Recording and Communicating Shade With Digital Photography: Concepts and Considerations

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The aesthetic restoration of a single anterior tooth involves numerous tasks and has always posed a challenge for even skilled clinicians. These dental professionals must treat the level and health of the surrounding soft tissues, reproduce the shape and surface texture of the adjacent teeth, and select the proper shade and color, which in and of itself is a primary determinant of clinical success.[1-3] The parameters that define tooth color (hue, chroma, value, translucency, opalescence, and fluorescence) are well known.[1,4-8] The determination of color continues to evolve, however, and it is no longer sufficient to measure these criteria with outdated shade guides alone. The communication of these different parameters to the laboratory is difficult and requires the clinician and laboratory technician to use identical shade selection systems in order to achieve optimal aesthetics.[1-3,5,9-11]

Considerations for Digital Camera Selection

Traditional means of transmitting color information include color prescriptions, photographs, and pencil sketches. Digital cameras, however, have recently become available and can pose clinical benefits. Prior to selecting a digital camera, however, the clinician must ask several questions:

- How does a digital camera work?
- What are its advantages in clinical dentistry?
- How do the cameras compare to each other?
- How can digital cameras be used to communicate color?

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Function and Operation of Digital Cameras

A traditional camera (or "optical eye") creates a picture by using light to activate the film, which is subsequently immersed in a sensitive chemical solution. When light reaches this film, a chemical reaction occurs and, depending on the intensity of the subject being photographed, the different particles of the film are exposed. The film is then developed so that a print of the photograph can be viewed.

On the contrary, a digital camera (or "electronic eye") uses light to *create* an image. Instead of a film, the camera uses a matrix of charge coupled device (CCD) sensors, which are essentially light-sensitive electronic components. When hit by light, the CCD sensors detect, generate, collect, and convert the light particles into an electric charge. The result is analyzed and then, as a digital file, is temporarily transferred to the camera's memory via its microprocessor. As in a human eye, the

Figure 1. Case 1. The central maxillary incisor has to be replaced. Multiple views (ie, frontal 1:1, magnified 2:1, value) must be taken to demonstrate proper shape and shade.

Figure 2. Facial view with shade tab is obtained for evaluation of color.

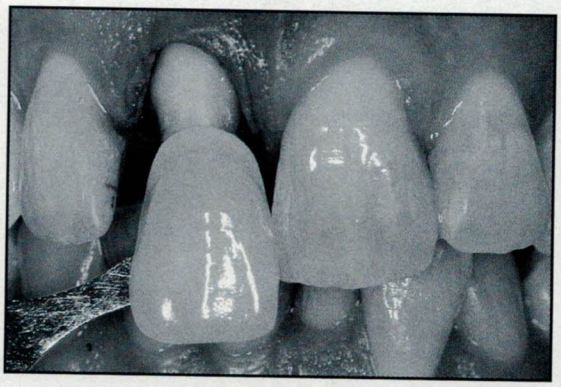

Figure 3. A black-and-white digital photograph is obtained for comparison of value.

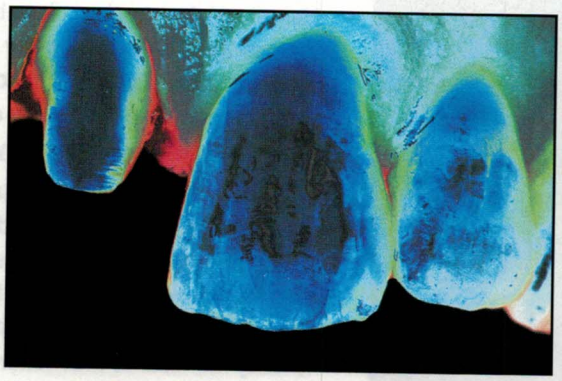

Figure 4. When adjusting the curves using computer software, the internal structures (eg, dentin mamelons, translucency) can be seen.

Figure 5. The technician can similarly document the laboratory buildup so that the clinician can observe the restoration throughout the fabrication process.

digital camera captures the intensity of the three additive primary colors: red, green, and blue. The combination of these three colors in varying degrees of intensity allows the creation of millions of different shades.[3,12,13]

Resolution of Digital Cameras

The resolution is of primary importance to the quality of a digital photograph. Resolution is generally expressed in megapixels (millions of pixels [or picture elements]). The ability of a digital camera to reproduce minute details is directly related to its pixel capacity. Cameras with lower resolution use the equivalent of computer screen resolution standards, such as VGA (640 pixels wide × 480 pixels high), EGA (800 × 600 pixels) or XVGA (1024 × 768 pixels). The printed resolution of an image is also defined by the number of dots per inch (dpi). This must not be confused with image size, however, which is defined by the total number of pixels. There is no standard-sized digital file or resolution. The higher the resolution (and quality) of an image, the longer it will take to transmit that file. Since the primary function of digital photographs is to facilitate rapid communication with the laboratory technician, smaller images are generally of greater benefit. For viewing and use on a computer screen, a resolution of 72 dpi to 96 dpi is sufficient.[13] For use in print media, however, this resolution must be significantly higher, and digital photographs taken for this purpose should be captured as large as possible (ie, 300 dpi).

Clinician/Technician Communication

The exchange of digital images between clinician and technician can be performed in two manners. The first involves e-mail and a web browser (eg, Netscape Navigator or Internet Explorer) to which clinical images may be attached. Images attached in a JPEG format

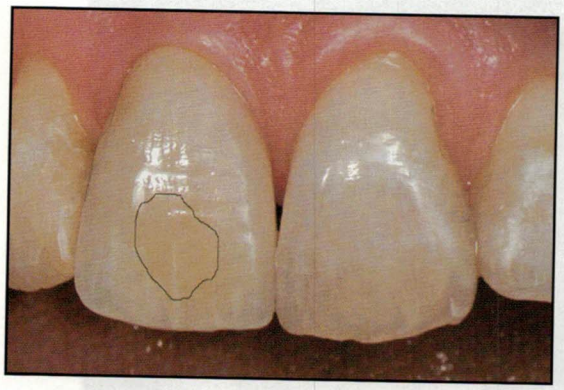

Figure 6. Digital photos enable the technician to visualize the result intraorally. Using computer software, the clinician can also draw the distal emergence profile.

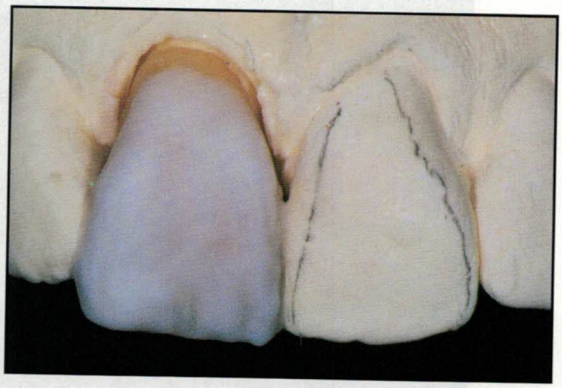

Figure 7. Facial view of the definitive porcelain crown on the master model. Note the translucency in the incisal third.

Figure 8. Postoperative view of the cemented full-coverage crown restoration. Note the harmonious aesthetic result achieved with effective communication.

Figure 9. Case 2. Preoperative facial view of two missing lateral incisors. The treatment consists of implant placement and prosthetic restoration with two all-ceramic crowns.

will be visible as the reader scrolls through an e-mail message. While compressing an image is destructive, a slight compression does not harm the overall quality of the images. Since dental photographs that are electronically transmitted are composed of various color nuances, specific details are not lost in these images. The use of high-speed internet connections (ie, DSL, cable modems) further enables the maintenance of significant data. The standard-sized digital photograph is at a resolution of 640 × 480 and 72 dpi. While larger images may be attached in this manner as well, they take longer to send and may exceed the size capacity of the recipient's e-mail. The use of compression software can reduce the size of the image to further facilitate transfer. The second method of exchanging digital images involves memory cards, which may be forwarded to the laboratory simultaneously with models, impressions, and standard clinical information. Memory cards (eg, CompactFlash or SmartMedia) have a capacity of 256 MB and 128 MB, respectively, which can contain approximately 20 clinical images.

Advantages of Digital Cameras

Digital photographs significantly improve the exchange of information between the clinician and the laboratory technician. The digital camera is easy to use, and — by eliminating the purchase of film and processing costs — images can be viewed instantly and economically. Digital cameras record images onto recordable memory chips that can be erased once the photographs have been transferred to a computer for permanent archiving and/or communication.

Nevertheless, the expense associated with the camera's purchase must be considered, and care must be taken to select the proper digital camera. There are currently dozens of models available; these vary in price,

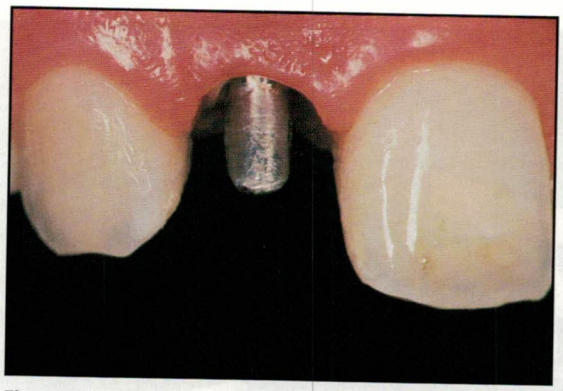

Figure 10. Buccal view of right maxillary lateral incisor 8 months following implant placement. Surgeon: Dr. P. Khayat.

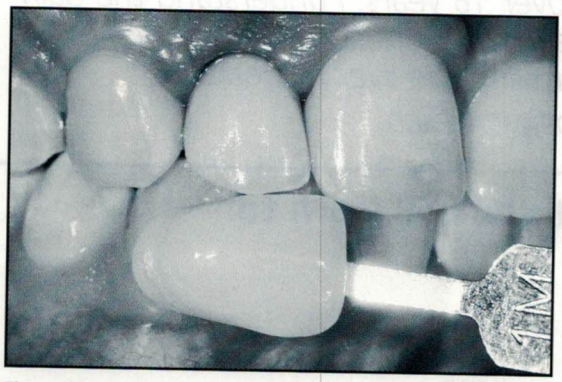

Figure 11. At the try-in stage, a black-and-white photograph is taken and sent to the laboratory so that value can be adjusted for improved shade match.

and it is important to find the camera that provides the best balance between cost and performance. It would be unwise for one to invest in an expensive camera that will be outdated in less than five years and is ill-adapted to serve in a communication capacity.

Market Analysis

Two different types of cameras are presently on the market: the reflex and compact cameras. While the single lens reflex (SLR) camera (eg, EOS-D30, Canon, Lake Success, NY; E10, Olympus, Melville, NY; D1X, Nikon, Melville, NY) has larger captors that provide bigger images (suitable for printing), this by definition generates files that are useless for effective digital communication. When such a camera is used, it is necessary for the operator to reduce image size to a maximum of 300 dpi. In addition, reflex cameras are expensive (minimally ~$5,000), and they have to be used in conjunction with a TTL flash.

The limited captor size of compact digital cameras, however, prevents them from acquiring quality intraoral photographs. A notable exception may be the Coolpix 995 (Nikon), which can be used to photograph a patient at full smile. Compact cameras require two additional components — a macro lens with a 13-cm focal length and a light diffuser or a light diffuser/divider (prism or mirrors) — to achieve even lighting on both sides of the patient's arch via its internal flash. This equipment can be purchased at camera retailers worldwide. Not all compact cameras are compatible. For example, those which cannot be operated manually, or where the camera does not choose the best aperture opening, or which have no place for attaching extra equipment, are not compatible. Compatible brands include the Olympus C 3000ZOOM, Epson Photo PC 3100Z, Casio QV-2300 UX, Nikon Coolpix 950 and 990, and Sony DSC-F505.

Clinical Use of Digital Cameras

Since most clinicians and laboratory technicians work apart from each other, communication is one of the most difficult challenges in dentistry. Using a digital camera, the following case presentations illustrate the various stages of clinician/technician communication. Photographs are taken at different steps of the treatment, and the obvious advantage of the digital camera is the speed by which they facilitate the exchange of images.

Initial photographs are taken at patient presentation and generally include a frontal view, a magnified view of the tooth to be treated (including the adjacent teeth), and additional images that document the dentin and enamel shade of patient's teeth as well as their value (Figures 1 through 3). Once transmitted to the technician as previously described, the images can be enhanced with computer software that allows the correction of exposure, saturation, and color. Using computer applications such as Adobe Photoshop, the image can be magnified to permit accurate viewing of the opalescent effect, fluorescence, incisal halo, or translucency of the tooth. In this manner, the internal structures (ie, dentin mamelons) can also be highlighted more effectively (Figure 4).

This color photograph can also be instantly transformed into a black-and-white image so that value can be determined, which is a considerable advantage for evaluating proper shade for the restoration. Due to the technology of the CCD sensors, the digital camera is

Figure 12. Right buccal view of all-ceramic crown (Procera, Nobel Biocare, Yorba Linda, CA) placed on customized metal-ceramic abutment (with ceramic base).

Figure 13. Postoperative facial view of seated and cemented full-coverage crowns. Note integration of restorations with adjacent natural teeth.

extremely sensitive to the differences in value. Once the crown is received at the bisque-bake stage for try-in, a second black-and-white photograph can be taken. This allows value to be controlled and indicates which kind of external layer of enamel must be created by the technician in order to increase or decrease brightness.[1,5,14,15] Surface texture can also be monitored with the black-and-white photograph.

Another color photograph is taken to permit evaluation of shape. In this manner, while the crown is being fabricated in the laboratory, the technician can envision the crown intraorally as if chairside with the patient and clinician. Any necessary alterations (eg, proportions, color) can thus be instantly and seamlessly communicated between clinician and laboratory technician (Figures 5 through 8).

Conclusion

Digital cameras are easy to use and only require a short period of time to master. They are becoming indispensable as means of communicating shape and color among the members of the restorative team. Many improvements are still necessary, however, before the optimum capacity of digital cameras is achieved. For example, digital cameras do not provide exact color match, as their images only facilitate subjective comparison to a shade system.

Nevertheless, as computers are mandatory in managing the dental office, it is impossible to work without a digital camera that helps the clinician obtain aesthetic results (Figures 9 through 13). Spectrophotometry is another means of researching. It does not need the operator's eye and it will probably be the most important color technological improvement to come.[9] It will, however, be another few years before the perfect "color machine" reaches the market.

Acknowledgment

The authors certify that at no time during the clinical cases above did they communicate by other means than by exchanging drawings and e-mails. The technician never saw the patients.

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