CLINICAL REPORTS

Fabrication of a Maxillofacial Prosthesis Using a Computer-Aided Design and Manufacturing System

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Purpose: Maxillofacial prostheses are usually fabricated on the basis of impressions made with dental-impression material. The extent to which the prosthesis reproduces normal facial morphology depends on the clinical judgment of the individual fabricating the prosthesis. This paper describes a computer-aided design and manufacturing (CAD/CAM) system for the fabrication of maxillofacial prostheses. This system will provide a more consistently accurate reproduction of facial morphology.

Materials and Methods: Facial measurements were taken using a non-contact three-dimensional laser morphological measurement system. The measurements were sent to a computer numerical controlled (CNC) milling machine to generate a cast of the patient's face for the fabrication of prosthesis.

Results: Facial contours were measured using a laser. This method minimizes patient discomfort and avoids soft tissue distortion by impression material. Moreover, the digital data obtained is easy to store and transmit, and mirror-images can be readily generated by computer processing.

Conclusion: This method offers an objective, quantified approach for fabricating maxillofacial prostheses.

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INDEX WORDS: non-contact three-dimensional laser morphological measurement systems, milling machine, facial defect, maxillofacial prosthesis

TREATMENT OF EXTENSIVE facial defects using maxillofacial prostheses requires impressions of the entire face, including the defect. Dental-impression material is customarily used for this purpose.[1-3] Potential problems associated with this method include interference with normal breathing and distortion of facial soft tissues.[4]

Recently, as a result of the developments in computerized three-dimensional (3D) data processing, it has become possible to obtain facial morphology measurements using non-contact 3D laser morphological measurement systems.[5-8]

In this clinical report, no traditional impressions were made. Instead, using the computer-aided design and manufacturing (CAD/CAM)[9-12] technique combining a non-contact 3D laser morphological measurement system and a computer numerical controlled (CNC) milling machine, wax models were made.[13]

Technique

Prostheses were fabricated for a 61-year-old man who had surgery for carcinoma of the left posterior maxilla (Fig 1). The fabrication process involved 3D morphological measurement of the face, morphological design using CAD, fabrication of the facial wax cast using CAM, and fabrication of a wax pattern for the facial prosthesis using the mold of the facial wax cast and a silicone rubber impression of a mirror-image-wax cast generated from the normal side of the face.

To obtain 3D morphological measurements of facial defects, a non-contact 3D laser morphological measurement system[5-8] (SURFLACER VM-300P-4, Unisn, Osaka, Japan) was used (Fig 2). This system enables the clinician to obtain high-precision facial morphological measurements at

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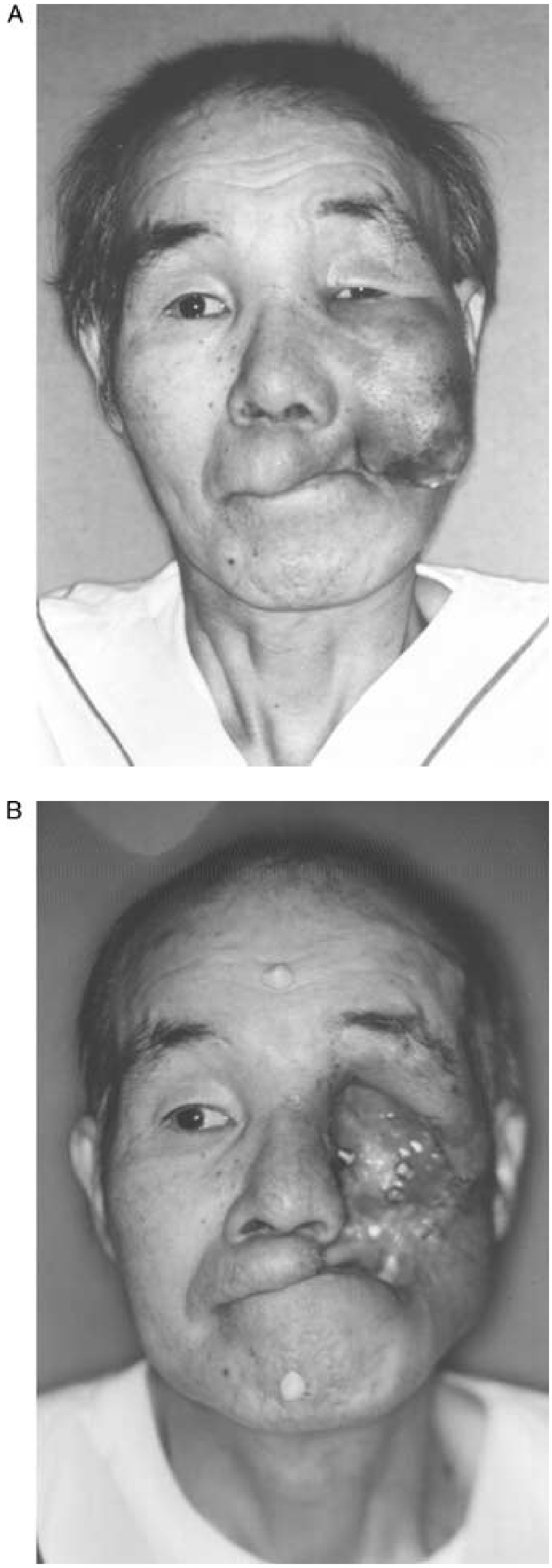

Figure 1. (*A*) Preoperative view. (*B*) Postoperative view.

Figure 2. Non-contact 3D laser morphological measurement system.

high speed using a laser system. The laser system involves two semiconductor lasers applied under computer control to the patient's face. The projected light is received by four charge-coupled device (CCD) cameras. The time needed to obtain measurement data is approximately 5 seconds.

The received signals were processed using an image processor and transferred to a personal computer (PC9821, NEC, Tokyo, Japan) to generate 3D images. Using a computer, morphological design processing, including the generation of a mirror image by reflecting the data for the normal side relative to the facial median line to the defect side, was done.[8] This morphological data were converted to the data used for processing and then output to an image processing system for fabrication of a morphological cast.

Using the processing data sent from the computer to the CNC milling machine (PNC-3100, Roland, Hamamatsu, Japan), the morphological cast was fabricated by milling a wax block with a melting temperature higher than that of paraffin wax. Facial casts of the affected side and a mirror image of the normal side were fabricated (Fig 3).

Silicone rubber impression material was used to make an impression from the mirror-image facial cast of the normal side produced by the CNC milling machine and fitted to the facial cast of the affected side. Thus, a mold that approximately reproduced normal facial morphology of the affected side was obtained. Next, to make a wax pattern of the facial prosthesis, liquid paraffin wax was poured into the mold through an opening in the posterior surface of the facial cast of the defect (Fig 4).

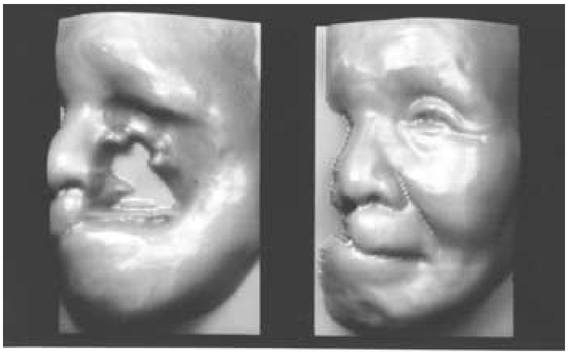

Figure 3. Left: A wax block was milled with a CNC milling machine to fabricate a facial cast of the normal side. Right: A mirror-image facial cast of the normal side.

An artificial eye was attached to the wax pattern, which was then fitted to the patient. Minor corrections were made to the wax pattern, and the final color tone of the prosthesis was determined at the clinic. The wax pattern was replaced with silicone rubber (Silicone Elastomer: Clear Grade, Factor II, Lakeside, AZ). After polymerization, the surface color tone of the prosthesis was adjusted (Fig 5) and hair was implanted.

Two cranio-facial implants were placed into the zygomatic bone to retain the prosthesis. In addition, as with many patients with oral defects, a maxillary denture was retained via two palatal implants. The remaining teeth were also used for retention of the prosthesis. Magnets (Magfit EX400, GC, Tokyo Japan) were used as retentive attachments for the prosthesis and the maxillary denture (Fig 6).

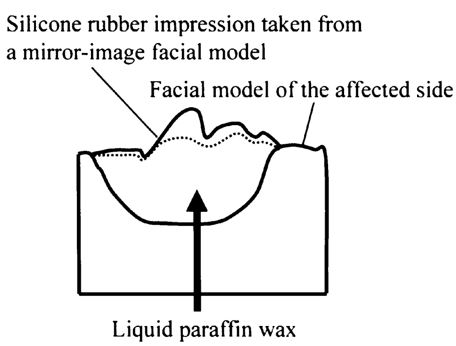

Figure 4. Schematic illustration of the fabrication of a wax pattern of the prosthesis.

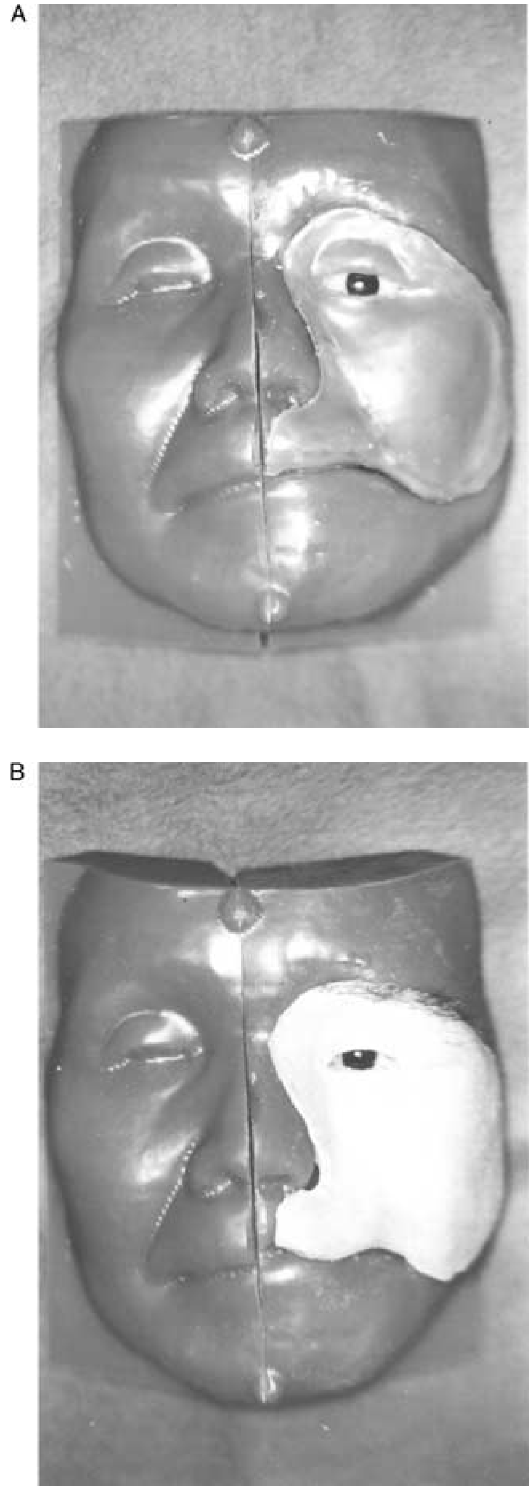

Figure 5. (*A*) An artificial eye was attached to the wax pattern, which was then fitted to the patient. (*B*) Minor corrections were made to the wax pattern, and the final color tone of the prosthesis was determined at the clinic.

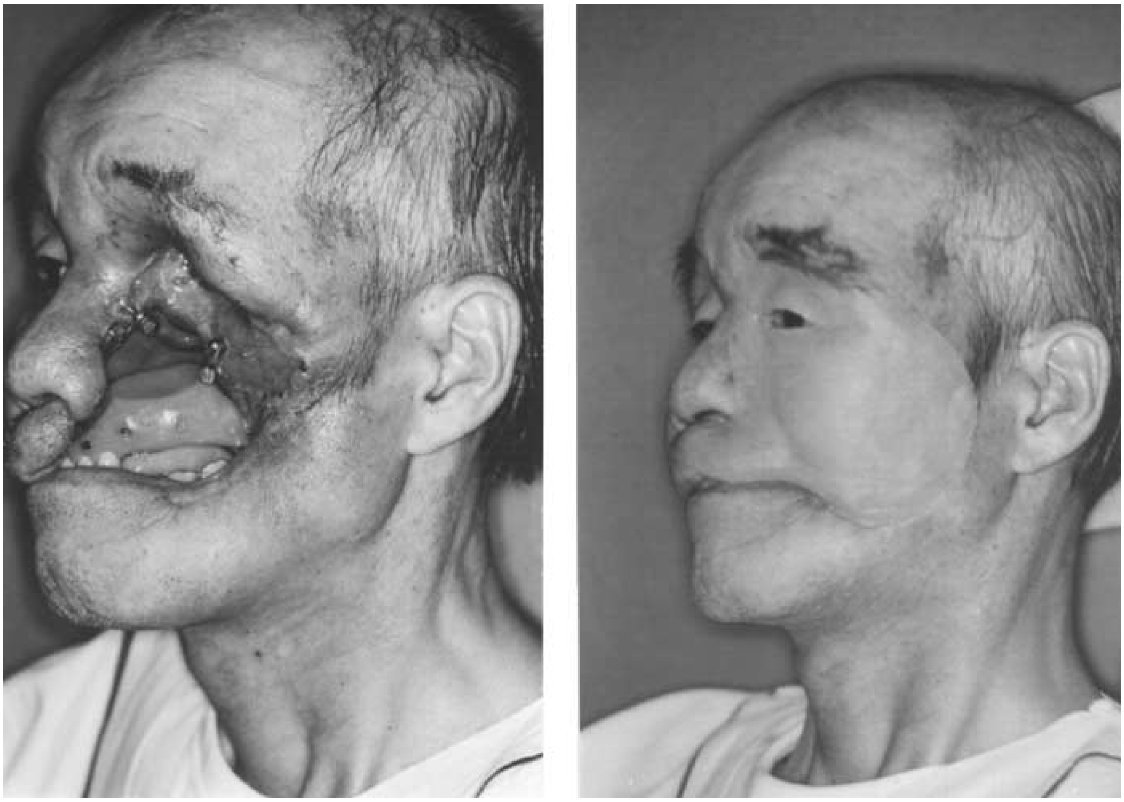

Figure 6. Left: Two implants were placed into the zygomatic bone and used to anchor the prosthesis. Right: Patient with the facial prosthesis in place.

Discussion

When a facial impression is obtained using dental impression material, the impression will tend to be precise in regions where soft tissues are thin, and relatively immobile and less precise in regions where soft tissues are thick and more mobile. Distortion of the soft tissue is a function of both the type of tissue and the weight and consistency of the impression material.[1-4]

In contrast, the use of a laser to obtain facial measurements allows precise measurement without distortion of the facial soft tissue. In addition, patient anxiety and discomfort resulting from covering the face and restricting the airway during the impression procedure are reduced. The method is also useful for obtaining morphologic measurements without contact in patients suffering from infectious disease.

In the conventional method, a wax pattern is fabricated to reproduce normal facial morphology. The prosthesis is based on a plaster cast produced by the open-eye impression technique for orbital prostheses. The quality of the prosthesis is strongly dependent on the subjective judgment of the person who produces the wax pattern of the prosthesis.[3,14]

In the method described here, facial morphological measurements are obtained with the eye open, and the morphological data on the normal side is reversed against the facial median line. This allows the technician to develop optimal anatomic morphology of the prosthesis. In addition, the procedure for making a wax pattern is much simpler, resulting in a shorter processing time. No special skills are required in the person producing the pattern, and the 3D facial morphological data obtained can be retained as long as required, without the need to store actual physical casts.

It should be noted that the mirror image of the normal side may not perfectly match the normal morphology of the affected side because facial morphology is typically asymmetrical.[15,16]

As a result, the shape of the wax pattern must be adjusted when it is fitted to the patient.

Compared to the traditional method, the fabrication procedures in the method described here are simplified. In procedures currently under development, the production of the wax cast and silicone rubber mold may be omitted. Fabrication of a facial prosthesis by milling silicone rubber directly may be much simpler than current maxillofacial laboratory procedures.

Chen et al have reported a method in which facial morphological measurements were obtained using a non-contact 3D morphological measurement system. Their method consisted of developing a wax pattern of the maxillofacial prosthesis that was fabricated directly using a milling machine.[8] Even the morphological design of the maxillofacial prosthesis was performed by computer; complicated data processing such as curved surface generation was required. In contrast, in the method described here, a wax pattern is fabricated manually based on a facial wax cast of the affected side and a silicone rubber impression of a mirror-image facial cast. Although the method reported by Chen et al has great future potential, practical implementation will require the development of a new software. In addition, problems relating to the compatibility of the facial prosthesis with surrounding tissues remain to be overcome.

It can be anticipated that patient discomfort will be further reduced when high-precision computer-designed facial prostheses can be directly fabricated, without the need to produce an intermediate wax pattern.

Conclusions

A simplified method has been developed for the fabrication of facial prostheses using a non-contact 3D morphological measurement system and a CNC milling machine. Application of the methodology to the fabrication of actual prostheses is described.

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