The 8th TSME International Conference on Mechanical Engineering
12-15 December 2017
Bangkok, Thailand

BME0011
(this number will be assigned after full manuscript is accepted)

A potential approach for custom-made ocular prosthesis using UV-printer

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Abstract. The lost of an eye results in psychological impact, decrease self-esteem and low quality of life. Fabrication of a custom-made ocular prosthesis is very challenging and requires artistic skill to mimic the remaining eye. The prosthesis needs to be precisely fit and matches the color of the iris and the sclera. A cosmetically acceptable prosthesis is that reproduces the color, form and orientation of the iris and the characteristics of the sclera. The purpose of this study was to assess the color printing of both iris and sclera of an artificial eye using UV-printer machine to process the staining procedure. It can reduce time consumed, adjustable shade and provide more stable color mapping on the acrylic resin eye prosthesis.

1. Introduction

The custom-made ocular prosthesis first discovered and fabricated using acrylic resin by the United States Naval Dental and Medical Schools. This innovation was published in 1944 [1]. Acrylic resin material was replaced the use of glass eye because of easy-to-manage properties, for example adjusting the size and the shape, processing method, strength of material during flasking and curing, inert to eye fluid and body tissue and also staining method can be done easier compare to glass material [2].

The sequence to fabricate custom-made ocular prosthesis consists of packing whitish acrylic resin, sometimes mixed with tooth-shade acrylic resin to get a closer match with the patient's sclera. Then the part of iris is fabricated and fixed in the position. Normally the color of sclera is not completely matched due to several reasons such as variety of the natural colors, and depends on the skill of ocularist. So, the color of sclera usually has to be stained in details and finally processing of a clear acrylic covering. However, the iris part has its own method to fabricate includes painting on disk, using the photograph of contra lateral eye. The painting of iris has many techniques [3, 4]. Sometimes use direct coloring on circle black disc or paint on iris button and place it onto the position [5-9]. There are some literatures compared the advantages and disadvantages between painting technique and digital photograph of contra lateral natural iris and they concluded that the digital photograph has advantage of easy procedure, less time, and quite match of true color. But the disadvantages are requiring specific software program and more experienced human skills [10-12]. Moreover, painting of iris was found to have a color change after a period of time [13, 14]. The study of Artopoulou, et al., 2006 proposed the technique using digital photograph attach to iris button and process by packing ocular prosthesis. The result was quite good appearance [1]. After that, in 2014, Shah et al. presented

the ocular prosthesis by a technique using a computer program to adjust brightness and contrast of the digital eye image. They selected the most closely match with the natural iris of the patient and bring this image to use [15]. Once again in 2015, Buzayan, et al. revealed a case report, they used adjusted iris image for processing [11]. In addition, there are several articles presented the use of staining technique and also the method to attach the iris image to the sclera part [16-19].

However, the idea about esthetic is more concerned include the field of ocular prosthesis fabrication. The custom-made ocular prostheses were evaluated for the natural appearance. The measurement tools or grading scales were developed to determine how real-looking the prosthesis. Dave, et al. in year 2016, set the criteria for grading the ocular prosthesis due to the appearance. The grading was precise and reliable which separated into 3 sub-topics for evaluation; first: naturally of limbus area (the junction between iris and sclera), second: color matching of sclera (which combine staining and vessels) and third: color matching of iris. The total score from 3 sub-topics expressed the whole appearance score for the prosthesis [20]. In the present time, computer technology becomes the important part of every work field, including fabrication of the ocular prosthesis. This can be proved by new release publications (within 1-2 years), for example, Ruiters, et al. used computer combined with CT scan to get space of missing eye ball and also can form the shape or prototype of the prosthesis more precise than conventional technique using impression materials [21]. Nowadays, the concern of esthetic is the big issue and there's more advanced technology development, so that a lot of researchers turn to find out and do the experiments involving the technology to create the beautiful or naturally-looking prosthesis. Chinnery, et al., 2017 revealed the new article stated that they used advanced technology to improve ocular prosthesis fabrication [22]. Their work was performed with iris part by taking digital photograph of the patient's natural eye, adjusted color, brightness and contrast by a graphic program such as Photoshop. They got the picture of iris that was quite naturally looking. After that the iris was brought to fix and covered with resin. This technique enhanced the precise iris color. Beside the literatures indicated that in the future technology can do more, for example, scanning technology which can detect curvature and details the eye socket or 3D CAD software which can produce the accurate surface texture. This technology consists of the process of rapid prototyping and manufacturing (RP & M) which can create a wax-pattern for any piece of work. Nevertheless, there're some concerning aspects that technology still cannot create, like how to put sclera color including vessels to the white part of the eye, also the procedure for the finishing and polishing the ocular prosthesis. Therefore, this can be the recommendation for further study to find a method of mapping 2D picture of sclera and vessels then bring on acrylic resin of the eye prosthesis and make it looks realistic.

As the main problem in the fabrication of the ocular prosthesis is that the characteristic and color is usually not completely matched with the normal remaining eye due to several reasons such as lack of technical skill. So, the color of prosthesis usually has to correct again and again by hand-painting before delivery to the patient. The time consumed and wasted materials are of significant consideration. However, because of more advanced technology nowadays, the printing process from hi-tech machines can be the solution. This present experiment tries to find out whether the UV-printer can overcome those situations or not.

2. Conventional technique

The fabrication of custom-made ocular prosthesis in Thailand normally uses the staining method. The sequence to fabricate custom-made ocular prosthesis consists of packing whitish acrylic resin, sometimes mixed with tooth-shade acrylic resin to get closer match with the patient's sclera. Then the part of iris is fabricated and fixed in the position. All the characteristic details are painted on scleral surface. The stained color and attached vessels are dried, and then the outer surface was covered with clear acrylic resin.

3. Materials and method

Materials

1. DSLR camera: Nikon D5300 with a macro lens (Tokina AT-X PRO) and ring flash (LED macro ring flash FC100, MEIKE)
2. Computer software: Illustrator CS6 and Adobe Photoshop CS6 (Adobe System Inc.)
3. UV- printer: Versa UV LEF-300 (UV flatbed printer, Roland)

Method

1. *Preparation of the samples*

Heat-cured clear acrylic resin was packed in a dental stone mould formed by wax-pattern of the ocular prosthesis's shape. Reduction of 2 mm. in thickness from the outer surface was preformed. The center of the sample was flattened in accordance to the diameter of the iris in adjusted image. Finishing was done by pumice. The stone mould was kept for later packing of clear outer surface acrylic resin.

2. *Characterization studies*

A high quality digital photograph of the patient's contra-lateral natural eye was captured using a DSLR camera (Nikon 5300) with a macro lens (Tokina AT-X PRO) and a ring flash (LED macro ring flash FC100, MEIKE) Set the aperture to between f22 and f25, the shutter speed to 1/125 second, the white-balance to between 5000 and 5500, the ISO to 400, and the flash exposure compensation to 1/18.[19] The distance between the camera and the patient's eye was 60 cm in a room without direct light to the patient's eye. The photograph obtained was edited by mirroring the image and extending the sclera part by the use of a cloning tool. The diameter of the iris should be 1 mm less than that of the natural iris measured earlier to compensate for the magnification caused by the clear corneal prominence.[11] Software Illustrator CS6 and Adobe Photoshop CS6 (Adobe System Inc.) were used in this case. Different combination of brightness, contrast and hue were adjusted to produce an image to match the patient's eye perfectly at the time of try-in (see figure 1).

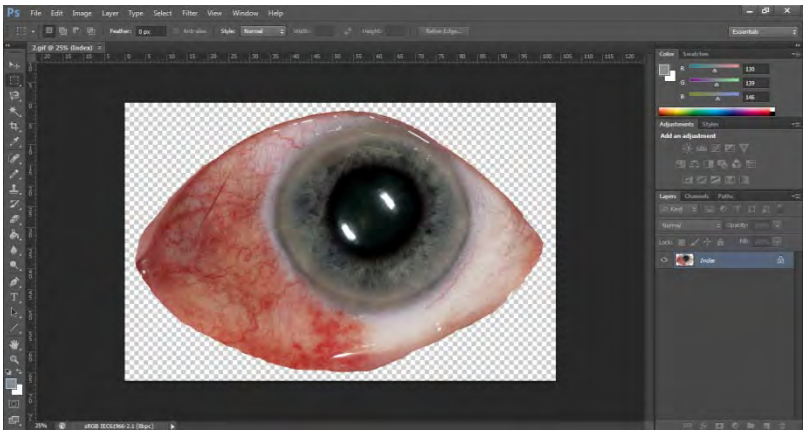

Figure 1. Adjusted image using software program.

The final image printed on a photo-paper using a laser printer (Canon printer image CLASS LBP7110Cw) with a color-ink print cartridge (Canon Cartridge 331) (see figure 2).

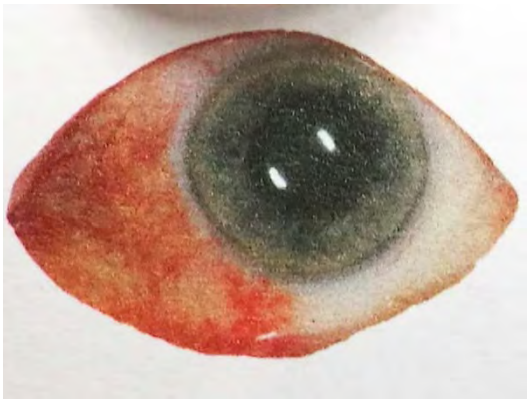

Figure 2. Image printed on photo-paper.

Once verified, the color of iris and sclera matched with the patient's natural eye and then the method of UV-printing was started. The acrylic blank was placed on the base inside UV-printing machine. All the figures were managed properly to fit the image onto the acrylic blank and run the printing process.

Then the printed acrylic was removed from the UV-printer and checked for any defect (see figure 3).

Figure 3. Image printed on acrylic sample.

Covered the surface with 3 light coats of water-resistant spray used for artwork and applied monopoly syrup on top to achieve seal and prevent dissolve of the printed color. Packing and curing with clear heat-cured acrylic resin was carried out in the conventional manner. Finishing and polishing of the prosthesis with care of the shape and contour. The ocular prosthesis was compared again with first image of patient's natural eye. We found that the color was matched with the original shade but the texture of surface color was destroyed by the monomer of dental resin.

So, we have to find out the method to protect the color layer from contacting with monomer until the clear acrylic set.

4. Results

The procedure of characterization ocular prosthesis using UV-printer can achieve the color matching or the appearance of natural eye without significantly difference from the conventional staining technique. The process of staining can be shortened by only set the software and place the piece of acrylic inside the printing machine. Anyway, the important obstacle was the printed color can be

dissolved by the monomer which is the content of acrylic resin used for external surface packing in this kind of prosthesis. For further study we should looking for the best procedure to stuff or fix the printed color permanently. This can complete the process of fabrication of ocular prosthesis using UV-printer.

5. Discussion and Conclusion

Ocular prosthesis fabrication has several critical steps which result in the success of the treatment. The most important aspect affects the esthetic appearance refers to the staining. Characterization of the acrylic prosthesis is one of the unique skill performances that spent time and delay the prosthesis delivery. Also if the cured prosthesis can be detected the color mismatch, then it will fail the whole work.

Conventional technique is separated into 4 – 5 visits. The first visit begins with making impression of patient's defective eye socket. The impression is sent to lab for fabrication of conformer. The second visit patient is asked to try-in the conformer. The doctor then adjusts for passive fit and proper eye opening. This conformer is given to the patient to wear for a few weeks. In the third visit while the shape of the conformer is corrected and accepted by both the patient and the doctor, then continue with step called marking center. This center-marked conformer is sent to lab again for definitive mold that used to fabricate the real-looking ocular prosthesis. Finally forth visit patient comes to receive the definitive ocular prosthesis. If the prosthesis matches with the natural eye in every detail, the ocular prosthesis can be delivered to the patient. Totally, the patient has to spend about 5 weeks. But if something mismatches even the size of the iris or the color of iris or sclera, means that the prosthesis has to be corrected again by doctor himself or send to lab technician and the patient is postponed for next visit for delivery. The delayed overall time may be more than 2 or more months.

The technique of taking photograph and printing presented in this study can help to reduce human skill error no longer than 5 weeks as described above. However, the management to control discrepancy from image capturing and adjustment by computer software is necessary to be concerned. First the image should gain enough details without artifacts; the software compensation to alter the image before printing should compatible with the capability of the UV-printer. Therefore the technique recommended in this study is one of the useful alternative treatments of choices. While the cost of investment for the technology is quite high, the faster and more valid treatment procedure for a large number of patients is in beneficial advantage. One more technique sensitive referred to the un-clear part of iris that out of focus. The printer cannot auto-change focus for the several directions of color painted if the iris part of acrylic resin pattern was not prepared precise straight plane. This problem can be solved in the process by try to set the tip of the printer exactly adapted to the outline of the iris part before start the printing process. Although changing from conventional technique to the new technology processing has to be gradually adapted and modified. Once the software is ready set, the UV-printer works properly, there's an exactly chair-time visit for each patient.

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