Short Communication

Computer-Aided Design and Rapid Manufacture of an Orbital Prosthesis

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This clinical report presents a novel approach that integrates a new optical digitizing (scanning) technique, a three-dimensional ocular prostheses database, and the Selective Laser Sintering technique to achieve the computer-aided design and manufacture of an orbital prosthesis. An optical-structured light scanner was used to develop a color digital model of the unaffected orbital contour, which was copied and then mirrored to generate the orbital prosthesis contour data. The ocular prostheses database was applied to ascertain the size and position of the eyeball within the orbital prosthesis. Then, a Selective Laser Sintering machine directly manufactured the wax pattern of the definitive orbital prosthesis from the three-dimensional orbital data. This new approach is time and cost-effective and can be considered an alternative to traditional manual techniques of creating facial prostheses. *Int J Prosthodont 2009;22:293–295.*

Fabrication of esthetic orbital prostheses is traditionally a challenging process. An unesthetic orbital prosthesis creates even more psychological trauma for the patient than does not having a prosthesis at all. Over the past decade, advances in rapid prototyping technology have renewed interest in developing new fabrication techniques for maxillofacial prostheses. Various computer-aided design/computer-assisted manufacturing techniques have been successfully introduced for the fabrication of maxillofacial prostheses. However, the usefulness of these techniques for fabricating orbital prostheses has not been adequately addressed or validated.[1]

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The present study describes the computer-aided restoration of a unilateral orbital defect by combining the use of an optical scanning technique and Selective Laser Sintering (SLS) technology. The purpose of this article is to present a novel approach for fabricating a wax orbital prosthesis pattern directly by machine.

Materials and Methods

A 45-year-old Chinese female who underwent a right orbital exenteration due to malignant melanoma presented at the Department of Prosthodontics, School of Stomatology, Fourth Military Medical University, Xi'an, China, for an orbital prosthesis. Before starting treatment, the patient was informed of the study procedures and signed a letter of consent.

Digitization of the patient's face was carried out using an optical digitizing scanning system (3DSS-STD-II, Shanghai Digital Manufacturing), which operated using structured light and utilized a phase shift to increase the precision effect. The acquired data were then transformed into a color surface model (Fig 1) by triangulation using Geomagic software (Raindrop Geomagic). The contour surface of the healthy side of the patient's face was flipped and superimposed onto the defective side using the facial median sagittal plane as a mirror. This produced an orbital prosthesis model reflecting the presurgical facial appearance of the deformed region (Fig 2a). The margins of the mirrored healthy section were adapted to the resection margins using a nonuniform rational B-spline (NURBS) rendering model.

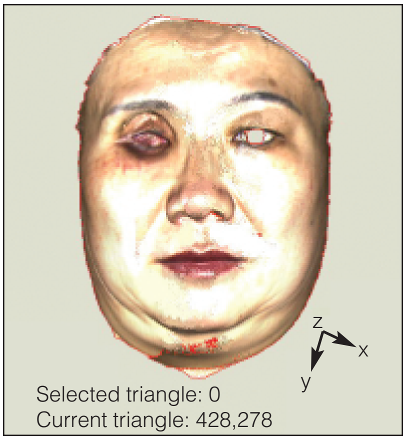
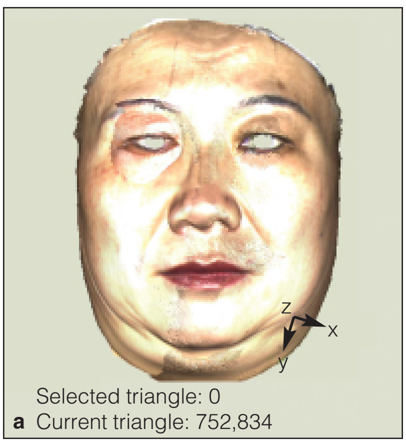
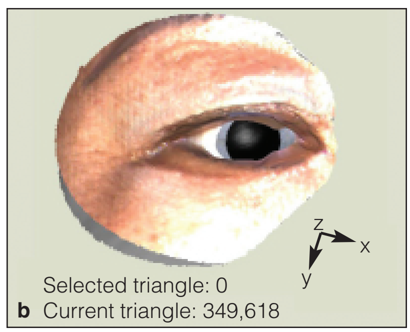


Fig 1 Digitization model of the patient's face based on the optical scanner.





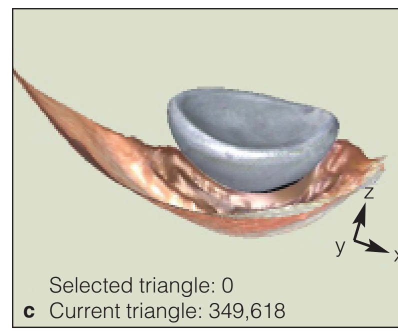


Fig 2 Computer-aided design process for the orbital prosthesis: **(a)** Mirror the contour surface of the healthy side to the defective side to generate the orbital prosthesis model and **(b and c)** match the orbital prosthesis model with the selected ocular prosthesis model. **(b)** Front view; **(c)** vertical view.

A three-dimensional (3-D) database of prefabricated ocular prostheses was developed and populated using the 3DSS-STD-II system at the Fourth Military Medical University of Xi'an. The ocular model was selected from the database to compliment the orbital prosthesis model. Closely approximating the patient's remaining eye, selection was based on the size and color of the iris and sclera (Figs 2b and 2c). Placement of the ocular model within the orbital prosthesis was determined by anatomic parameters of gaze and optimum esthetics. The solid ocular prosthesis corresponding to the virtual ocular model was then selected for assembly with the solid orbital prosthesis.

The definitive orbital model was exported as an .stl file, the standard file format for rapid prototyping systems, and later transferred into an SLS system (AFS-360, Longyuan Automated Fabrication). The accompanying software sliced the model into thin layers (0.1 mm/0.004 in). The SLS machine produced the models by building them layer-by-layer on a moveable platform. For each layer the machine deposited a film of powdered wax material and the laser projector melted the selected areas. The platform then moved down the required layer thickness, a fresh film of powder was applied, and the next layer was melted by the laser. This continued until the wax orbital pattern was completed (Fig 3).

The solid ocular prosthesis was positioned in the wax orbital pattern according to given anatomic parameters. This assembly was later tried on the patient's face for modification and correction. It was then flasked and processed with room temperature vulcanized silicone material (A-2186, Factor II) according to routine procedures.

Results

A digital color model of the patient's face was successfully acquired with her remaining eye open. This consisted of 428,278 triangulated point sets. The duration time of scanning was 4 seconds. The normal reconstructed anatomy of the orbital defect region was successfully reproduced by mirror projection of the corresponding contralateral healthy region using Geomagic Studio 6.0 in combination with the 3-D ocular model. A wax pattern of the orbital prosthesis was automatically generated by the SLS machine in 2 hours. This pattern fit the patient's face very well. Although there was an admitted discrepancy in color, the technology facilitated and expedited the process

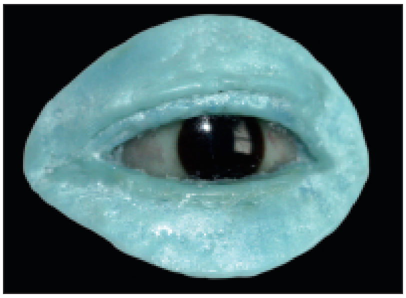


Fig 3 *(left)* Wax pattern of the orbital prosthesis from the SLS process assembled with the solid ocular prosthesis.

Fig 4 *(right)* Completed orbital prosthesis in place.

of pattern dimension, position, and development, which the patient appreciated. The patient was very satisfied with the definitive orbital prosthesis (Fig 4).

Discussion

The first application of a structured light scanner in data acquisition for facial defects was reported by Runte et al.[2] In that study, some disadvantages of the procedure were noted (ie, the scanning process was 10 to 20 seconds long and therefore movement artifacts caused by breathing led to significant inaccuracies). The latest optical scanning technique reduces these inaccuracies by requiring shorter measuring times,[3] with the 3DSS-STD-II system completing the measurement within 4 seconds. In addition, the technology is capable of acquiring both optical data in conjunction with vivid color characteristics. In this study, the color facial model provided both the patient and designer with an opportunity to view the exact restoration effects. A problem to consider is that optical scanners have difficulty capturing the reflecting and transparent structures of the remaining eye. As a result, the acquired facial model lacks the data of the iris and sclera. Thus, a 3-D database of prefabricated ocular prostheses was built and developed to meet the challenge. The selected virtual ocular model can then be correctly matched to the orbital model in size and contour.

SLS (DTM) is a process that was patented in 1989.[4] One of its chief advantages is that it can generate solid medical models directly from a powdered wax material.[5] In this study, manual labor was significantly reduced because the wax orbital pattern was automatically fabricated by an SLS machine. SLS wax is very inexpensive. Furthermore, the used wax material can be collected and recycled, making the entire process very cost-effective. The precision of the computerized model allows for a satisfactory restoration of the patient's appearance.

While this new technique brings distinct advantages, there are acknowledged limitations. Theoretically and in practice, the structured light digitizer can acquire information about the color and texture of a patient's skin, but currently available rapid prototyping systems cannot recreate any fine structures, like the skin's texture. Therefore, technique-sensitive work is still required to carve skin texture on the wax replica by hand. In addition, current computer shade-matching techniques cannot closely match a patient's skin color. In this study, the color selection and painting of the prosthesis were manually completed according to the technician's experience.

As rapid prototyping systems and associated technologies advance, the potential exists for these attributes to be addressed in an acceptable way. The hope is to facilitate the restoration of orbital and other craniofacial defects, and thus expedite the physical and psychological rehabilitation of the patient.

Acknowledgement

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