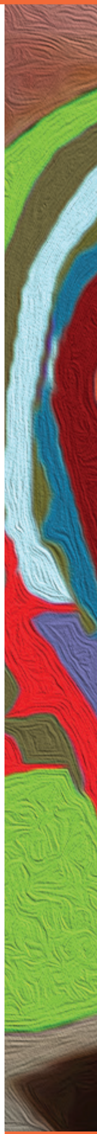
New Algorithm in Shade Matching

Achieving a More Predictable Shade Match and Color Map Using a Technology-Driven and Laboratory-Supported Process

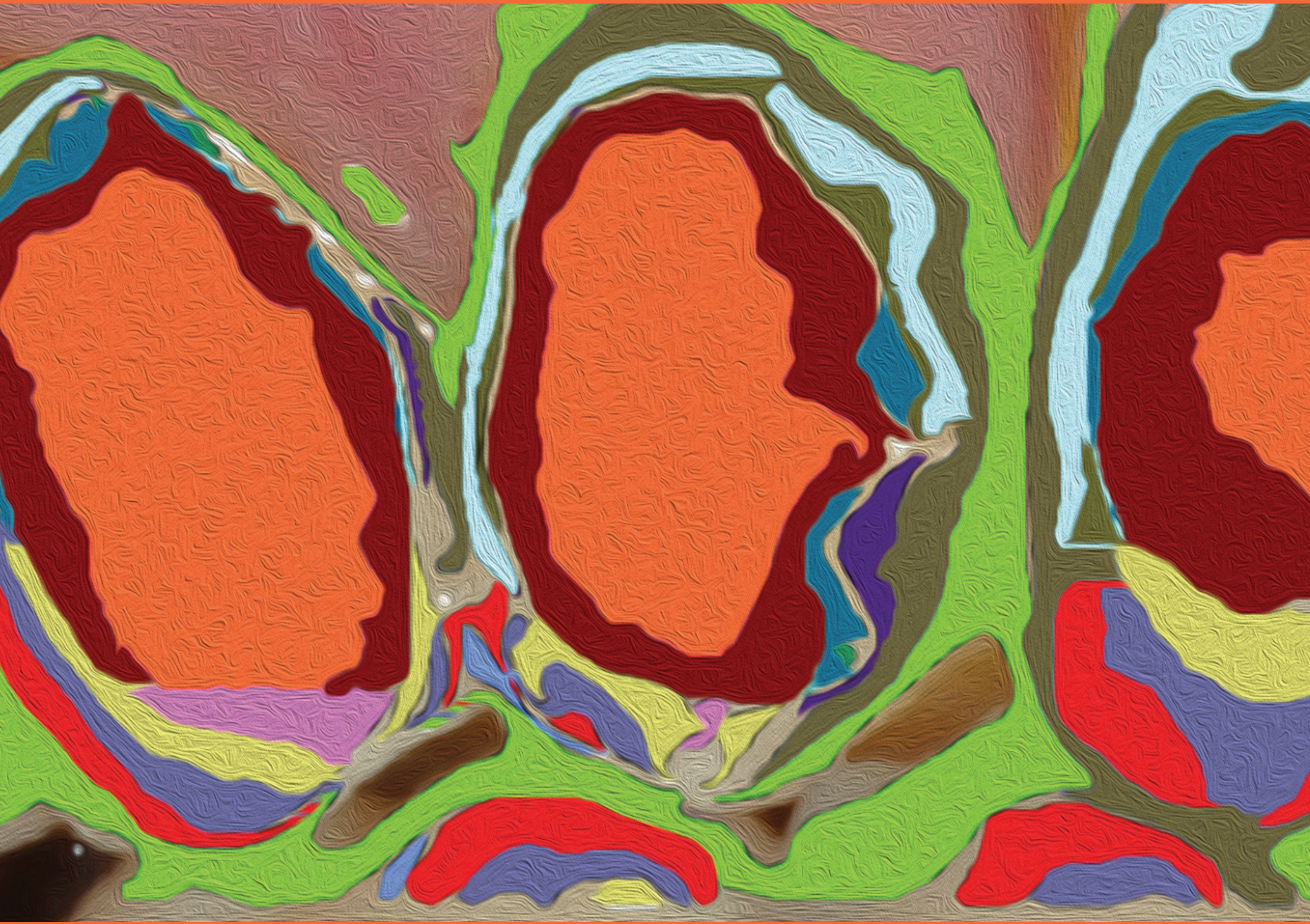


Jerry C. Hu, DDS
Chu Han Wang, BSc
David Kuhns, PhD

Abstract

Determining an accurate shade can be very challenging because the process is inherently wrought with potential for error on multiple levels. Individual human differences in perception, variations among shade tabs and how they are used, inconsistent lighting conditions, and the documentation equipment can all contribute to inconsistent and inaccurate shade matching that leads to discrepancies in final restorations. Although a variety of digitally based shade-taking solutions have been introduced to supplement classic manual methods, what has been needed is a standardized process that not only incorporates technology, but also accounts for how easily the equipment and process can be integrated and utilized by the dental practice staff. This article describes a technology-driven and laboratory-supported process for digitally determining and simplifying the shade-matching process.

Key words: technology-driven and laboratory-supported process, integrated digital shade-taking technologies, digital image shade-matching software



Introduction

Among the collaborative dentist-laboratory tasks required to produce natural-looking esthetic restorations is accurate shade matching. Determining an accurate shade, however, can be very challenging because the process is inherently wrought with potential for error based on multiple and individual human differences in perception; the use of different shade-matching techniques, materials, and equipment; and other influences, such as varied lighting conditions and clothing and background color.[1,2]

Traditionally, determining a tooth's shade is accomplished by one or more dental office team members, with each tooth to be restored requiring a separate shade to be matched with an individual shade tab. Several team members may provide their opinions to determine which shade is a correct match, and identifying the ideal shade may be further complicated if the practice uses several different shade guides, including stump shades.[3-5]

Each commercially available shade tab demonstrates a single value, but presents different properties and multiple chroma areas in the gingival, body, and incisal zones. Gingival areas present more chroma than body and incisal areas, and it may be difficult for laboratories to determine which shade tab zone was concentrated on when selecting the restorative shade, especially if it was not communicated by the dentist. Additionally, the manner in which the shade tab is oriented next to the tooth also affects how tooth shade is determined.[6]

These shade-taking nuances—in addition to environmental variables (e.g., overhead and ambient light, background, sunny or overcast weather)—are all significant factors in correctly determining the shade properties of individual teeth.[1-4] They are also essential considerations in cases involving adjacent teeth requiring restoration, or those in which six or more units must be matched with the premolars or posterior teeth, where value, chroma, and hue should blend harmoniously in every respect.

Lighting, in particular, will impact how tooth shade color is interpreted and how different material translucencies will affect that interpretation of color.[7] Interestingly, the interplay of light with different anatomical tooth characteristics (e.g., primary to tertiary details, embrasures, overall contours), can also contribute to difficulties when shade matching to adjacent teeth, such as in a single or two-unit case in the maxillary esthetic zone.[1]

For this reason, conventional shade taking has been supplemented and/or replaced by shade mapping, in which the occurrences of multiple hues, chromas, and values within natural teeth are accurately depicted and communicated to enable reproduction not only of color, but also polychromatic detail.[1,4,7] Shade maps illustrate the value of the tooth in different areas (e.g., gingival, body, incisal) independently compared to the shade guide, enabling dental ceramists to determine how much transparency or opalescence is required to achieve the desired esthetic effect.[1,3] However, even shade-mapping accuracy is subject to individual differences and outside influences that affect the interpretation of color, value, hue, and chroma, as well as how specifically those components are communicated.

Given these contributory variables that affect shade taking—as well as differences among photography skills and the equipment used—it is not surprising that inconsistencies in shade matching have been cited in the literature.[8] When different individuals attempted to correctly identify the same shade under different lighting conditions, individuals agreed on the exact same shade only 29.3% of the time, with a wide variety of shades selected the remaining 70.7% of the time.[8]

Resolving Shade-Matching Issues

Over the years, dental product, equipment, software, and other manufacturers have endeavored to resolve the issues and challenges associated with accurately taking tooth shades and color matching restorations. It is generally agreed that a consistently reproducible systematic process is needed to enable dental practice team members to easily, efficiently, confidently, and independently determine accurate shades.

In response to these needs, a variety of digitally based shade-taking solutions have been introduced to supplement classic manual methods, including but not limited to spectrophotometric approaches and three-dimensional intraoral scanning techniques, and success has been documented for each technology.[9-11] Some of these technologies include SpectroShade System (MHT International; Newtown, PA), ShadeScan System (Cynovad; Saint-Laurent, QC, Canada), 3Shape (Copenhagen, Denmark), Vita EasyShade (Carestream Dental; Atlanta, GA), and others.

Despite the numerous benefits of these advancements, creating standardized processes has been difficult. Doing so depends not just on the technology, but on how the technology is integrated and utilized by the dental practice and laboratory on a daily basis to achieve consistently optimal outcomes across many cases and difficulty levels. For example, a need has been observed for a standardized photography process for dental practices in which a defined photographic setup incorporates a digital shade map and in-lab protocol to reduce the likelihood of errors.[12]

As a result, many laboratories have developed their own process systems for use with their dental practice customers to streamline shade taking and build strong, consistent communications about restorative requirements.[13] These systems may incorporate and combine advanced digital shade taking technologies (e.g., scanners, photospectrometers, shade-mapping software), customized shade tabs, and single lens reflex (SLR) photography.

New Shade-Taking Technology

One such system is the MicroShade process (MicroDental Laboratories; Dublin, CA), which combines digital image shade-matching software (ShadeWave; Issaquah, WA), color mapping, digital photography, and specific dental practice and laboratory techniques to help eliminate individual influences and external variables that can impact shade taking accuracy and consistency.

Dental Practice Process

The necessary technology includes a single calibrated shade tab (ShadeWave), moderate-quality SLR digital camera, and extension arm attached to the bottom of the camera via a screw—which is common on all SLR cameras—that holds the tab at the correct angle and distance from the camera and flash **(Fig 1)**, but can collapse for easy storage.

With this configuration, the geometry of the camera lens, flash, and shade tab is already set, which is critical to ensuring that shade photographs are in focus and no glare results on the teeth or tab. The tab does not need to be adjacent to a particular tooth, only in focus with the teeth of interest. This geometry also enables the shade-mapping software to properly analyze the tooth color and shades.

It allows the dental practice staff to produce the same quality shade images quickly and consistently. Once the photograph is taken, it is uploaded to the laboratory via a custom portal (e.g., MyDentallab.com, MicroDental) as part of the digital laboratory prescription process and submitted accordingly.

Laboratory Process

At the laboratory, the uploaded images are transferred directly into manufacturing software, which is accessed by the technician and analyzed using the software. To determine the shade, the technician first uses the software to correct the image and normalize for light conditions **(Figs 2a-2c)** according to an algorithm that accounts for known hue, chroma, and value of the gray, black, white, and shade sample on the shade guide **(Figs 2a-2c)**. This algorithm is then applied to the entire photograph to account for light variations, after which a shade map is displayed.

Since each area of the tooth is mapped, the process also overcomes another common error related to conventional shade tabs: single value with multiple chroma areas. Instead, the software maps the tooth shades, determines the level of characterization required, and matches neighboring teeth according to the doctor's prescription.

Figure 1: A retracted smile photograph is taken with an SLR camera, attached and fixed photo arm, and calibrated shade tab at the proper angles to facilitate shade verification and streamline the shade selection process.

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Figure 2a: Original patient photograph taken chairside with the reference tab.

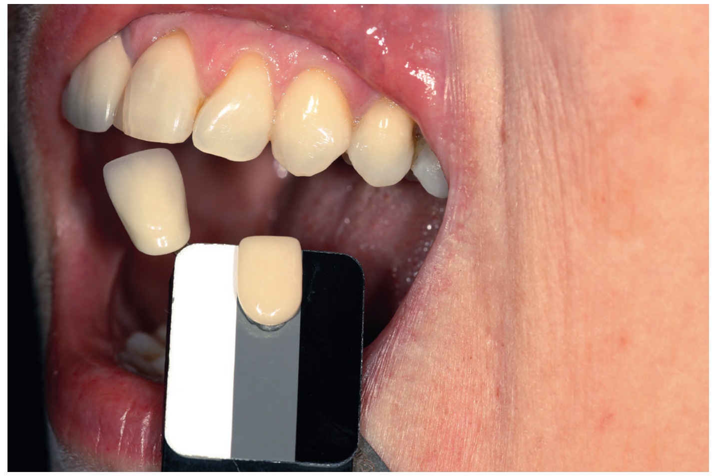

Figure 2b: Software and the reference tab were used to correct the photograph for hue and value.

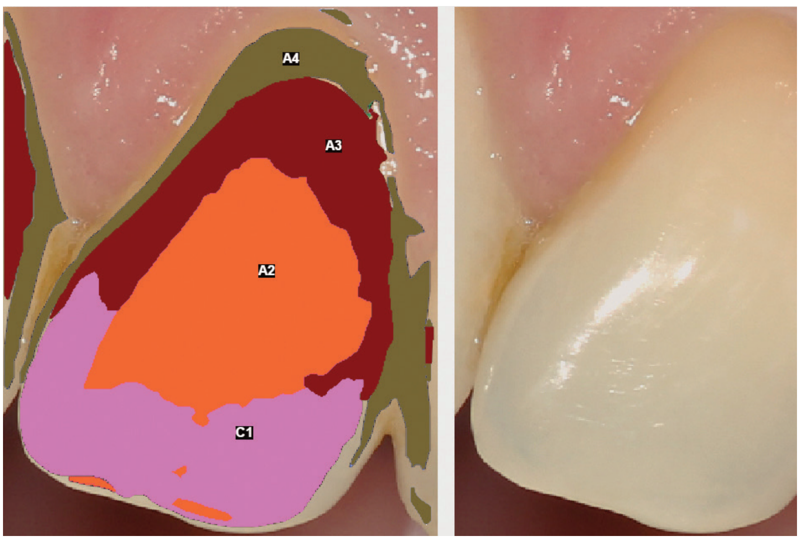

Figure 2c: A shade map showing the shade values were calculated based on the photographic adjustments as shown in Figure 2b.

> "...a variety of digitally based shade-taking solutions have been introduced to supplement classic manual methods..."

Further, because how the value and chroma of final restorations is controlled varies among each ceramic material, the laboratory follows a protocol and applies the software to assess the hue, chroma, and value of the shade map according to the restoration design and selected material. Value is the most misrepresented variable in shade matching. Since highly translucent materials usually demonstrate lower value compared to low translucency materials, once the value is known across the tooth and the restorative material is chosen, an experienced technician can create the proper value for the selected ceramic system.

This is especially critical when a stump is colorized, which can influence the final shade. By following this protocol, the technician can layer or adapt a substructure value by adding thickness or substructure stains to achieve the desired end result.

Additionally, because the software can verify the hue, chroma, and value of particular ceramic system samples, a shade map of a reference crown and stump can be mapped from the same photograph to correctly stack value.

The following cases demonstrate the manner in which the MicroShade process was used between the dental teams and laboratory to enhance the accuracy and efficiency of determining tooth shades. Once the dental teams were properly trained to take, orient, and produce a good quality digital photograph, the entire process required less than two minutes, on average. In fact, in each case, shade-taking time was reduced from 10-20 minutes to less than 5 minutes.

Case Reports

Case 1: Maxillary Esthetic Zone, Teeth ##6-11
A 33-year-old female who was always displeased with the gaps and old direct restorations on her maxillary anterior teeth presented as a new patient for a smile makeover **(Figs 3-5)**. She also did not like the shape of her lateral incisors, where prior dental work made them much "wider" in efforts to decrease the diastemas between her central incisors. Axial inclinations, contours, and proportions were also problematic. Planned treatment involved six conservative and minimally invasive lithium disilicate veneers (IPS e.max, Ivoclar Vivadent; Amherst, NY).

The patient was advised that careful planning would require detailed photography for communication with the laboratory, as well as precise shade matching between her anterior teeth, posterior bicuspids, and/or buccal corridor to ensure her new smile would appear as natural and pleasing to the eye as possible. The shades were mapped out using the discussed process. Evaluating her midline, cervical and incisal embrasures, and proper axial inclinations was also of paramount importance for achieving the best esthetic outcome.

During the preparation appointment, the same shade-mapping process was used to verify how the temporaries (Integrity, Dentsply; York, PA) looked adjacent to her bicuspid teeth **(Figs 6a-6c)**. Utilizing this communication method midway through treatment provided the dentist, patient, and laboratory technician with a sense of security regarding the esthetic and color-mapping direction of the case.

After the definitive restorations were seated, the harmonious blend of the veneers with the full smile confirmed the success and accuracy of the shade-taking and color-mapping process used **(Figs 7-8b)**. The patient reported they looked very natural, especially noting they all looked polychromatic and "lifelike."

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Figure 3: Case 1: Preoperative full-face frontal view.

Figure 4: Case 1: Preoperative retracted frontal 1:2 view at 1:3 magnification.

Figure 5: Case 1: Preoperative non-retracted full smile, frontal 1:2 view at 1:3 magnification.

Figures 6a-6c: Case 1: Midway through treatment during the preparation and provisional phase, the same communication process was used to confirm the shade mapping and shade selection prior to fabricating the definitive veneer restorations.

Figure 7: Case 1: Postoperative full-face frontal view.

Figure 8a: Case 1: Postoperative retracted frontal 1:2 view at 1:3 magnification.

Figure 8b: Case 1: Postoperative non-retracted full smile, frontal 1:2 view at 1:3 magnification.

Case 2: Maxillary Esthetic Zone Implant Restoration

An 82-year-old female presented with a prior root fracture on tooth #8 **(Fig 9)**. Old porcelain-fused-to-metal (PFM) crowns were present on all other adjacent maxillary teeth in the esthetic zone and she was adamant that she did not want them replaced. She requested only implant placement and restoration at the #8 site.

The initial shade was captured using the discussed process **(Fig 10)**. Because she had existing PFM material in the esthetic zone, the process and software were used to match those materials as well as fabricate an implant-supported PFM crown for #8 **(Figs 11 & 12)**. The final result was a well-matched, esthetically pleasing implant restoration that demonstrated the proper emergence profile, gingival architecture, and support.

Figure 9: Case 2: Preoperative full-face frontal view.

Figure 10: Case 2: A shade-mapping photograph was taken for the implant restoration planned for the #8 site. Note the adjacent teeth all have existing PFM crowns.

Figure 11: Case 2: Postoperative full-face frontal view.

Figure 12: Case 2: Postoperative non-retracted lateral right 1:2 full-smile view at 1:3 magnification.

Case 3: Single Posterior Restoration

A 45-year-old male presented with cracked tooth syndrome; an old mesial-occlusal-buccal-lingual amalgam restoration on tooth #3 was leaking and had recurrent caries. He eventually wanted to have all of the amalgam restorations replaced. His maxillary right bicuspids were all natural virgin teeth, and he wanted his molar restorations to blend in.

A shade was taken **(Fig 13)** and mapped **(Fig 14)** using the same process as in the previous two cases. Because the affected tooth was a posterior molar, a strong zirconia material (ZEUS Zirconia, MicroDental) was selected. Having the correct shade information would enable optimization of esthetics into the full-contour zirconia unit.

After cementation **(Fig 15)**, the definitive restoration met the patient's expectations, and the shade match was digitally confirmed **(Fig 16)**.

Figure 13: Case 3: Preoperative retracted view, shade-mapping #3.

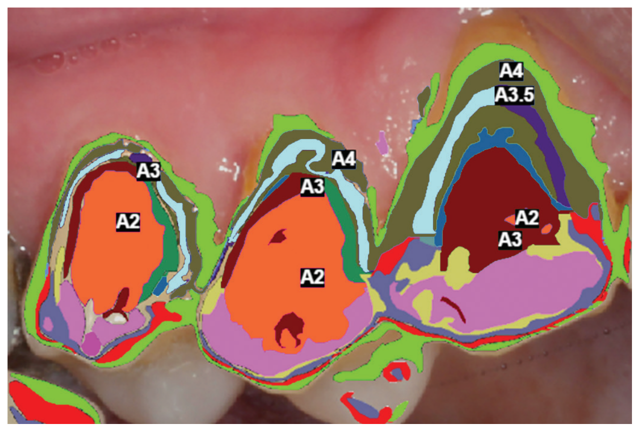

Figure 14: Case 3: Preoperative digital shade map to verify the shade match of #3 to the adjacent #4.

Figure 15: Case 3: Postoperative retracted view of #3 to verify shade matching.

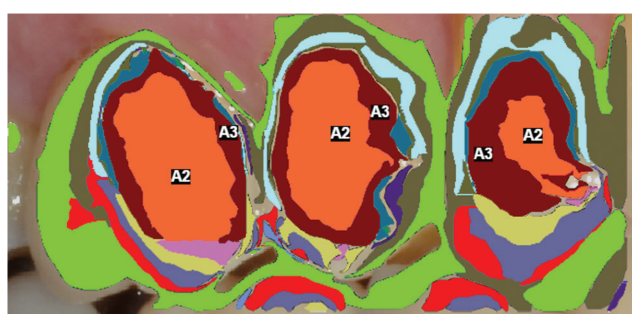

Figure 16: Case 3: Postoperative digital shade map confirms the shade match of the restoration.

Summary

Using a technology-driven and laboratory-supported process can help to simplify and streamline how dental practices obtain and match shades for esthetic restorations. The systematic approach described in this article can help dental practice staff and the laboratory to determine an accurate shade by removing many of the inherent variables that can lead to errors. The process and protocol discussed can be easily integrated and represent a reproducible and controlled method for taking shades.

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Dr. Hu maintains private practices in Anchorage and Soldotna, Alaska.

Ms. Wang is an intern at Dr. Hu's practices.

Dr. Kuhns holds a PhD in analytical chemistry from the University of Washington.

Disclosure: Dr. Kuhns is the senior director of product development and technical sales at MicroDental Laboratories, where the MicroShade process was developed.