Prosthetic reconstruction of maxillo-facial defects by means of 3D optical reverse engineering and prototyping

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We present a novel approach that combines optical three-dimensional imaging, reverse engineering (RE) and rapid prototyping (RP) for mold production in the prosthetic reconstruction of facial prostheses. 3D acquisition of the patient's face is performed, a virtual prosthesis is generated, two physical models of both the deformed face and the 'repaired' face are obtained, and can be used either to directly cast the final prosthesis or to fabricate the positive wax pattern. Two case studies are presented.

1 Introduction

Prosthetic reconstruction techniques of maxillo-facial defects have recently gained increased interest in post-oncological reconstruction and in the treatment of congenital defects. Both functional and aesthetic characteristics of the prosthesis are here crucial, to allow the patient to overcome social, psychological and the economic problems deriving from their handicap [1,2]. As an alternative to traditional, time consuming and discomforting manual prosthesis manufacturing procedure, we applied 3D whole-field profilometry based on 3D eye-safe laser scanners (or, in alternative, 3-D system with incoherent light projection). This is justified by (i) complete non-invasiveness for the patient, (ii) speed of the acquisition, and (iii) availability of rugged, portable scanners on the market. We combined optical 3D acquisition, reverse engineering, and rapid prototyping procedures for virtual sculpturing and fabricating of facial prostheses, applied in two cases of eye and nose reconstruction.

2 Study case 1: eye prosthesis

The system used for the acquisition was a commercial 3D system, (Konica Minolta VIVID 910 laser stripe scanning projector). The system was operated at different resolutions, to acquire the face of the patient in a single view and then to acquire details of the face, at higher resolution, in correspondence with the orbital zone. The acquisition was accomplished in a few minutes. These views were then aligned to the former and fused together. The polygonal model of Fig. 1 was created. The orbital area corresponding to the defect was not completely captured, because of the deepness of the orbital hole, but this was not a problem, since only the borders of the hole were of interest to make the replica.
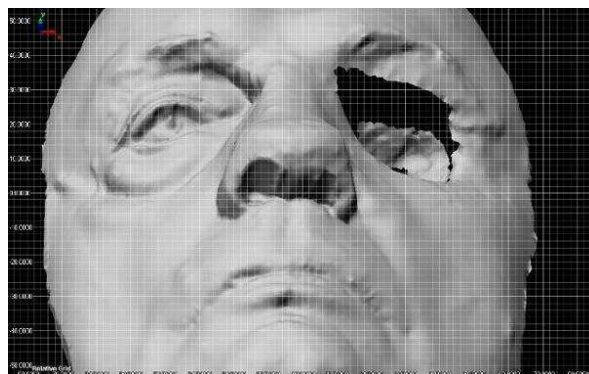

Fig. 1 Polygonal model of the face

The modeling of the replica was carried out taking advantage from the symmetry of the face. The right, safe eye was selected and mirrored with respect to the sagittal plane of the face (Fig. 2, left). The model of the eye was then positioned in correspondence of the orbital cavity at left (right).
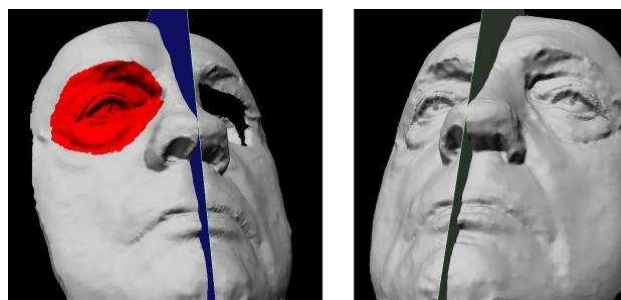

Fig. 2 Sectioning and mirroring of the polygonal model: (a) selection of the right eye; (b) mirroring of the eye and positioning on the left orbital cavity

Then, the region to be reconstructed was selected and the negative model for the mold was obtained. The availability of this model allowed the fabrication of the physical mold. The mold represented a valid aid to the anaplasthologist, to position the pupil elements in the prosthesis.

3 Case study 2: reconstruction of a nose

This patient suffered from a total loss of the nose, following excision of a tumor. The Konica Minolta Vivid 910 was aligned on a tripod to optimize the acquisition view point (Fig. 9, left), with the corresponding point cloud (center), and the polygonal mesh (right). A 4mm thickness was then internally added. This mesh was saved in a 9 MB STL file, for subsequent prototyping.

Fig. 3 *Fabrication of the nose prosthetic replica. Left: acquisition of the patient's face; Center: aligned point clouds of the whole face; Right: triangle mesh.*

The nose was modeled by choosing a nose from a number of healthy 'donors' acquired at high definition. The nose was carefully positioned onto the reference model. The resulting sculptured model is shown in Fig. 4 (left). A 4mm thickness was externally added.
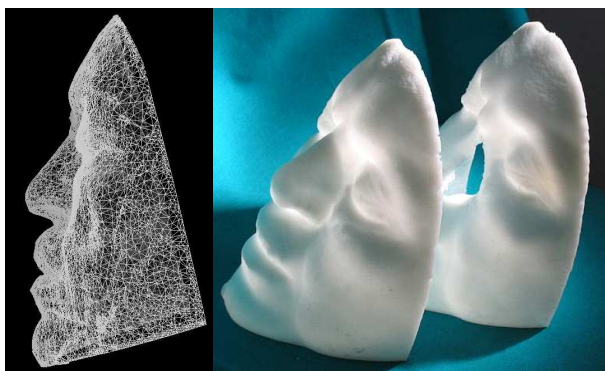

Fig. 4 *. Left: triangle mesh of the face after the superposition of the virtual nose; Right: superposition of the two physical models*

Then, two physical models were created using an epoxy photo-polymerizing resin by a Prototyping Machine. Since the former was externally extruded and the latter was internally extruded, they perfectly overlapped with the exception of the defect region.

To fabricate the prosthesis, the conventional wax positive pattern was cast. The two physical models were physically overlapped and the wax poured as shown in Fig. 5 (left). The wax pattern was then positioned on the prototype of the reference model as shown in Fig. 5 (right). In this way, it was possible to perform the try-in and refinement of the prosthesis without disturbing the patient.

Fig. 5 *Fabrication of the prosthetic element: (a) wax positive pattern fabrication by using the two prototypes; (b) try-in of the wax pattern onto the physical model prototyped by means of the mesh in Fig. 9(c).*

The final prosthesis was obtained by conventional flasking and investing procedures. Fig. 6 shows the patient aspect after the positioning of the prosthesis.

Fig. 6 *. The prosthetic element obtained.*

4 Conclusions

The manufacturing system proposed in this work does not require initial casts, thus reducing the dependence on the anaplasthologist skill and increasing the process efficiency. The patient's comfort is maximum, and this is of primary importance, especially in view of the subsequent replacements of the prostheses, which are necessary due to color changes, aging, contamination and loss of fit.

References

[1] G. Sansoni, M. Trebeschi, G. Cavagni, G. Gastaldi: 3D Imaging acquisition, modeling and prototyping for facial defects reconstruction. Proc. SPIE 7239-36 (2009).