CAD/CAM and rapid prototyped titanium for reconstruction of ramus defect and condylar fracture caused by mandibular reduction

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Fracture or defect of the mandible is a serious complication of mandibular angleplasty, and precise reconstruction for such defect is still a huge challenge. This case report provides a new method based on CAD/CAM and rapid prototyped titanium for individual design, fabrication, and implantation of a mandibular ramus and angle. A 25-year-old woman with a square-shaped face, who had undergone mandibular outer cortex split ostectomy (MOCSO) 3 months earlier, was afflicted by a series of symptoms: asymmetric face, collapse of the right face, masticatory problems, deviation during mouth opening, malocclusion, and TMJ clicks. These symptoms were caused by unintentional removal of the fractured ramus during MOCSO. By means of CT scan data, rapid prototyping, reverse engineering, 3D display, and CAD/CAM, the individualized titanium implant was designed and fabricated. The 3D demo system of operative scheme demonstrated the operative procedure, and determined the position of the implant so as to obtain a perfect fit. Postoperatively, the patient regained satisfactory morphologic symmetry, facial appearance, occlusion, and TMJ functions. (Oral Surg Oral Med Oral Pathol Oral Radiol 2012; 113:356-361)

In East Asians, a square face is considered unappealing, as it imparts a coarse and masculine look. Asian women prefer to have an ovoid and slender facial contour, which is thought to be more feminine and attractive. Mandibular contouring surgery has become a commonly performed procedure1-4; however, there are some serious complications reported. One complication is a fracture or defect in the mandibular ramus and condyle,5,6 which might occur during mandibular outer cortex split ostectomy (MOCSO) when the horizontal ostectomy line is too deep or the ramus is too thin. During splitting, if the surgeon is unaware of the full horizontal fracture, the split ramus might be inadvertently pulled out. Here, we report a case of application of computer-aided design/computer-aided manufacturing (CAD/CAM) and rapid prototyped titanium reconstruction for such a ramus defect and condylar fracture created during MOCSO.

CASE REPORT
A 25-year-old woman with a square-shaped face underwent MOCSO. The right mandibular angle and the posterior border of mandibular ramus were osteotomized and freed. However, an unusually large bony segment was pulled out unintentionally. As the surgeon could not cope with this daunting task, another surgeon fixed the free mandibular condyle by pulling it antero-inferiorly, to the stump of the ramus under direct vision by approaching through the extended preauricular incision.

The patient visited our hospital 3 months after the ill-fated operation. She complained of a variety of symptoms, such as reduction of masticatory efficiency, deviation of mouth, collapse of the right face, malocclusion, and temporomandibular joint (TMJ) clicks soon after the operation. We discovered that the loss of the right mandibular ramus and shortening of the right ramus led to these symptoms. The occlusion was barely acceptable, and the maximal mouth opening was 22 mm and mouth-opening deviation was 8 mm (Fig. 1). Computed tomography (CT) scan showed that the right defective mandibular ramus appeared irregular. Because of antero-inferior displacement and oblique position, the condyle was not completely located in the glenoid fossa. The coronoid process had also shifted anterosuperiorly. A mini plate had been used to fix the condyle and the ramus (Fig. 2).

Autogenous bone graft is the most commonly accepted method for reconstruction of bone defects; however, it has some drawbacks, such as exploration of a second surgical site, donor site morbidity, poor abrasion resistance, and bone resorption. More importantly, it is difficult to obtain satisfactory restoration of facial contour and TMJ functions. At present, a new method based on CAD/CAM and rapid prototyped titanium provides a promising solution.7

The data of the CT scan acquired with a 0.1-mm slice thickness was imported into 3DSMR software (Beijing Gim-mafei Science and Technology Development Co., Ltd, Beijing, China). The craniofacial skeleton was visualized with a slice reconstruction interval of 0.5 mm in a 3-dimensional (3D) display for evaluation of the defect. Pro/E (PTC Corp., Needham, MA, USA), Solidworks (Dassault Systemes S.A.,
Velizy, France), and Geomagic software (Raindrop; Geomagic, Research Triangle Park, NC, USA) were used to reconstruct the right missing segment by mirroring the left healthy ramus. After reverse engineering, it was shown that the right digitalized individualized titanium mesh and the left healthy ramus were absolutely symmetric. Then, the data were converted to a mesh-based surface representation (STL) format and was downloaded to a CAM machine to fabricate the skull replica and the digitalized titanium mesh in the My Center-3XiF laser prototyping system (Beijing Gimmafei Science and Technology Development Co., Ltd, Beijing, China).

Placing the titanium implant in the correct position and replacing the condyle in the glenoid fossa is a key procedure in restoring the defective ramus to improve preexisting problems, such as facial asymmetry, malocclusion, and mouth-opening deviation. The 3D display was used to locate the titanium mesh, which ensured the location of the titanium implant in complete concordance with the original bone (Fig. 3).

Fig. 1. a, Preoperative anterior view of the patient: note the facial asymmetry. b, maximal mouth opening: note the deviation toward the right during mouth opening. Preoperative lateral views of the patient: right side, note the collapse of the ramus and gonial area (c), left side (d).
Fig. 2. Visualized 3D display based on helical CT: a, the dorso-ventral view; b, the right lateral view. The right posterior border of ramus was missing, the condyle was fixed antero-inferiorly to the stump of the ramus, and the coronoid process was positioned antero-superiorly because of temporal muscle pull.

Fig. 3. a, The CAD display shows orientation of implant by surgical guides. b, CAD/CAM and rapid prototyped titanium implant. The implant was inserted into the defective area and fixed using miniscrews. c, The view from the extended preauricular incision, note the condyle and coronoid process reset and fixed at the exact normal position by the implant. d, The view from the intraoral incision.
Stable occlusion was obtained by intermaxillary fixation (IMF) with dental arch splints before surgery. The complete exposure of the TMJ area and the defective ramus was achieved through the intraoral route and preexisting preauricular scar. The 3D demo system of operative scheme was also developed to determine the position of the mesh, and also to observe the amount of contralateral mandibular angle to be resected to obtain facial symmetry. The condylar segment was mobilized postero-superiorly and coronoid segment antero-superiorly back to their original location. The titanium implant was then placed in the defect site reestablishing the connection between the condylar and the coronoid segment.

Fig. 4. Views of the patient at follow-up, 6 months after the operation. a, The anterior view. b, Maximal mouth opening, note the marked decrease in deviation during mouth opening. The lateral views: c, right side; d, left side, note the symmetry of the facial contour.
and the mandibular body. The titanium mesh was fixed at the designated position using screws (Fig. 3). Mouth opening training was performed for 3 months postoperatively as per the methods of Kun Hwang et al.6 During the follow-up period of 6 months, correction of facial asymmetry was ultimately achieved, with maximal mouth opening increasing to 40 mm, and mouth-opening deviation decreasing to 2 mm. There was disappearance of TMJ pain and acceptable occlusion was achieved postoperatively (Figs. 4 and 5). The 3D-CT also showed the ramus defect well reconstructed by the digitized titanium mesh. The implant was oriented at the designated position and the condyle and coronoid process were reset and fixed at the exact normal position by the implant (Fig. 6).

DISCUSSION
Fracture or defect of the mandibular ramus, which is considered a serious complication of mandibular reduction, is still a daunting task, largely because surgeons have trouble reforming the original morphologic symmetry along with restoration of the various TMJ functions.5,6 To date, autogenous bone graft is the gold standard for reconstruction of mandibular ramus and condyle. However, there are some inevitable disadvantages, such as exploration of the second surgical site, donor site morbidity, poor abrasion resistance, bone resorption, and difficulty in reshaping. Even more demanding is the difficulty in regaining an exact mandibular contour.7-9

In view of the imperfection of the traditional methods for reconstruction of mandibular ramus defect and condylar fracture, we should explore new ways that have obvious superiority. Titanium is known for its biostability, biosafety, and biocompatibility. In this case, the digitalized individualized titanium implant was designed on the basis of the patient’s CT scan data, which were input into reverse engineering software to
reconstruct the defective ramus through the mirror imaging of the left part, thus providing exact facial symmetry.\textsuperscript{7,10} The digitalized implant was made according to the virtual data with rapid prototyping technique. CT scan, rapid prototyping, reverse engineering, and computer modeling are the determinants of simplification, acceleration, and perfection of surgical planning, manufacturing of customized mesh, and immediate reconstruction. Likewise, autogenous mandibular angle bone graft obtained from MOCSO of the contralateral side can avoid the second surgical site and donor morbidity. These techniques similarly ensure less surgical time, fewer operational errors, more precise fit, and much better stability postoperatively.\textsuperscript{11,12} This method also helps achieve preoperative mesh fit testing and definition of the desired location of the mesh, resulting in near perfect implantation.

REFERENCES

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