Fabrication of an Orbital Prosthesis Using a Noncontact Three-Dimensional Digitizer and Rapid-Prototyping System

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Abstract

Conventionally, fabricating a facial prosthesis requires complicated steps and sophisticated skills. Particularly, the facial impression can be uncomfortable for the patient and can cause compression because of the weight of the material. The new approach presented in this report could simplify the fabrication of facial prostheses using a noncontact three-dimensional digitizer and binder multinozzle inkjet printer, without computed tomography or making a conventional impression. Treatment time was reduced, and the patient expressed satisfaction after 6 months follow-up.

Although various reconstructive and regenerative treatments have been developed, a facial prosthesis is an effective rehabilitation for patients with congenital or acquired facial defects, including those resulting from trauma or surgical removal of neoplasms.[1–3] The fabrication of a facial prosthesis requires numerous complicated techniques to obtain a morphologically satisfactory outcome.

A conventional facial impression can be uncomfortable for patients because most of the face must be covered with impression material until it sets. Furthermore, the weight of the impression material or the patient's body posture during impression can cause deformation and inaccuracy. Sculpting the wax prototype is also time consuming and requires professional training or further experience and skill.[4]

Recently, a rapid-prototyping (RP) system was developed as a simpler method for fabricating prostheses without a facial impression.[5,6–10] The facial data of patients can be acquired by computed tomography (CT), magnetic resonance imagery (MRI), and surface scanning (photography, laser).[11] For post-surgical patients who already have CT data, those data could be useful for designing and manufacturing facial prostheses; however, it is clinically difficult to obtain additional CT data from patients in whom there was a delay in starting prosthetic treatment or who had been subjected to surgery at other facilities. The radiobiological risks of several X-ray exposures from retaking a CT simply for fabricating a facial prosthesis might not be acceptable for patients with maxillofacial defects.

The purpose of this study was to develop a new method to simplify the fabrication of facial prostheses using a noncontact three-dimensional (3D) digitizer and 3D design software without a facial impression or CT.

Clinical report

The patient was a 72-year-old man with a right orbital defect due to surgical resection of a malignant tumor in 1986. For the last 20 years, the patient used a facial prosthesis that had been refabricated more than nine times because of discoloration or soft tissue changes. The patient visited our clinic requesting a new facial prosthesis.

After detailed discussion of the entire treatment process and thorough examination of the defect area, data were acquired using a VIVID 910 3D noncontact digitizer (Konica Minolta, Osaka, Japan). VIVID 910 employs laser-beam light sectioning technology to scan objects using a slit beam. Light reflected from the object is acquired by a charge-coupled device (CCD) camera, and 3D data are then created by triangulation to determine distance information. The laser beam is scanned using a high-precision galvanometric mirror, and 640×480 individual points can be measured per scan. Data were recorded with and without the existing prosthesis. It took 2.5 seconds to obtain the data. The distance from the digitizer to object was 70 cm. The measuring accuracy is purported by the manufacturer to be 0.008 mm. The acquired point-cloud data were converted into a triangular mesh as an Stereo Lithography (STL) file to output and load into computer-aided design (CAD) software (Mimics and Magics, Materialise, Leuven, Belgium). After data obtained with and without the prosthesis were superimposed in Mimics, the difference between the two sets of data was masked as the new facial prosthesis data (Fig 1).

At the same time, a facial photograph was taken and mapped on the CAD model using the photo-mapping function of Mimics, and the image of the final prosthesis was shown to the

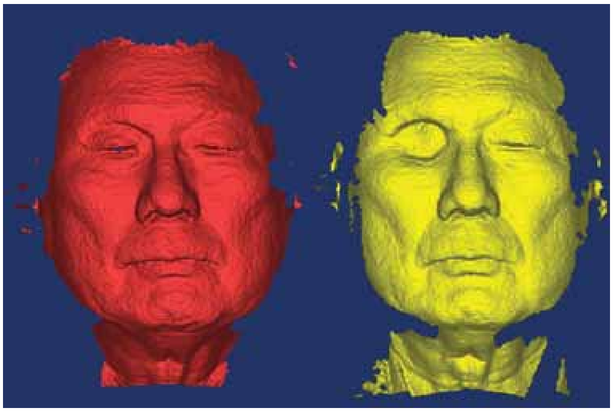

Figure 1 Designing facial prosthesis using Mimics. (l) 3D data with previous prosthesis in place. (r) 3D data without prosthesis.

patient (Fig 2). This step is very important to motivate patients who are receiving facial prostheses, because it is the first time for the patient to see the final image of his or her face with the prosthesis in place. In the meantime, referring to a photograph, the position of the pupil was chosen and marked in a balanced position compared to the normal side.

After designing the prosthesis, the CAD model was transferred into a physical model as an upper and lower negative

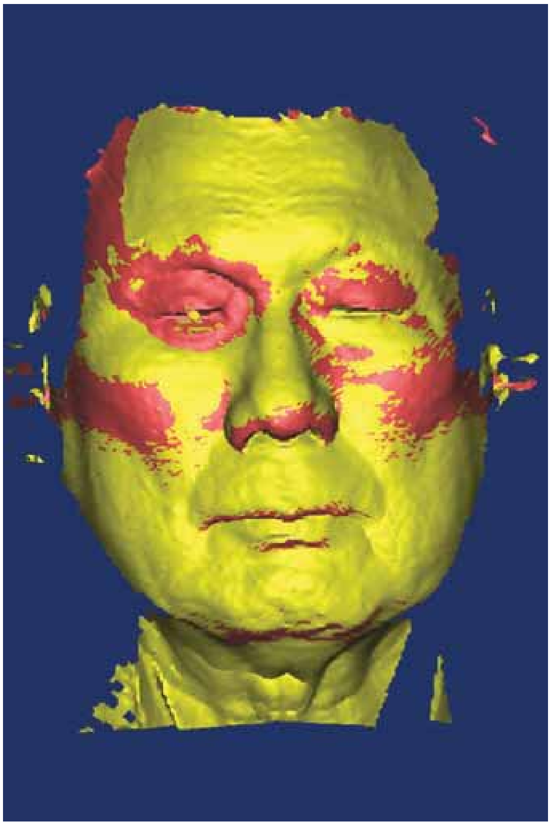

Figure 2 Superimposed data with and without prosthesis.

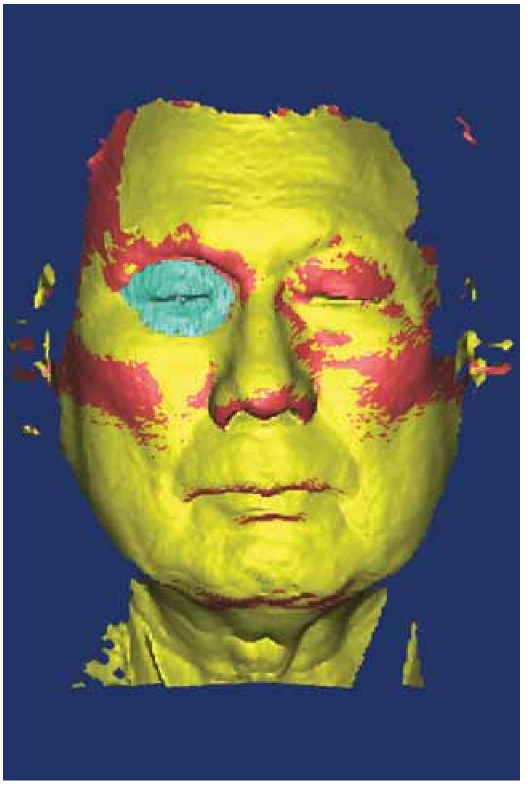

Figure 3 Masked data for difference.

Figure 4 Prosthesis in place.

mold of the designed prosthesis using a 3D thermojet printer (Z510, Z Corporation, Burlington, MA) with hybrid plaster (ZP® 150, Z Corporation). This negative mold included an index for the marked pupil as designed.

Heated wax was then poured into the mold to fabricate the wax prototype, in which the position of the pupil was also indicated as an index. At the next appointment with the patient, trial fitting was done to confirm the profile, marginal fit, and harmonious positioning of the pupils (Fig 3).

The wax prototype was finalized on the patient's face, the texture of the skin was added, and final modification of the cast in the marginal area was performed. The prototype was flasked and packed with intrinsic colored silicone material in the conventional way. The final prosthesis was delivered to the patient (Fig 4), and he was satisfied. A follow-up after 6 months revealed that the patient was still satisfied with the prosthesis.

Discussion

This report demonstrated a simple method for the fabrication of facial prostheses using a noncontact 3D digitizer and RP system. The VIVID system uses a low-power laser (FDA class 1) that emits harmless radiation and makes it possible to obtain surface data of the scanning object in a very short time (2.5 seconds) without discomfort for the patient. The simpler method described here is safer than CT, in which the subject must be exposed to radiation.

Reitemeier et al[4] described the 3D modeling method using a structured light system without taking CT or making an impression. The system took 20 seconds to obtain the data, allowing the motion artifact for children or patients who have involuntary action. The VIVID system enabled us to obtain highly accurate data in a shorter time. Additionally, the patient's physical and psychological stress may be reduced.

In designing facial prostheses on a CAD model, the mirror image technique is commonly introduced,[8] in which a cut is made through the center line of the model—reflected from the healthy side—and the difference between mirrored data and defect data forms the model of the prosthesis. However, in cases with a large defect or deformation of residual soft tissue, facial prostheses based on the mirror image technique may result in too much extension of the prosthesis size in order to maintain symmetry, causing unnaturalness or discomfort for the patient because of the prosthesis' weight or mass. Since our patient wanted a new facial prosthesis similar in shape to his existing prosthesis, a new prosthesis was designed with reference to his old prosthesis in this special case.

The novel photo-mapping function of Mimics enabled us to paste a digital photograph three dimensionally on the CAD model and confirm the external profile and position of the pupil on the designed model. Using CT or facial impression, the accurate positioning of the pupil cannot be obtained because the patient's eyes must be closed. In addition, the image of the final prosthesis generated by Mimics is effective for motivating patients.

One disadvantage of using VIVID might be its limited reproducibility. Though no significant difference among the accuracy of the three types of 3D data-acquisitioning systems (CT, MRI, laser scanning) has been reported,[6] clinicians should consider that laser is absorbed by dark areas such as eyebrows, eyeballs or eyelashes, and at undercut areas, which are important for fabricating orbital prostheses.

Many types of materials have been used as RP materials. We used hybrid plaster as the material for fabricating the prosthesis because it is stable and inexpensive compared to other materials. Moreover, the properties of hybrid plaster are quite similar to those of dental stone, and it is easy to handle and modify.

Conclusion

Using the proposed system, the time to fabricate the wax prototype was shortened, and the patient's chair time was minimized. As for patients, elimination of the need for facial impression and the CAD reduced discomfort and appointment time, which further improved patient motivation and outcome.

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