The Use of Dental Colorimeters in Shade Communication

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INTRODUCTION

Matching a prosthetic replacement to the natural dentition can be one of the more challenging things the restorative dentist does in practice. Several companies have recently applied colorimetric/spectrophotometric technologies to help the restorative dentist create lifelike restorations. In a matter of seconds, hue, chroma, value, and translucency measurements of the proximal teeth can be taken and used by a laboratory technician to construct a restoration. The information contained in the readout can be more helpful to the laboratory technician than is the average dentist-generated prescription. Obviously, any improvement in the communication between dentist and technician will be of great benefit to the restorative outcome.

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Colorimeters are optical reading devices that can assess what wavelengths are reflected back to its sensors. The technology of these sensors has improved to the point that they are extremely accurate when assessing opaque objects. Colorimeters have been used for decades in the color industry to match opaque color swatches. Opaque objects, when illuminated, will reflect variable amounts of light back to the viewer; the dominant wavelength(s) reflected back to the eye is the perceived color of the object.[1]

Now colorimeters have been introduced into the dental arena to help with shade assessment. At the present time, accurately matching shades has had varying levels of success, requiring both the dentist and the laboratory technician to have artistic skills and knowledge of basic color science. Conversations with laboratory technicians about shade prescriptions often demonstrate their frustration at wanting to provide a pleasing restoration but not getting the information needed to accurately match the natural dentition. Laboratories receive prescriptions every day with confusing written descrip-

tions such as, "B-1 with characterization"; colorimeters provide a quick, easy upgrade to this weak link in the restorative process.

THE SCIENCE BEHIND THE ART

The science behind the art of matching restorations is poorly understood by many dentists and their technician colleagues. To achieve higher-quality matches it is necessary for both partners to fully understand the science of matching. The clinician must create an environment in which to properly assess the target teeth, understand what he or she sees in the teeth, what factors are most important in making a restoration invisible, and the best way to communicate the information to the laboratory. Ideally, the dentist should evaluate shades with full-spectrum white light[2] with the correct intensity.[3] The majority of dentists use a dental unit light, most of which are incandescent with a light spectrum skewed to the red[4]; these lights are also too bright and cause glare.[5] Ideally, shade assessment should be done at light levels between 75 and 200 footcandles.[3,6-10]

Bright colors in the operatory and in the oral environment also affect our ability to assess color. For example, a patient's red lipstick, or even the oral tissue background, can cause the red-sensitive cones in the clinician's eyes to become saturated and fatigued, giving an after-image of red's complementary color, blue-green. Therefore, the clinician's color assessment of the teeth will be too blue. The color of the walls in the operatories and laboratory can also alter color perception. In a blue room, more orange is seen than is actually present, as the complement of blue is orange. The ideal background when assessing color is neutral gray.[11,12] Neutral gray has no complementary color and is restful to the cones. This is more critical with aged teeth that have a glossy surface that will reflect the shade of any color placed in close proximity.[3,12,13] Although few dentists follow these guidelines as outlined in the literature, colorimeters do utilize the proper illumination. They also control the environment by limiting what light comes into the sensors by covering the sampling area with their sensors. This offers a tremendous advantage over the usual bad lighting and inadequate cropping.

Dentists are human, and there will always be day-to-day variations in the their performance. These new mechanical devices will have the same level of accuracy each time they are used and may offer more uniformity and add details missed by even the best clinicians.

The more information the colorimeter provides to the laboratory, the more work there is to create the three-dimensional rendering of the printouts.

WILL COLORIMETER USE AFFECT COSTS?

There are many different colorimeters on the market today. They range from the simplest, which give the closest Vita Classic® shade tab, to the more advanced models, which give multiple printouts of hue and chroma, value, and translucency mapped over the entire buccal surface. If colorimeters prove to be accurate shade assessment devices, then by using even the simplest device, we can limit the number of re-dos and thus decrease the practitioner's associated laboratory costs. The more sophisticated colorimeters provide assessments that substantially increase the amount of information that would normally be available to the laboratory technician. To exploit this supplemental information requires more understanding/education and increased time to put it into the restoration. It is possible that the knowledge or artistic talents of the technician are not at a level to fully grasp a more detailed prescription. As the restorative dentist provides additional information to the laboratory, there will be an expectation of more fidelity to nature. Clinical outcomes will improve but we can expect the costs of the lab work to increase along with that quality.

WILL THEY BECOME MAINSTREAM?

Will colorimeters eventually be used in every restorative dentist's office and will different colorimeters work best in different market niches? These machines are too easy to use not to look at seriously. The quality continues to improve and the purchase cost is dropping. A certain amount of training on how to use the printouts of the many dental colorimeters on the market will be necessary. Combining all the numbers of colors, intensities, values, and translucencies to create restorations from these printouts will be no minor task. The technician will need to do a substantial amount of work to fabricate a restoration that is faithful to these printouts. The more information the colorimeter provides to the laboratory, the more work there is to create the three-dimensional rendering of the printouts. The quality goes up and so does the cost. Those laboratories serving less expensive dental practices may find that higher-end colorimeter usage does not fit the cost realities of their

Figure 1: Appearance varies depending on surface contour and the angle of illumination.

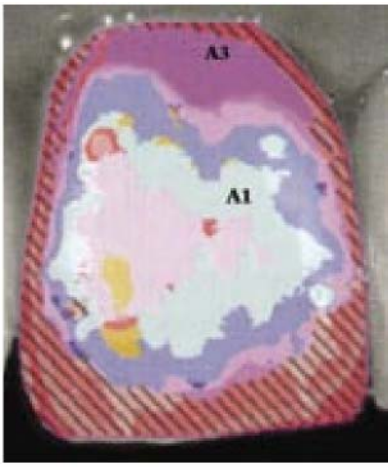

Figure 2: Chroma and value readings will be inaccurate on surfaces not perpendicular to reader. The chroma will be higher and the value will be lower than actual.

niche, so simpler models are best. If the client dentist will pay only for a "B-1" cap, then there may be no benefit to having a colorimeter at all.

Will colorimeters penetrate the highest levels of dentistry? The top 5–10% of restorative dentists already provide substantial amounts of information. Their laboratory technician partners expect multiple high-quality color-accurate photographs of the target teeth and shade tabs,[14] as well as detailed shade prescriptions with attached shade and surface morphology maps. This generally will provide more information than what is generated from colorimeters, and probably in a more accurate and user-friendly form. Colorimeters will probably not penetrate the top 10% niche in dentistry.

HOW ACCURATE ARE THEY?

How well do colorimeters assess shades? The simplest devices on the market give only one to three readings of chroma, hue, and value, employing the Vitapan® shade guide; or the chroma, hue, with implied value on the Vita Classic® shade guide. Natural teeth normally have many colors in them, with chroma gradients from gingival to incisal that are missed by the simpler devices. The more expensive colorimeters do accurately portray the chroma gradients and other hue variations. The accuracy is especially high when evaluating flat opaque surfaces. However, because tooth surface morphology is curved and varied, this will yield less accurate value readings. Surface morphology affects surface reflectivity. Colorimeters show an inverse linear relationship between chroma and value.[1] We know that surface reflectivity skews these linear relationships. The heights of contour on the buccal surface of the maxillary centrals will polish with wear and age. They become shiny and are called *specular highlights.* These specular highlights reflect light back with a spectrum substantially the same as the source. The colorimeters will read these areas as higher value, opaque, and a different chroma and hue.

Teeth have characteristics that stretch the limits of what can be done with colorimeters. It is important to remember that matching the chroma and hue are fifth and sixth in importance on the list of things to match when constructing a prosthetic replacement; silhouette, surface morphology, value, and translucency (in that order) are more important.[4] You have to be fairly close to someone to detect subtle differences in hue; yet shape, surface morphology, value, and opacity disparities can be seen from five to 10 feet away or more. The appearance of teeth is mostly determined by how light is reflected, transmitted, or scattered from its curved and varied surface. Violating conformity of the unique surface characteristics of the natural dentition will cause an unwanted prominence of your restoration.[2, 15-19] Figure 1 shows an example of this with sand, which can look very different depending on its contour and angle of illumination.

A colorimeter sees an object only when light comes from that object.

Surfaces that are perpendicular to us send the most light back to us. The reflective surfaces of the tooth will not return significant light to our eyes if they are not perpendicular to our eyes. Colorimeters take shots from one vector perpendicular to the mid-buccal of the tooth and do not take into account the surface orientation. The readings of colorimeters will vary depending on the angle of illumination or vector of highly textured teeth, with the convexities reading a higher value and the concavities and embrasures reading a lower value than actual (Fig 2). The perimeter surfaces are not perpendicular to the colorimeter sensors, thus causing these surfaces not to reflect light directly back to the sensors. The overall accuracy of colorimeters will be highest in teeth that are flat with less translucency.

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As the more opaque superficial layers of enamel wear off with age, the more translucent enamel underneath exhibits more opalescent complexities. Opalescence not only brightens the tooth, but it also imparts the blue appearance of the translucent enamel that is not backed by dentin. Colorimeters will interpret this blue optical effect as lower value. These optical complexities and distortions are magnified by tooth curvature.

Lastly, unlike an artificial sensing device, the human evaluator will disregard the surface stains on the buccal, interproximal, and lingual and on the remaining teeth and other imperfections, and will determine an "average" appearance that is acceptable for the mouth.

Colorimeter technology will improve over time, but there will always be some inaccuracies in highly textured, high-luster, and translucent teeth. Even with these minor limitations, however, this technology is here to stay and will find its way into a significant percentage of esthetic-oriented offices.

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