Mandibular Defect Reconstruction with the Help of Mirror Imaging Coupled with Laser Stereolithographic Modeling Technique

Jing-Wei Lee,[1]* Jing-Jing Fang,[2] Li-Ren Chang,[1] Chau-Kai Yu[2]

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With the advent of microsurgery, composite defect in the mandible can be repaired with various forms of osteocutaneous free flaps. However, it is difficult to accurately reconstruct a large defect in the mandible when not enough mandibular reference blueprints remain. This case report describes a large ameloblastoma at the left lower molar region and ascending ramus of the mandible in a 53-year-old male patient. Before surgery, spiral computed tomography scanning of the whole skull of the patient was performed. Using three-dimensional reconstruction and mirror imaging coupled with laser stereolithographic technique, a complete mandibular biomodel with idealized shape was fabricated. A titanium reconstruction plate was made using the biomodel as a guide. The tumor mass together with the left mandible from the second premolar to the condylar head area was resected *en bloc*. The large mandibular defect was then reconstructed with the precontoured titanium plate and three segments of vascularized fibular bone graft fixed along the plate. The temporomandibular joint was restored with temporalis muscle as an interpositional disc replacement. The complex defect in the mandible was thus repaired with satisfactory functioning and esthetic result. We suggest that with the help of mirror imaging coupled with laser stereolithographic technique, a precontoured titanium plate can be made for the reconstruction of large mandibular defects. [*J Formos Med Assoc* 2007;106(3):244–250]

Key Words: ameloblastoma, laser stereolithography, mirror image, temporomandibular joint

With the advent of microsurgery, composite defect in the mandible can be repaired with various forms of osteocutaneous free flaps. There are numerous publications describing personal favorable experiences,[1] and yet a truly flawless reconstructive result is not easy to attain. First, it is difficult to replicate the complex three-dimensional conformation of the mandible. Second, any aberration in its structural alignment may very likely lead to functional disturbance like malocclusion or temporomandibular joint (TMJ) syndrome. Situations like extensive bone resection, temporomandibular joint involvement, or severely distorted bony contour would add to the difficulties in a reconstructive task.

We report a case of ameloblastoma involving the left mandible with severe destruction of the native bony structure. The mandibular condyle was removed together with the surgical specimen and needed to be restituted. With the combined use of

[1]Section of Plastic Surgery, Department of Surgery, National Cheng-Kung University Hospital, and [2]Department of Mechanical Engineering, National Cheng-Kung University, Tainan, Taiwan.

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***Correspondence to:** Dr Jing-Wei Lee, Section of Plastic Surgery, Department of Surgery, National Cheng-Kung University Hospital, 138 Sheng-Li Road, Tainan 704, Taiwan.
E-mail: jwlee@mail.ncku.edu.tw

mirror imaging technique and stereolithographic modeling, we were able to produce a biomodel of the mandible with an idealized morphology. A reconstruction plate was bent and contoured accordingly. It was then employed as a surgical template that greatly facilitated our work in mandibular reconstruction utilizing vascularized fibular flap.

Case Report

A 53-year-old man presented with a painless, progressively enlarging mass on his left cheek (Figure 1A and B). The mass measured 6 × 5 × 4.5 cm in extent, and appeared to arise from the marrow space of the left mandibular body, with upward extension to the condylar head region. The inner and outer cortex had been separated far apart by the expansile force of the cystic lesion and attenuated to a thin layer of bony shell (Figure 1C and D). The mass was hindering his jaw motion and also caused a cosmetic problem. Clinical evaluation favored the diagnosis of ameloblastoma.

Preoperatively, spiral computed tomography (CT) scanning of the whole skull was done, using 1–3 mm slice thickness. The acquired digital data were transferred to self-developed surgical planning software in a personal computer for advanced process planning. Through a series of region of interest extraction and management, we were able to reconstruct the patient's skull (Figure 2A). For the purpose of rebuilding a left-side mandible from the right, we first employed the cutting tool provided in the software to remove

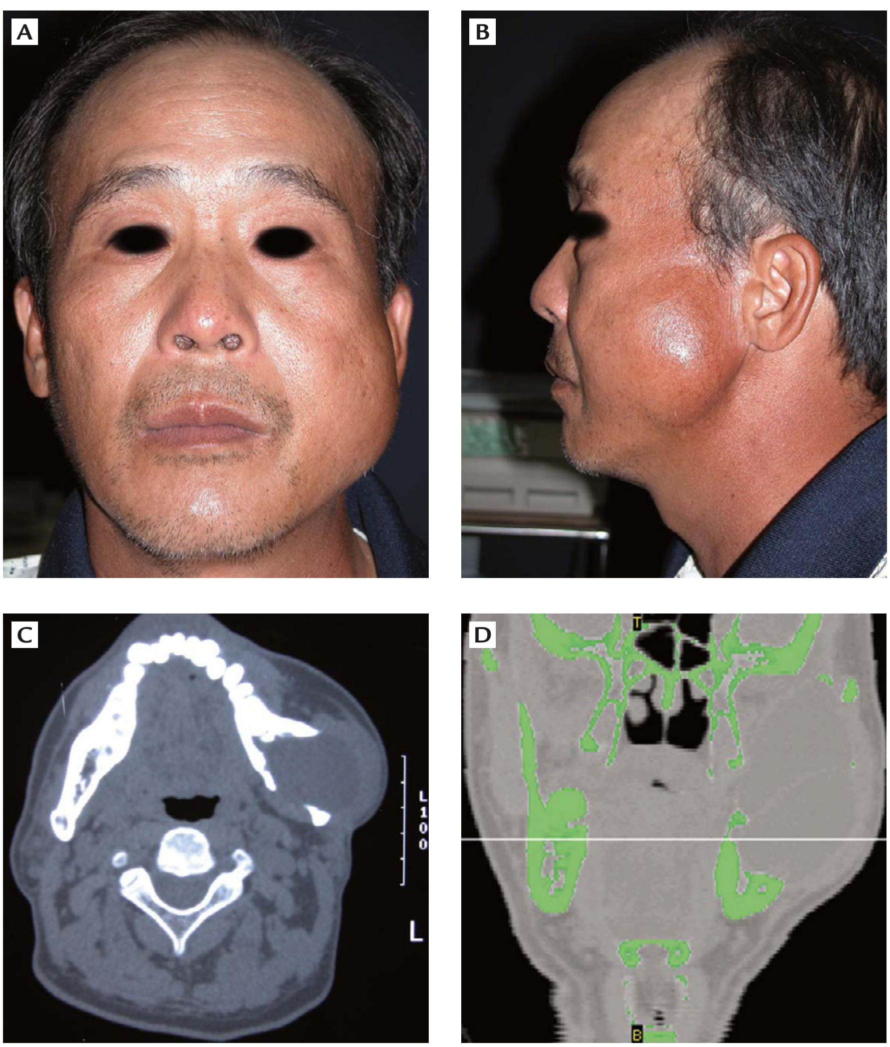

Figure 1. A 53-year-old man with a left cheek bulging mass arising from the mandibular angle and ramus. (A) Frontal view. (B) Lateral view. (C) Axial view on computed tomography (CT). (D) Coronal view on CT reveals bone resorption and condyle destruction.

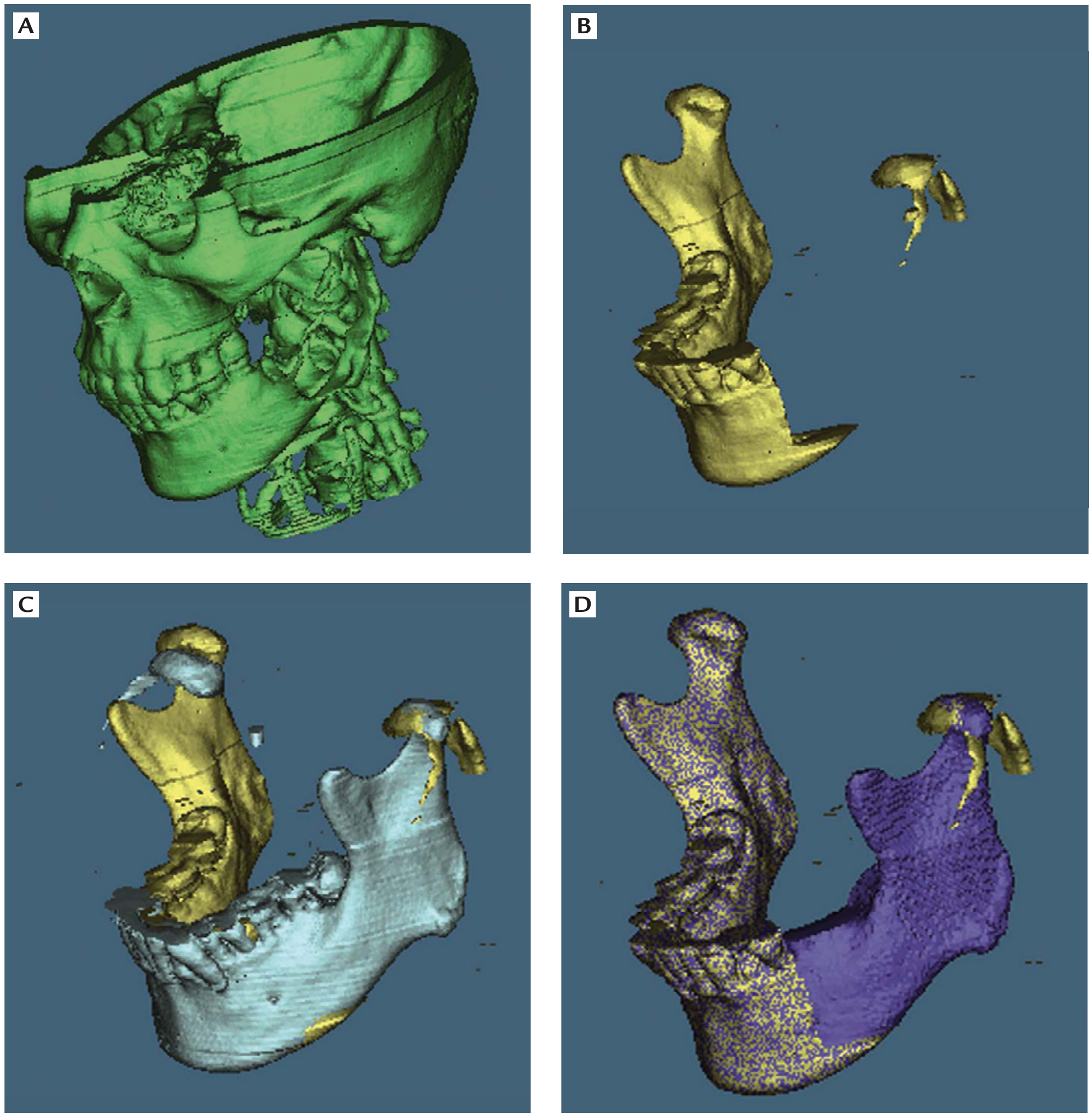

Figure 2. Three-dimensional reconstruction of computed tomography imaging data. (A) Original contour in green color. (B) Isolated mandibular shadow in yellow color. (C) Mirror image in light blue color, merged into the original framework. (D) The hybridized final construct in deep blue and gray color.

the disease-afflicted portion and the remnant mandible image was portrayed in yellow color. The condylar cap was retained as a guidepost to ensure accurate positioning of the final construct (Figure 2B). The mirror image of this remaining mandible was then created sideways and shown in light blue color. The mirror image mandible model was moved to match the primary mandible remnant until the maximal degree of merging was achieved (Figure 2C). The replacer, shown in purple blue color in Figure 2D, was extracted from the mirror image mandible model via difference operation. Consequently, the final appearance of the mandible was settled on by coaptating the healthy segment with the replacer. The preplanning data of this virtual mandible and the replacer were then transferred into physical production as a facsimile model using laser stereolithographic technology. The biomodel served as a guide for surgical planning (Figure 3A). A reconstruction plate was bent and adapted to fit the outer surface of the model. Numerous reference points were demarcated on the biomodel so as to define the exact localization of the plate and screws. The restituted condylar head was noted to be 1.2 cm above the superior edge of the

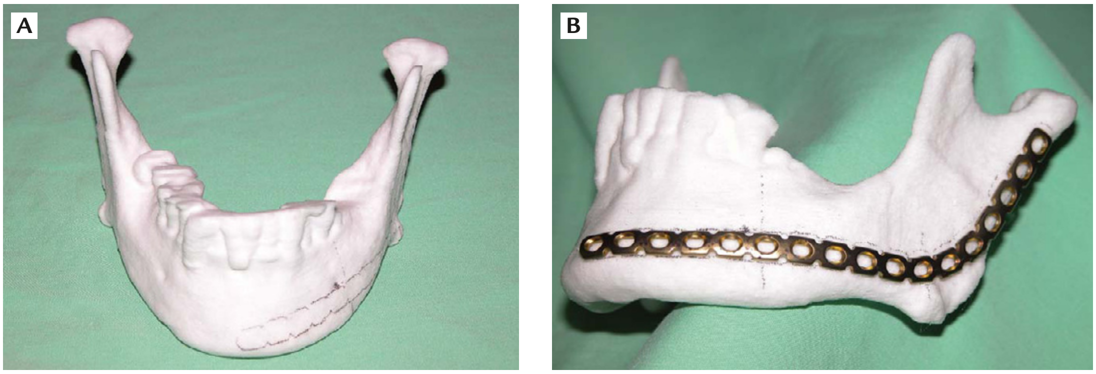

Figure 3. (A) STL model of the revised mandible. (B) Biomodel with preformed reconstruction plate in place. The stylographic landmark denotes the exact localization of the plate and screw in real surgery.

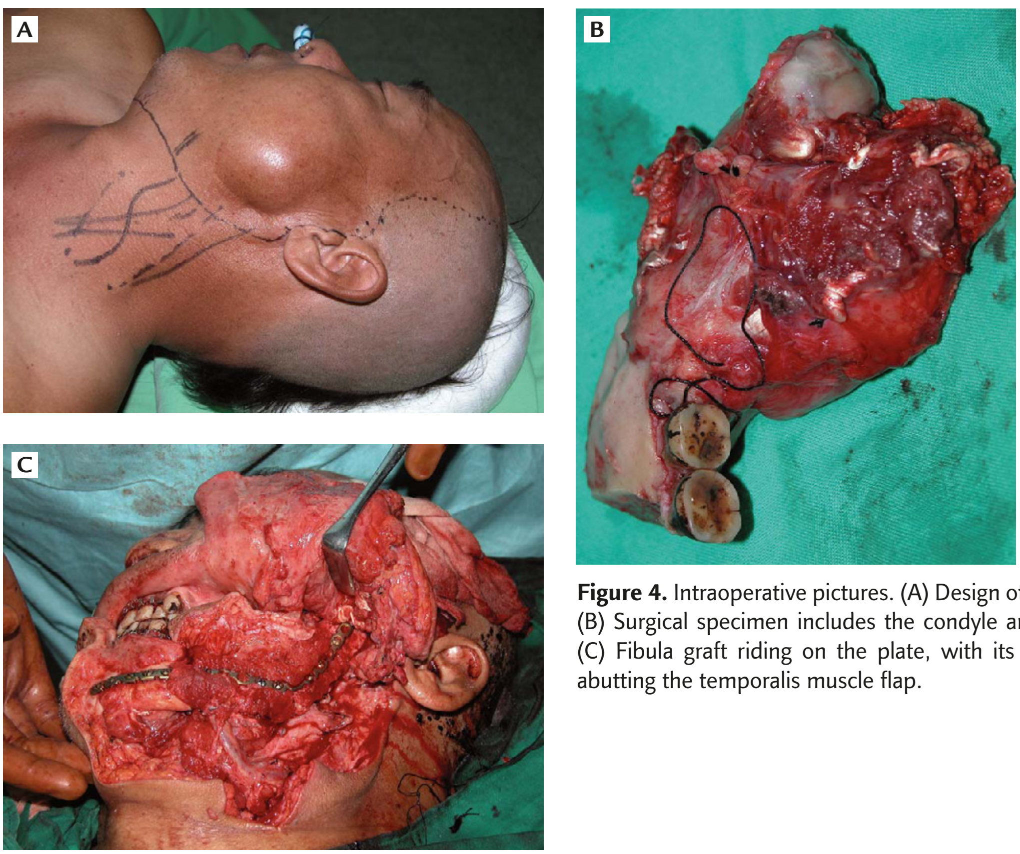

Figure 4. Intraoperative pictures. (A) Design of skin incision. (B) Surgical specimen includes the condyle and the tumor. (C) Fibula graft riding on the plate, with its rounded end abutting the temporalis muscle flap.

plate (Figure 3B). This prefabricated plate then served as a reference template to guide the orientation and positioning of the graft.

During surgery, the skin incision was designed in such a way that the soft tissue envelop of the left lower face could be raised like an apron flap and flipped up superiorly to expose the bony structure (Figure 4A). In the meantime, the facial nerve was dissected out and looped up to avoid inadvertent damage. A 10.5-cm long segment of left mandible, from the second premolar to the condylar head level, was resected *en bloc* (Figure 4B). Intermaxillary fixation was achieved using soft arch bar appliance. Then, the precontoured reconstruction plate was fixated onto the remaining mandible. An 11-cm long vascularized fibular bone was osteotomized into three segments and fixated along the plate. The free end of the fibula was shaped into a rounded form so as to function like an articular surface, thereby simulating

Figure 5. Follow-up pictures. (A) Frontal view 15 months postoperatively. (B) Open mouth view 15 months postoperatively. (C) Stable dental occlusal pattern 3 months postoperatively. (D) Panorax film follow-up.

a condyle. Next, a piece of pedicled temporalis musculofascial flap was inserted into the joint space to act as a cushion (Figure 4C). Intermaxillary fixation was maintained for 2 weeks. In the following 6 weeks, by varying the number and strength of the orthodontic elastics, we allowed the patient to open and close his jaw with the mandible consistently kept in the midline. The patient fared well finally with stable occlusion, symmetric facial appearance, acceptable diet quality, and mouth opening up to 35 mm during 15 months of follow-up (Figure 5A and B); occlusal relationship appeared acceptable 3 months after surgery (Figure 5C). Postoperative panorax film demonstrated good alignment of the skeleton and acceptable positioning of the renewed "condyle" (Figure 5D).

Discussion

Large segmental defects in the mandible are difficult to reconstruct. It is well recognized that free fibular flap is the preferred donor site for this object. Almost any length or localization of mandibular defect can be amended using this technique.[2–4] However, the straight configuration and the rigidness of the fibula incur much difficulty in carpentering, which can result in a less-anatomic reconstruction, with a degree of malocclusion or disfigurement.[5]

Such a reconstructive task may become even more difficult when there is an associated TMJ destruction. There are three types of treatment tactics commonly utilized for condylar restoration.[6] One option is to reimplant the resected condyle on top of the fibular free flap end. Another choice is to use a prosthetic condyle and attach it to the end of the fibular flap. A third solution is to shape the end of the free flap to mimic an articular surface, thereby making it behave as a functioning condyle.

The prosthetic joint procedure has largely been abandoned due to its high failure rate. We therefore elected to use the third strategy, i.e. shaping the graft end to simulate a condyle. Although the rationale of this method seems viable, we still had concerns about the wearing and attritional effect at the contact zone. We thus decided to transpose the temporalis muscle flap as an interpositional disc replacement. This transferred muscle flap serves to absorb the physical impact during mastication and helps to lessen the abrasion damage upon joint motion. Besides that, rotational movement is greatly facilitated and is observed to be associated with stretching of the intervening muscle layer.[7]

Laser stereolithography was introduced in the early 1990s. A high-precision anatomic facsimile model can be fabricated utilizing photocurable, liquid acrylic resin. It is instrumental in the visualization, measurement, and analysis of complex facial features. Operative procedures can be simulated on the models. Implants or surgical templates, if indicated, can be preformed on the models prior to the real operation.[8–10] Thus, it helps to reduce operation time and enhances the accuracy of surgery. In the past, most clinical applications were related to defect repair at the calvarial, midfacial, or orbital region.[11–13] Its use in mandibular restoration was relatively less frequently reported in the literature.[14] Though in recent years, as the technology has become mature and advanced, simultaneous correction of dental and skeletal derangement, which involves the presurgical fabrication of a dental implant or occlusal splint and meticulous techniques for registration, has become feasible.[15,16]

Stereolithographic biomodeling played an important role in the management of this patient. Since the regional anatomy had been distorted by the expanding mass, we had trouble in defining the original contour of the skeleton, which in turn caused great disturbance in surgical planning. Thanks to the technologic progress in computer-aided design, it is now possible to mirror an intricate structural image from the healthy side and use it as a gold standard to rebuild the diseased component. Traditionally, the method used to produce a mirror image part is a digital comparison (subtraction) on either side of a "user-defined plane of symmetry", which is assumedly equivalent to the midsagittal plane of the body.[17] However, the human skull has a highly intricate and irregular configuration, and is never perfectly symmetrical geometrically. Therefore, identification of the anatomic midpoint or sagittal plane is not so straightforward as one might think. Any deviation or slanting of this selected plane would result in two-fold discrepancies from the real truth. In view of this, we abandoned the traditional approach and set up the virtual mirror plane outside the whole skull territory. Thereby we could generate a mirror image of the entire subject rather than copying only half of it. Then we proceeded to merge the two images together so that the maximal degree of confluence was achieved. It is noteworthy that the final positions of bilateral condyles as well as the chin point should be kept exactly the same as they were before. This tenet helps to guarantee the preservation of the preoperative dental occlusal pattern and to produce a symmetric facial contour.

It should be noted that the mirror image technique, although it is a powerful workhorse in the field of computer-aided design, is not without its limitations. For instance, it would not be suited for those who have cross-midline lesions, since both sides of the skeleton are involved and neither could be used as the standard template. In that case, we would have to seek other sources of geometric reference. The maxillary alveolar arch could be used as a guide to determine the approximate configuration of the mandible. Besides that, using an average person's mandibular model as the basic reference is another practical approach, since the morphologies of a mandible among general people are so much alike. Usually, a reasonable result can be achieved with just minor adjustments in contour.

With all the sophisticated and painstaking preparation, it is equally important that the operation should be executed precisely as preplanned. In order to achieve this, we meticulously recorded the localization of the plate in relation to the mandible body and nearby teeth. Those measurements were repeatedly checked and strictly followed during the actual surgery. Besides that, the fibula bone graft was adapted passively upon the reconstruction plate without straining it, lest any deformation occur. Furthermore, the round-ended fibula that acts as the condylar head was exactly 1.2 cm beyond the edge of the reconstruction plate as predicted from preoperative planning. The satisfactory final outcome speaks favorably for the effectiveness and the accountability of our strategy.

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