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A Digital Method to Fabricate the Ocular Portion of An Orbital Prosthesis with A Smartphone Camera, Color Calibration and Digital Printing

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Abstract

Conventional techniques described in the literature for the manufacture of ocular prostheses are time-consuming since they involve manual work. The use of technologies could improve this laborious process, providing better esthetic outcomes. This technique describes how to manufacture the ocular portion of an orbital prosthesis using a smartphone camera, color calibration with a tooth shade guide, and digital printing. This method allows clinicians to fabricate customized ocular prosthesis by using a photograph of the patient's eye, thus eliminating the need for hand-painting and manual work, and reducing fabrication time.

Patients with orbital or ocular defects could have psychological traumas, such as emotional stress, anxiety or depression, due to their physical appearance.[1] To reduce such traumas, prosthetic rehabilitation with orbital or ocular prosthesis is the treatment of choice.[2,3]

An ocular prosthesis is manufactured for both ocular and orbital defects, as the orbital prosthesis has an ocular component integrated into it. Conventional techniques for the manufacture of ocular prostheses demand time and hand painting abilities to characterize the patient's iris and sclera.[4–6] In an attempt to improve this process, some authors have reported the use of digital photograph of the iris and its digital printing.[2,7,8] However, the lack of color calibration, manual characterization of the sclera, and multiple laboratory steps are still a problem. Photography of the iris and sclera with digital single-lens reflex (DSLR) cameras and color calibration with a gray card and its digital printing have also been used for manufacturing ocular prostheses.[9]

The quality of a photography obtained by a DSLR camera is excellent, but it is a high-cost piece of equipment. The latest generation of smartphone cameras can also take good-quality photographs, and the investment is much lower. A study demonstrated excellent results regarding the use of a smartphone camera to take photographs of patients for manufacture of a facial prosthesis.[10]

Color calibration is necessary to ensure authentic color reproduction in photographs. In dentistry, gray cards are used to calibrate the color through coordinates. Gray cards are used to white balance a photograph and remove unrealistic colorcast.[11]

Color coordinates are used in color space systems, such as the CIELab system, which provides a specific numerical value for each color and is defined by three coordinates: L* for luminosity, a* for the chroma on the red-green axis, and b* value for the chroma on the yellow-blue axis.[11]

The use of specialized equipment, such as gray cards and DSLR cameras, could increase the manufacturing costs of the ocular prostheses. An alternative way to calibrate the colors of a digital image is the use of L*, a*, and b* values of an element present in a photograph, such as a tooth shade guide. The purpose of this article is to present a digital method to manufacture the ocular portion of an orbital prosthesis using a smartphone camera, color calibration by means of an A2 tooth shade, and digital printing, thereby reducing manufacturing time and overcoming the difficulties of analog workflow of traditional techniques.

Technique

In this method, an A2 tooth shade from a shade guide (Vita classical; VITA Zahnfabrik, Bad Säckingen, Germany) was used for color calibration, employing L*, a*, and b* values. These values of the A2 shade (L* = 83, a* = 1, and b* = 22) were obtained using a dental spectrophotometer (Easyshade; VITA Zahnfabrik, Bad Säckingen, Germany).

1. Adapt two pieces of a polarizing film (B+H Polarizing film linear; Jos. Schneider Optische Werke GmbH, Bad Kreuznach, Germany), placing one on the camera (Galaxy S10; Samsung, Seoul, South Korea) and the other one on the flash of the camera, to produce a cross-polarization effect.
2. Ask the patient to open his/her eyelids with one hand and hold the A2 shade, with the other hand, close to his/her eye. In the automatic mode, capture the image with the smartphone camera, with 2× zoom. Keep a distance of about 10 cm between the smartphone and the eye. Measure the patient's iris size using a digital caliper.
3. Use a software program for image edition (Photoshop CC 2019; Adobe Inc., San Jose, CA) to calibrate color according to the L*, a*, and b* values of the A2 shade. Open the picture using the software and select image-mode-lab color in the menu bar.
4. Use the rectangular marquee tool to draw a rectangle in the middle third of the A2 shade guide. Then, in the menu bar select, filter-blur-average. Use the command Ctrl + D to deselect the rectangle (Fig 1).
5. Use the color sampler tool to select one point inside the rectangle area in the A2 shade guide. A box will appear with the L*, a*, and b* mean values of the rectangle area (Fig 2). Then, in the menu bar, select image-adjustments-curves to open the curves adjustment box. Select the lightness channel to adjust the L* value, the "a" channel for a* value, and the "b" channel for b* value. In each channel, move the cursor from the input to modify L*, a*, and b* values of the rectangle area of the A2 shade until you obtain 83 for L*, 1 for a*, and 22 for b* (Fig 3).
6. Eliminate the light reflections inside the patient's eye by using the brush tool or clone stamp tool. Flip the photograph horizontally to obtain the appropriate orientation for the desired ocular prosthesis. Adjust the photograph size by utilizing the patient's iris measurement and cut the image, leaving approximately 1 cm around the eye (Fig 4).
7. Change the printing settings in the image edition software and select the International Color Consortium

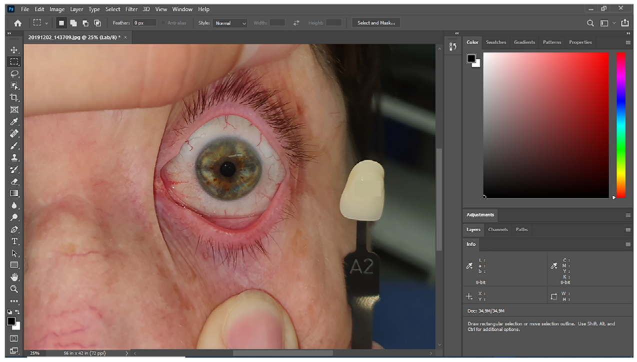

Figure 1 Blur filter applied.

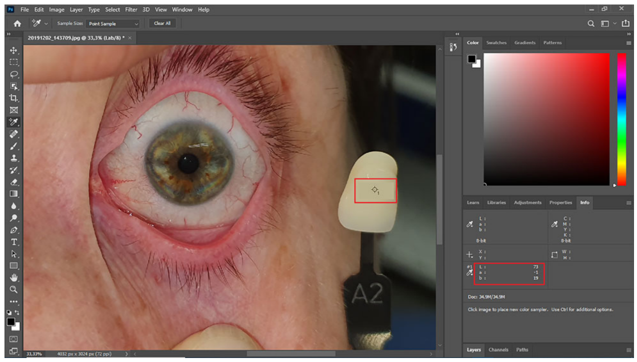

Figure 2 L*, a*, and b* values of the A2 shade guide before color calibration (73, −1, and 19, respectively).

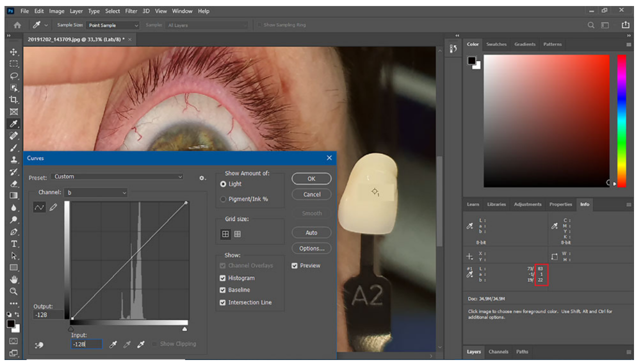

Figure 3 Curves adjustment for color calibration. The red box frame shows calibrated L*, a*, and b* values (83, 1, and 22, respectively).

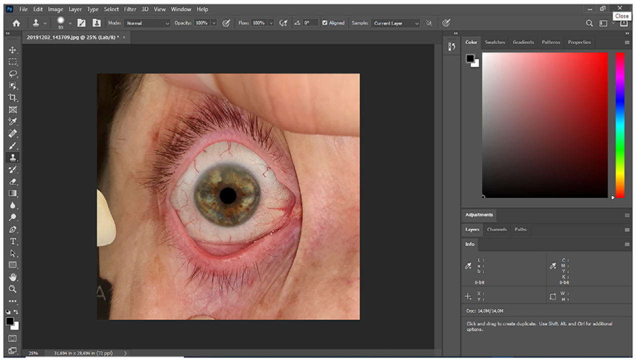

Figure 4 Color calibrated and edited photograph.

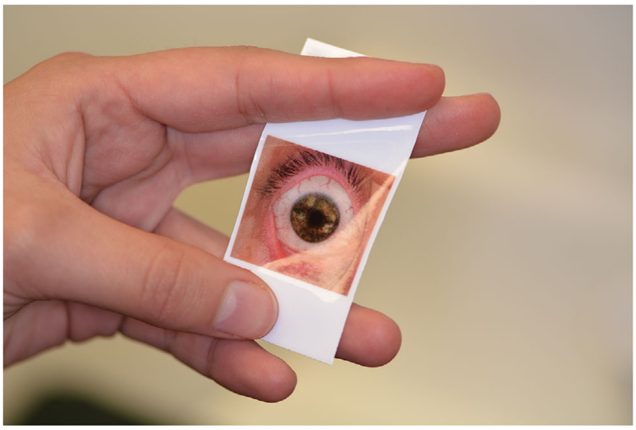

Figure 5 Printed photograph with transparent film placed.

(ICC) profile that corresponds to the printer and paper to be used to guarantee the color reproduction of the digital photograph to the printed one. Print the photograph in an inkjet printer (Latex 370; Hewlett-Packard, Palo Alto, CA) using polyvinyl chloride (PVC)-based adhesive white paper (Orajet 3651; Orafol, Oranienburg, Germany). Let the ink dry and then place a PVC-based adhesive transparent film (Oraguard 270; Orafol, Oranienburg, Germany) onto the photograph surface to protect the ink and to give it a shiny appearance (Fig **5**).

8. Remove the adhesive protector sheet from the white paper and apply heat using a heat gun (HG1500-BR; Stanley Black & Decker, Inc., New Britain, CT) to soften the paper. Place it into an acrylic resin scleral blank and cut the printed photograph around the eye using a cutter. Press with your fingers to adapt the edges to the curved surface while the paper is still soft (otherwise apply more heat).
9. Use the ocular prosthesis to manufacture the orbital prosthesis (Fig 6).

Discussion

This article describes a method for fabrication of the ocular portion of an orbital prosthesis using technological resources. The main advantage of this technique is that iris hand-painting and the manual characterization of the sclera are eliminated by using a photograph of the patient's eye. In addition, as conventional laboratory procedures involved in the manufacturing of ocular prostheses were not used in the present technique, fabrication time could be reduced.

Figure 6 Ocular prosthesis placed into the orbital prosthesis.

The time necessary to fabricate an ocular prosthesis by conventional techniques ranges from 6 to 10 hours.[5,6] By contrast, the manufacturing time is less than 40 minutes in the present method.

The type of paper used in this study was essential to obtain the outcomes achieved. The PVC-based adhesive white sheet was used to print the photograph because its plastic nature allowed a good adaptation of the paper and of its edges over the scleral blank curved surface during heating.

In the present technique, a PVC-based adhesive transparent film was applied to the printed photograph to protect the ink and give it a glossy appearance to mimic the eye's natural glow. Thus, it was unnecessary to apply some acrylic resin coating over the photograph, as shown in other techniques[2,7–9] when digital photography is used.

The proposed technique allows less experienced and less skilled maxillofacial prosthodontists to manufacture ocular prostheses with excellent esthetic outcomes. Besides, the utilization of a tooth shade guide for color calibration through its L*, a*, and b* values and an ICC profile for printing allowed color reproduction of the patient's eye color in the ocular prosthesis. Moreover, using a photograph of a patient allows clinicians to fabricate a customized prosthesis that reflects the physical characteristics of the patient's eye. Thus, this could increase patient acceptance of the prosthesis. However, future studies need to be conducted to analyze the prosthesis acceptance when the proposed technique is used.

This method used linear polarizing films to take a photograph. Linear polarizing films convert unpolarized light to linear polarized light, reducing reflections. The cross-polarization technique was used to reduce, as much as possible, reflection in the photograph. This technique is achieved by placing one filter on the camera lens and another one on the flash. Filters must be rotated 90° from each other. Thus, a perpendicular or cross-polarizing plane is achieved.[12] Nevertheless, photographs taken using the cross-polarization technique appear to have more color saturation. Thus, when photographed, a dark brown eye could show little contrast between the pupil and the iris, which might not be advantageous.

Summary

The present method describes a digital workflow using low-cost technological resources, such as a smartphone camera, a tooth shade guide for color calibration, and digital printing for the manufacture of a customized ocular prosthesis incorporated into an orbital prosthesis. With this timesaving method, the analog workflow is replaced by obtaining relevant results in the prosthesis.

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