ordered first by hue and then lightest to darkest within the hue group (Figure 4). It is worth noting that the only tooth shade guide which uses a value-based design is the Vitapan 3D Master and its variations (Vitapan 3D Master Bleach Guide, Linear Guide). Including the optional bleach shades, it has 26 tabs that cover the following 6 value-based groups: zero, 1, 2, 3, 4, and 5 (with zero being the lightest or highest value and 5 being the darkest or lowest value). Within each value group, there are the following 3 hue variations: M = standard hue, L = yellow, and R = red. Each of the hue groups is further differentiated by 2 or 3 chroma variations (i.e., 1M1, 1M2, and 1M3). In spite of the limited shade range and less than ideal design for all manual shade guides, they are so universally entrenched into clinical and dental laboratory practices and dental material manufacturing that we are forced to use them to their best capacity and potential.

**MANUAL SHADE GUIDES SUGGESTIONS TO OPTIMIZE SHADE MATCHING**

1. **Try to utilize a shade guide that is color keyed for the restorative material or media that you are using.** In most cases, manufacturers offer their denture teeth, porcelain powders, ceramics blocks, and acrylic and composite resins in the shades corresponding to one of the common shade guides (VITA Classic, VITA 3D Master, Chromascop, and Trubyte Bioform).

2. **Try to use a shade guide made of the actual restorative material.** When using a shade guide that is made of a material other than the actual material, it will likely have different optical properties. Fluorescence, opalescence, and translucence all vary greatly from one material type to another, and even one brand to another; and so does surface finish and texture. Using a porcelain or plastic shade tab to select a shade for a resin composite may not always produce a good match. If a manufacturer does not make such a guide available, the dentist or lab technician should consider making up a custom guide from the actual materials.

3. **Use multiple shade guides to extend the shade range coverage.** Assuming that all current guides offer only partial coverage of the total tooth color space, using one guide exclusively is extremely limiting. Additional guides extend the likelihood of finding a better match.

4. **Always take the shade at the very beginning of the dental appointment before the teeth have a chance to dehydrate.** It is well known that dehydration temporarily raises the value of the teeth. This effect is significant and may not fully resolve for up to 24 hours.5 If you forgot to take the shade at the beginning of the appointment and the aesthetic match of the restoration is critical, it is better to have the patient return the following day for treatment or shade evaluation.

5. **Your first step in any shade evaluation is always to find the best value match.** Buy your shade guides prearranged by value or arrange them by value from lightest to darkest. Even if they are hue-based, most manufacturers can offer you a recommendation for value ordering. To save time and to help with finding the best hue and chroma match, it is a good idea to keep a second shade guide which has been prearranged by hue groups.

**Recommended Procedure for Using a Shade Guide**

**Step 1.** Review and optimize your ambient lighting conditions6 or use a dedicated task light to help facilitate the most ideal lighting to select the shade. An example of a particularly useful hand held task light is the RiteLite 2 (AdDent). It uses 2 types of LEDs to provide a choice of the following 3 different controlled light temperatures: 5,500 K (the daylight standard for dentistry), 3,900 K (ambient mix), and 3,200 K (incandescent). This offers the operator the ability to judge the shade match under differing lighting situations and help avoid problems related to metamerism (Figure 5).

**Step 2.** Get 2 identical shade guides. Prearrange the tabs of one guide in value order (lightest to darkest) with the incisal edges toward the holder. Leave the other guide in its native order arranged in hue groups with the cervical portion of the tabs facing up.
Lightly wet the patient's teeth and the tabs of the guide with water or a clear fluid to eliminate any surface textural differences. Using the guide which has the value ordered tabs, squint the eyes slightly while quickly moving the various tabs across the tooth being matched. As the tabs move, try to focus on the junction between incisal and middle one third of the teeth and tabs and only on their relative brightness (value). In most cases, you should be able to eliminate most of the tabs while finding 2 or 3 tabs that seem to match well to the brightness range of tooth (Figure 6). If you have a digital camera available, take 2 images of the selected tabs against the tooth, one in monochrome or grayscale and one in color (Figure 7). The monochrome photo demonstrates only value information, so it can help confirm a value match while the color photo can be used to evaluate hue and chroma.

**Step 3.** Now take the other shade guide, which has the tabs set up according to hue with the cervical portions facing up. If the tabs you preselected for value fall within only one hue group, you may skip to step 4 to establish the best chroma. If more than one hue group is represented in the value selections, you'll need to determine which hue group provides the best color match. For hue matching, focus mainly on the junction of middle and cervical one third of the tooth and the shade tabs. If using a VITA Classic Shade Guide, you may want to grind off the necks of the tabs because these tend to be higher in chroma and could distract from the true hue (Figure 8). As before, try to eliminate obvious hue mismatches first leaving the one hue group that seems the best overall match. To avoid color fatigue, each color assessment should take no more than 5 seconds and may be improved by occa-
sionally looking at a neutral gray or blue colored card or patient napkin.

**Step 4.** The final step is to establish the best chroma. Once you have selected the appropriate hue group, remove those tabs from the shade guide, fan them out, and pass them across the tooth being matched. With a little luck, you'll find one tab that is the best chroma match to the tooth. As a final check, take color and grayscale photographs with the tab selected near the tooth to help verify the value, hue, and chroma of your selection.

**VALUE-BASED SHADE GUIDES**

**Recommended Procedure**

To select a shade with a value-based shade guide (VITA 3D Master), the following clinical protocol is recommended.

**Step 1.** Review clinical and ambient lighting conditions or use a dedicated task light to facilitate the most ideal lighting.

**Step 2.** Evaluate the best value group. While this can be done with all tabs in the 3D Master guide, it is somewhat easier if you remove all of the R and L hue groups from the guide leaving only the M hue groups (Figure 9). Alternatively, it may be more convenient to purchase a Valueguide 3D Master (VITA), consisting of only the 6 value tabs in the M hue (Figure 10). Starting from darkest to lightest, move the tabs across the tooth being matched while squinting the eyes slightly. It should be easy to eliminate some groups/tabs that are obviously too light or dark. Remove those tabs from the guide. Focusing on the remaining tabs, try to select the 3 value groups where one is clearly lighter than the tooth being matched and one is clearly darker than the tooth. Select the value group between those 2. If you are not sure which is the best for value, take a monochrome or grayscale photograph of the shade tab and tooth. This will be very helpful to confirm the best value match.

**Step 3.** The next step is to select the most appropriate chroma. Take the M hue group with the value determined earlier out of the holder and fan the 3 tabs out. Pass each tab one at a time over the tooth adjacent to the tooth being matched viewing them side by side. Try to select the best chroma match of the 3 tabs. In most cases, if you have gotten a very close match with the value and chroma, it may not be necessary to look at variations in hue.

**Step 4.** The final step would be to “confirm or refine” the hue. The M hue group is found exactly in the middle of the yellow to red color range of
teeth and is therefore orange. Studies have shown that this hue is very close to more than 50% of the population. However, if you feel the actual hue for the tooth being matched is skewed to the yellow or red range, you’ll want to evaluate the L (yellow) and R (red) hues. These hues only contain 2 possible chroma variations, one light and one dark. Even if a color shift is not suspected, it is a good idea to confirm that an L or R hue is not better than the M hue. As before, always confirm your final hue, value, and chroma selection by taking a color and grayscale photograph using electronic flash as the sole illumination.

**TECHNOLOGY-ASSISTED SHADE MATCHING**

Included in this high-tech arena are electronic digital shade analyzers, computer software assisted shade-matching programs, and digital cameras, which have been discussed previously. Several clinical studies have confirmed that these devices may be more accurate and more consistent than subjective shade assessment using manual shade guides.\(^8\) Ideally, they can help provide an objective tool that can complement or even supersede a subjective approach using standard manual shade guides.

There are a few key technological variations found in the digital shade analyzers of which the dentist should be aware. First, these fall into 3 main categories: RGB devices, spectrophotometers, and colorimeters. RGB devices are the least complicated and work by capturing a digital image, which is then used for additive color (red, green, and blue) and chromatic mapping. The final color maps are interpreted by complimentary software to elicit shade information. The weak link for these devices is the quality of the digital image captured. With higher quality optics and digital sensors, they should provide clinically useful shade information. However, these devices may not be able to efficiently evaluate other key color variables that were discussed earlier. So it is highly important that the color analysis obtained from an RGB device be confirmed subjectively. To the author’s knowledge, there are no longer any dental RGB shade analyzers that are commercially available. The ShadeScan (Cynovad) is an example of a previously available RGB shade-matching device.

**Colorimeters** make use of filters to measure the intensity of red, green, and blue light reflected from the object/tooth. This is sometimes referred to as tristimulus values. As such, they are engineered to work in a similar fashion as the human eye. The color filters reduce the total spectral information down to just a few key wavelengths. This lowers data loads and manufacturing costs while increasing operational speeds. Because color filters are subject to aging and fading, the long-term accuracy of colorimeters may be adversely affected. Overall, they are thought to be more accurate than RGB devices but less accurate than spectrophotometers. The ShadeStar (DeguDent GmbH) is an example of a small portable colorimeter that is still commercially available (Figure 11). The ShadeVision (X-Rite) and ShadeEye NCC (Shofu Dental) are examples of dental colorimeters that are no longer available commercially.

**Spectrophotometers** are the final group of digital shade analyzers and are considered to be the most accurate for color matching in dentistry. They measure and record the amount of visible radiant energy reflected or transmitted by an object/tooth one wavelength at a time for each value, chroma, and hue present over the entire visible spectrum, generating considerable amounts of data. Until recently, the complexity and expense of producing spectrophotometers has hindered their introduction into dentistry. However, as in other areas of technology, miniaturization and manufacturing costs have fallen, making it possible to produce affordable and practical units for dental research and clinical use. Examples of dental spectrophotometers that are currently available include the following: The Easyshade Compact (VITA) (Figure 12), SpectroShade Micro (MHT Optic Research), and the Shade Pilot (DeguDent GmbH).

One important feature for all digital shade devices is whether they are designed for spot measurements (SM) or for complete tooth measurements (CTM). The average optical diameter of the SM shade device is 3 to 5 mm, thus providing only a limited spot reading of color and shade. Considering that most teeth are not monochromatic, multiple readings should be taken with SM devices to ensure that the dentist and technician have an accurate mapping of the tooth’s shading. In comparison, CTM devices read the entire tooth surface and provide a complete map of colors and shades. Most CTM devices allow the color maps to be printed or transmitted electronically.

An interesting and innovative alternative to purchasing a digital shade analyzer is to use a shade-matching software program that works with the dentist’s own digital camera and clinical photographs. Shadewave Software (Shadewave) is a cloud-based software program that maps a tooth’s shades to popular dental shade guides from a color digital image obtained.
with any camera or optical recording device (figure 1). The dentist simply uploads the image to the company’s website and then performs the shade analysis using the online software interface. The advantage of a cloud-based approach is that the software is continually updated and can be utilized with any Internet accessible device such as a computer, tablet, or smartphone. Since digital cameras and images can differ greatly in quality and color accuracy from one to another, color standardization is required prior to performing the final shade analysis. This correction is accomplished by analyzing a handheld color reference which is simultaneously captured in the digital image with the tooth. After normalization of the uploaded photographic image, the software compares the shades and colors detected in the digital photo and maps them to a database of commercially popular shade guides. The shade map generated can be stored online for future reference, printed out for clinical use, or sent digitally to a dental laboratory. One limitation of this approach is that the dentist cannot tell which of the possible shade guides provides the closest match to the natural tooth. If a chosen guide does not correlate well, the shades mapped to it will only be approximations.

**CLOSING COMMENTS**
Achieving an excellent aesthetic match between a dental restoration and a natural tooth is no longer considered to be elective. Our dental patients expect and demand natural-looking, aesthetically pleasing restorations. If you are using manual shade guides, keep multiple guides on hand and use all of them to cover more tooth color space and improve the chances of finding a better shade match. Make sure that the area where shade selections are being made has appropriate ambient lighting conditions. Consider using a handheld multispectral task light to help optimize the light to ideal standards and avoid errors due to metamerism (Rite-Lite 2). Sending the shade tab to the laboratory can help communicate the shade more accurately. Use a “value ordered” arrangement for the tabs in your manual shade guides and start every subjective shade evaluation with value assessment. Keep all color evaluations to 5 seconds or less and utilize a neutral gray or blue card handy to refresh the cones of the retina. Have a high-quality digital camera in the office with an electronic flash. Adjust the camera to use the flash as the primary light source and set the white balance to daylight or electronic flash. Capturing grayscale (monochrome) images of the shade tab and tooth helps identify a good value selection while a color image can be used to narrow down hue and chroma choices. If budget allows, using a technology-based shade-taking device can offer an objective evaluation to compliment your subjective assessment. But don’t rely solely on technology, because the human eye is still the ultimate judge of an ideal shade match.

**References**

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