Shade analysis and communication: 2012

The essential elements of evaluating and communicating tooth colour

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Fig. 1


Fig. 2


Fig. 3

Fig. 1_Using two OttLites held at tooth level 24 inches from the patient to control lighting colour temperature.
Fig. 2_Using the Trueshade light and magnifier to control light.
Fig. 3_Image of two of the same shade guides with different surface texture. Notice the one with a different texture is perceived as a different colour.

_With ever increasing emphasis on aesthetics in dentistry, and patient demands to fabricate ceramic restorations that mimic natural teeth that are indistinguishable from adjacent natural teeth, the ability to evaluate tooth shade information correctly and communicate it to the ceramist effectively is now more critical than ever. Correctly evaluating tooth shade is as much an art as a science.

Many articles[1–7] and even whole books[7] have been devoted to this topic, yet in hundreds of informal polls of technicians, problems with shade analysis is the second reason given for remakes, with impression/preparation problems being the first.

Many factors contribute to this problem: lighting variables that contribute to perception errors; multiple shade systems available with a lack of standardisation in colour systems and corresponding porcelain systems; individual human variables in colour perception; lack of understanding of colour science, especially as it relates to tooth shade; and the ability to interpolate shade information into a porcelain layering technique that obtains the desired shade. A full article could be devoted to each of those topics. There are many references in dental and non-dental literature on the topics of colour, colour as it relates to teeth and human perception of colour. The objective of this paper is not to offer an exhaustive review of these topics but to distil the essential aspects of evaluating and communicating tooth colour. Also, to offer the reader an efficient and effective method for evaluating and communicating tooth shade.

This article will focus on:

_understanding how lighting (illumination) affects colour perception, and more importantly how to control it;
_understanding the parameters of colour that are most critical in evaluating tooth shade and how to access them relative to the tooth;
_the ideal set-up and use of current shade guides;
_the use of digital photography for communication; and
_the integration of computerised shade-analysis devices into the technique of taking and communicating tooth colour.

_Understanding lighting and the effect on colour perception

The perception of colour is affected by three primary factors:

_the character of the light;
_the observer; and
_the object being viewed.

A change in the condition of any of the three will cause a change in perception of colour. Thus, differing viewing conditions, that is changes in light or changes in position, can alter perception.[8] It is impossible to try and match tooth colour under every lighting and positional possibility. One then should try to match under the conditions in which the restoration is most likely to be viewed. Relative to tooth position most people are viewed standing up at conversational distance, so this is the best position in which to place the patient to evaluate shade. Too often, shade is taken with the patient lying back, which increases the chance of a misperception. The reason this happens is the shade guides do not have the same optical properties as the natural tooth. At different viewing angles, they look different, that is a perceived match from one viewing angle may not be a perceived match at another viewing angle.

Shade-analysis rule 1: take the shade with the patient sitting up, eye to eye at conversational distance.

There are many different types of light we are all exposed to, as will be your patients and the restorations you make. When the shade guides are manufactured, they are compared to a standard in a controlled lighting situation. It is very controversial as to what colour temperature light to use to view shade, that is 5,000, 5,500, or 6,500 K.[9–12] Most shade guides are fabricated to match a standard in a 5,500 K light source. As already stated, shade guides do not have the same optical properties as natural teeth. This means they do not reflect light in the same manner in all lighting conditions as the corresponding shade tooth would. Thus, visual shade matching should only be done in a lighting environment that is close to 5,500 K. From my experience, if the shade guide is matched to the teeth in a 5,500 K light, then it will match well in most lights, but if it is matched in a strongly biased light (for example blue) the restoration will only match in that light.

There are many different companies that sell florescent lights. Full-spectrum, colour corrected with a colour temperature of 5,500 K are the lights best suited for visual shade taking. Ideally, it is best to outfit the operatory with this type of lighting, but an inexpensive way to control light is to use two OttLites (Fig. 1) held at 61 cm from the patient at tooth level. Also, there are several innovative self-contained lighting devices available in dentistry. Optilume Trueshade (Optident Dental Products) works well for this and has a magnified viewer (Fig. 2).

Fig. 4

Fig. 5

Fig. 4_Classical Shade Guide in colour with the correct value relationship. Note how tabs with dissimilar chromas look very different in value.
Fig. 5_Classical guide in black and white with the correct value relationship.

There are many other things that could be covered about controlling the viewing conditions. The quantity of light and the hydration of the tooth are very important. Make sure when you are shade matching that there are no overt shadows on the teeth or shade guide and that the light is not so strong as to create specular highlights (reflective white spots). Also, the teeth need to stay hydrated. Saliva dries quickly, especially with cheek retractors in the mouth. We use a medium viscosity clear glaze liquid (Smile Line Glaze liquid, Smile Line USA) to wet the teeth and the shade guide. It is important to wet both, as differences in surface texture between the shade guide and the tooth can create a misperception. The same liquid on both surfaces can neutralise this (Fig. 3).

Shade-analysis rule 2: use full-spectrum, colour corrected lighting, keeping the teeth adequately hydrated.

_Understanding colour parameters critical to dental shade analysis

A basic understanding of colour terminology is necessary for one to be able to evaluate differences from the shade guide and to communicate colour to the ceramist. Colour has been defined in many


Fig. 6


Fig. 7

Fig. 6_Using the Classical guide arranged by value and working by a process of elimination to obtain to four tabs that cover the value range of the tooth being evaluated.
Fig. 7_Using the Classical guide to select the chroma level.

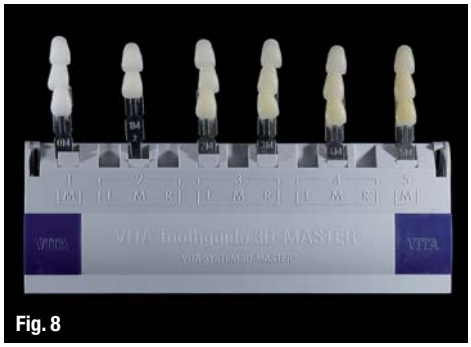

Fig. 8


Fig. 9

Fig. 8_The 3D-Master arranged with just the M shades from 0 to 5 value.
Fig. 9_Choosing the value for a patient case.

different ways. The most widely used colour ordering or descriptive system used in dentistry was developed by Mussell.[13] He defined colour according to three dimensions:

_hue, the specific wavelength of light energy that would be labelled red, green or blue and everything in between;
_chroma, the intensity, concentration or amount of a given hue (for example lighter yellow or deeper yellow); and
_value, or the lightness or darkness of a colour.

In real terms, if more light reflects off an object and hits our eyes, it will be perceived as brighter or higher in value. Conversely, if less light reflects off an object and hits our eyes, it will be perceived as darker or lower in value.

There is a fourth dimension of colour, translucency, that is important when evaluating tooth colour because teeth are translucent and translucency is directly related to the perception of value. When evaluating tooth colour, the most important colour dimension to match is the value and a close second the translucent zones. Next in importance are the chroma zones present in the teeth being evaluated. The least important dimension of colour relative to matching natural teeth is the hue. In natural teeth, the hue range is very narrow and in my experience matching the specific hue is unimportant as long as value/translucency and chroma are closely matched. In the discussion on shade guides and their use, I will give detailed descriptions on how to evaluate value, translucency and chroma in the shade-analysis process.

_Ideal set-up and use of current shade guides

The VITA Classical Shade Guide (Vident) has been the standard shade guide used in dentistry for several decades. More recently, the VITA 3D-Master Shade Guide and a recent significant upgrade, the VITA Linearguide, have been available for shade analysis.[14] The 3D-Master guide and Linearguide are based on actual spectrophotometer analysis of natural teeth[15] and are my preferred guide, but more than 50 % of dentists still use the Classical guide, so I will go through its optimised set-up and use and then detail the use of the newer guides.

VITA Classical Shade Guide

Every dentist and ceramist is familiar with the VITA Classical guide. This shade guide was initially developed several decades ago with the last modification or update in the 1960s. It was adequate for that time but analysis of the shade guide shows several problems that lead to the many shade mismatches that still exist. First, the shade guide poorly covers the measured range of natural teeth.[16] Nothing can be done about this except either changing the guide or using a different one. Second is the value arrangement. The value arrangement as reported by the company is different from what has been measured.[16] Figures 4 and 5 show the value arrangement as we measured it in both grey scale and colour images. A1 as we measured is higher in value than B1 and D2 is lower in value than A3. You will probably notice that the colour image of the value arrangement will be hard to believe, that is the tabs right next to each other that have significantly different chromas will appear to have significantly different values, when in fact they are very similar (view the black and white image). This is a problem with human perception that has not been discussed in dentistry before: if two objects have similar values but different chromas the observer will perceive the higher in chroma tab as lower in value when this is not the case. This is exactly what is happening when A1 is compared with B1 (Fig. 5). As previously stated, A1 is higher in chroma than B1 and thus perceived as lower in value when in fact it is higher in value. The same is true for other areas on the Classical guide. This

Fig. 10_The Linearguide used to choose value.
Fig. 11_Using the Linearguide to determine value.

Fig. 10


Fig. 11

I believe is the fundamental reason for the level of shade mismatches with this guide.

The first step in minimising this problem and using this shade guide effectively is to arrange the guide by value as shown. As stated earlier, choosing the correct value is most important, as is recording the value zones within the tooth being evaluated. After arranging the guide by value, lightly wet the teeth and shade guide with a clear glaze liquid. The best way to choose a shade is not to see first what appears to be a match, but to look first for obvious mismatches and eliminate them from the shade guide. The goal is to eliminate enough tabs so that you have remaining a range of tabs in which clearly one tab is slightly higher in value and one tab is slightly lower in value. Experience has shown that no fewer than four tabs will accomplish this value range determination (Fig. 6). Several images will be taken and the discussion of how to do it and the importance of calibrated images will come in the next section. Next, to narrow and simplify the chroma and hue choices, I use a second VITA Classical guide set up conventionally, that is A series, B series, C series and D series. I have found at this point that I can work with just the A and B series. I evaluate the A shades that are in the red-yellow (orange) range and then the B shades next to the teeth. I determine whether the teeth appear to have an orangish or yellowish hue. If they appear yellowish, I use the B shades; if they appear reddish or orangish, I use the A shades. I then hold up either the A or B shades next to the teeth to choose the appropriate level of chroma and take chroma images (Fig. 7).

VITA 3D-Master Shade Guide and the Linearguide

The 3D-Master was developed to be able to cover the range of measured natural teeth.[15] More recently, the Linearguide was developed. It is the same shades as the 3D-Master but in a much better tab holder that allows more accurate positioning and evaluation. Because of the similarities between the two, I will describe their use concurrently. Over ten years of personal experience has shown this to be the superior shade-analysis system.

The system is arranged first around choosing the value. There are six value levels that are equally spaced 5 ΔE apart within the colour space.[14] ΔE is a mathematical measurement of the distance between two points in colour space—the human eye can only differentiate points that are greater than 2 ΔE apart.

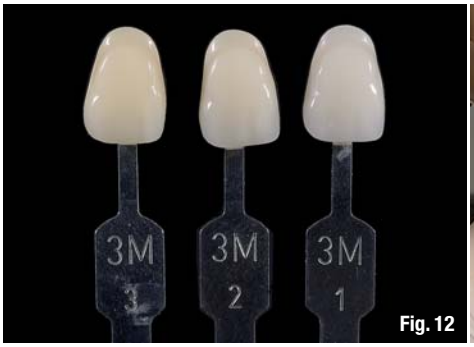

Fig. 12

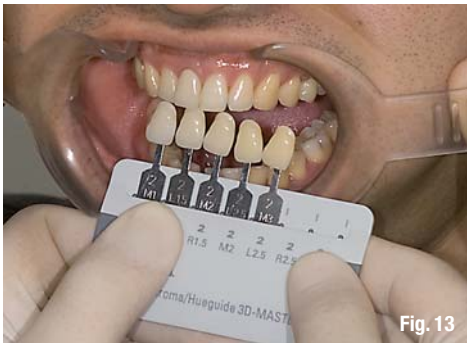
Fig. 13

Fig. 12_Image demonstrating chroma levels with the 3D-Master guide.
Fig. 13_Image demonstrating chroma levels with the Linearguide.

I have found that the L and R shades can be removed from the shade guide, leaving only the M shades (Fig. 8). This vastly simplifies the value-taking process. The procedure for choosing the value is best done by a process of elimination as described earlier. The two or three closest value groups are chosen so that the range has something that is perceived as slightly higher in value and something slightly lower in value than the natural teeth (Fig. 9). With the Linearguide, it is even easier. The six value groups are in their own holder and tabs can be evaluated more easily (Fig. 10). Again, work by a process of elimination, choosing two or three of the closest values (Fig. 11). Several value images are then taken.

The next step is to determine the level of chroma, of which there are three in most of the M shades. They are labelled 1, 2 and 3 (Fig. 12). Again, it is best accomplished by a process of elimination, recording the closest match or noting if it is between two chroma levels. The chroma levels are all exactly equidistant from each other within the colour space. With the Linearguide, all the different chromas of all three hues are in a special holder (Fig. 13). Using this system makes it easier to determine whether the chroma is at an in-between level. I pass the chroma guide of the closest value in the same plane as the natural teeth and then photograph the two closest chromas (Fig. 14).

The last step is to choose the specific hue. If the value and chroma are matched, experience has shown that an observer would not notice a shade

Fig. 14_Choosing the chroma for a patient case. The same image can be used to determine whether the teeth are redder or yellower than the M hue group shown.
Fig. 15_Image of hydrated tooth with shade tab.


Fig. 14


Fig. 15

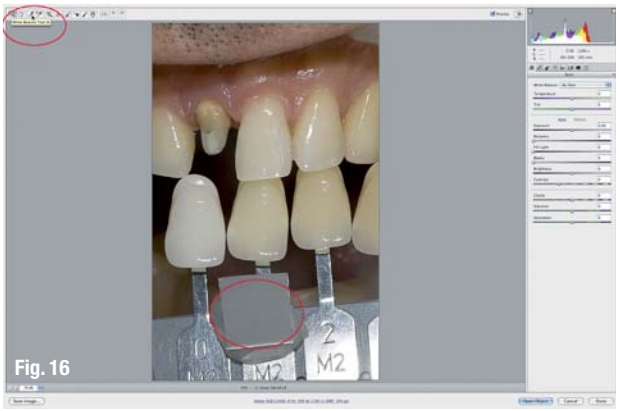

Fig. 16_Image of Camera Raw in Photoshop. The white balance eyedropper is activated by clicking and then the grey card is clicked on. This will neutralise a colour cast.

mismatch for mismatches in hue as long as the hue is within the natural tooth range, but is noteworthy to evaluate whether there is a reddish, orangish or yellowish hue to the teeth. There are three specific hues, a middle hue (orangish), which corresponds to the middle range of natural teeth, a yellower hue, and a redder hue equidistant in colour space from the middle hue. I would first evaluate the M hue of the closest value match relative to the tooth (Fig. 14), and decide whether it matches or if it is redder or yellower and then record the chosen hue. The final determination for the hue will be determined from the photography and computer analysis described in the next sections. Specific characteristics (such as crack lines or decalcifications) can be recorded with high quality photography.

_Digital photography for shade communication

The second part of my shade-taking technique is to record the value and chroma images previously described using digital photography. Information on camera and flash selection and specific camera settings is covered in detail elsewhere and the reader should review the references.[17–19]

The most important points are:

_use a digital SLR camera that allows interchangeable lenses,
_record shade images in RAW file format,
_control exposure and white balance ideally with manual exposure at specific flash/subject distances.

There are four images necessary for shade communication. One image is taken with the two or three value shade tabs closest to the teeth being matched using the 3D-Master or the Linearguide (Fig. 9). With the Classical guide, the four closest value tabs should be in the image (Fig. 6). Remember the goal is to have a range of values. Ideally, one tab should be slightly higher in value and one slightly lower in value. The second image is with the two closest chroma matches to the teeth. Again, one tab is slightly higher in chroma and one slightly lower. The third image is an image with what is perceived as the closest value, using a small piece of digital grey card that has been attached to the shade tab (you could do this with the first value image). I attach the digital grey card using white utility wax (Fig. 9). The reason for this is it allows the ability to correct colour bias that is inherent, as all flashes have subtly different colour temperatures and depending on the charge state of the flash capacitor can also affect the colour temperature of the flash. This technique will be discussed later. The fourth image (Fig. 15) is an image of the hydrated prepared tooth with a closely matched shade tab. This is for the ceramist to see the preparation colour to be able to modify the build-up or core colour as necessary to compensate for the preparation colour.

It is critical that all the images be taken with the shade guide and the teeth to be matched in the same vertical plane, as objects closer to the film plane will be perceived as brighter and objects farther away will be perceived as darker. The shade guide and the teeth should be wet with a glaze liquid as previously mentioned. This photographic information will be used by the ceramist to visualise contrasts between the shade guide and the natural teeth.

Photoshop to isolate the shade images

There are many uses of Photoshop (Adobe) for image management and manipulation. The scope of this article does not allow me to go into the use of Photoshop for these issues. Photoshop or Photoshop elements are used for two specific purposes in shade analysis and communication.

To correct a colour balance, open the shade images in Camera Raw and in the image window click on 'select all'. Then click on the white balance tool (Fig. 16) in the upper left of the Camera Raw window, then click on the grey card that is in the

Fig. 17_Image with backgrounds neutralised in Photoshop. It is much easier to evaluate colour.

Fig. 18_Image using the Easyshade compact.

image and the colours will be rebalanced if there is a colour bias. This will be applied to all the images selected.

Photoshop is an ideal tool to isolate (select out) the shade guides and the teeth to be matched from their surrounding backgrounds and then neutralise the backgrounds (Fig. 17). The reader is directed to the detailed technique to do this that has been previously published.[18]

_Integrating computerised shade-analysis devices

The third and equally important aspect of my shade-taking technique is using computerised shade-taking technology. Computers, the Internet and all digital technologies permeate every area of daily life, and dentistry is no different. Several digital shade-analysis technologies have been introduced to dentistry. Today, we would not be able to work without one of the digital shade-analysis systems but the systems have not evolved to the point that they can replace human perception. It would not be useful in an article of this type to go into the science and technology aspects of the various systems, rather it would be useful to tell you the practical application in state-of-the-art shade analysis and communication.

The computerised systems we tested in-house take a better base shade than the average human shade taker, but humans can detect the subtle variances of tooth colour better. So by experience, we believe the computers can be used to take base shades, then along with visual perception and high quality digital photography, the three used together will give accurate shade information to be used by the ceramist. I take my visual shade before taking a computerised shade so that it does not bias my perception. We have several systems at UCLA (University of California, Los Angeles), the VITA Easyshade (Vident), Shade-X and Shade-Rite (both X-Rite), and the Crystal Eye (Minolta), and there are several others on the market. All of them work to a certain extent. We believe from experience that a device should be simple and give an accurate base shade. Easyshade (Fig. 18) in our tests is the easiest to use for base shade and has been proven to provide as or more accurate base shade than the average visual shade taken by a group of dentists. If photographs are not taken (which is not recommended), the Crystal Eye also gives good shade information and a digital image, but the system is much more expensive. Figures 19 and 20 are before and after images of a single central incisor fabricated using this technique.


Fig. 19


Fig. 20

Fig. 19_Pre-op image of a crown of which the patient complained that the restoration was too low in value.
Fig. 20_Post-op image of a single central incisor using VM 13 (Vident).

_Summary

A three-part system for shade analysis and communication has been detailed in this paper. All three parts are interdependent and when used in concert have reduced remakes for shade mismatches in the UCLA's Center for Esthetic Dentistry clinic by more than 80 %._

Editorial note: A complete list of references is available from the publisher.

_about the author

cosmetic dentistry

Prof Edward A. McLaren maintains a private practice limited to prosthodontics and aesthetic dentistry. He is Director of the UCLA Center for Esthetic Dentistry, which offers a full-time didactic and clinical programme for graduate dentists. He is also the founder and Director of the UCLA School for Esthetic Dental Design. Prof McLaren is a member of the American College of Prosthodontists, Pacific Coast Society for Prosthodontists, International College of Prosthodontists, American Academy of Esthetic Dentistry, International Society of Dental Ceramics, International Association for Dental Research, American Association for Dental Research, American Dental Association and California Dental Association. He is actively involved in many areas of prosthodontic and materials research and has published several articles. He conducts ongoing clinical research on various restorative systems. He has presented numerous lectures, hands-on clinics and postgraduate courses on ceramics and aesthetics.

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