the preservation of a larger part of the lower jaw section, the use of an allogeneic prosthesis was entirely sufficient.[8,9] The custom-made prosthesis thus not only enabled reconstruction of occlusion and restoration of full jaw function, but the extended titanium section of the acetabulum component also covered the skull defect and the polyethylene part of the fossa concurrently replaced the absent zygomatic arch.[8]

CONCLUSIONS

An alloplastic custom-made prosthesis was the only option in the case of this patient. Although this was a patient at increased risk of recurrence, the authors gave preference to improving her quality of life. Taking into account the fact that a possible recurrence of the osteosarcoma could mean a significant risk of mortality then every year of life lived to the fullest is a benefit for this particular patient.

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OPEN

Computer-Aided Autogenous Coronoid Process Graft Combined With Median and Unilateral Sagittal Split Osteotomy for Late Reconstruction of Condylar Fracture and Occlusion after Trauma

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Purpose: This study proposes a high-precision surgical technique that combines both computer-aided design/computer-aided manufacturing (CAD/CAM) and the screw-track transfer technique for condylar and occlusal reconstruction.

Materials and methods: A 43-year-old male patient with facial asymmetry, limited mouth opening, and malocclusion underwent condylar and occlusal reconstruction surgery. An autogenous cor-onoid process graft was performed by combining CAD/CAM and the screw-track transfer technique.

Results: The surgical plan was transformed successfully from preoperative virtual surgical planning to actual surgery; this was confirmed by merging the postoperative computed tomography images with the preoperative three-dimensional surgical design. The patient recovered well and had better occlusion and facial symmetry, as well as an increased degree of mouth opening post-surgery. No complications were observed.

Conclusions: CAD/CAM combined with the screw-track transfer technique is a precise and feasible method that can be applied to autogenous coronoid process grafts. This approach can be used to reconstruct the condylar process and achieve a good occlusal relationship.

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Complex maxillofacial trauma not only causes soft tissue injury and maxillofacial bone fracture, but also a series of sequelae.[1,3] Despite appropriate treatment, condylar fractures can result in loss of the condyle, which means that reconstruction of the temporomandibular joint is necessary.[4–6] However, it remains a challenge to rebuild the condylar process to a structurally and functionally satisfactory standard.[7,8] Recently, autogenous coronoid process grafts have been recognized as an ideal option for condylar reconstruction, due to the suitable shape and thickness of the coronoid process, its accessibility, and the satisfactory postsurgical results.[9–14] However, the success of the surgery relies on the accuracy of the deformity diagnosis and the presurgical planning. It is generally agreed that computer-aided design/computer-aided manufacturing (CAD/CAM) can assist in the surgical correction of tissue defects, repositioning of dislocated fragments, and the shaping of bone asymmetry. However, while CAD/CAM can be used to predict and facilitate surgical results to some extent, the accuracy of the surgery still needs to be improved. Here, we report a new method combining CAD/CAM with the screw-track transfer technique for unilateral condylar reconstruction with an autogenous coronoid process graft. This approach resulted in both precise improvements in the occlusal relationship and satisfactory patient esthetic results.

CLINICAL REPORT

A 43-year-old male patient with a chief complaint of facial asymmetry and malocclusion almost one year following a car accident presented to our hospital (Fig. 1). CT scan of the craniomaxillo-facial area showed multiple morphological differences and variations in bone and soft tissue. Three-dimensional reconstruction showed a mandibular ramus partial defect on the right side. Clinical examination revealed that the chin had shifted 8 mm to the right, and an almost 10 cm-long surgical scar was observed on the right side of his face from his mouth to his ear. intra-oral examination showed permanent dentition with an absence of the bilateral lower central incisors and right lower lateral incisor as well as malocclusion with anterior open bite and posterior crossbite on the right side. The maximal mouth opening was 30 mm and mouth opening was deviated to the right.

To precisely reconstruct the right condyle and correct the occlusion, surgery was proposed based on CAD/CAM. The proposed surgery involved sagittal split ramus osteotomy (SSRO) on the left side, mandibular symphysis osteotomy, and right condyle reconstruction with a right autogenous coronoid process graft navigated by the screw-track transfer technique.

The CT scan data were acquired by a CT unit (LightSpeed VCT 64-slice Scanner; GE, Inc, Fairfield, CT) with a 0.625-mm slice thickness. Terminal occlusion was confirmed by a surgeon and orthodontist using dental super-hard gypsum. Then, scanning was performed with a 3D laser scanner (Activity 880; Smartoptics, Germany); the file was saved in STL format. After collection of the digital data and completion of the clinical examination, the data were imported into PROPLAN CMF^{TM} 3.0 (Materialise, Belgium) for surgery design and 3-dimensional (3D) display (Fig. 2).

FIGURE 1. Preoperative specialized examination. (A) Views from different directions. Obvious facial asymmetry and a contracted scar on the right side of the face can be seen. (B) Patient's preoperative occlusion.

The patient's dentition and occlusion were replaced by a laser-scanned 3D-operable super-hard gypsum model to achieve greater accuracy (Fig. 2A). Then, the left SSRO and mandibular symphysis split were virtually implemented to separate the mandibular body. Next, the final position of the mandible was matched with the terminal occlusal model in order to determine the position of the maxilla and mandible (Fig. 2B). To achieve better occlusion, we designed a surgical guide to remove a piece of mandible from the chin region during splitting of the mandibular symphysis, and

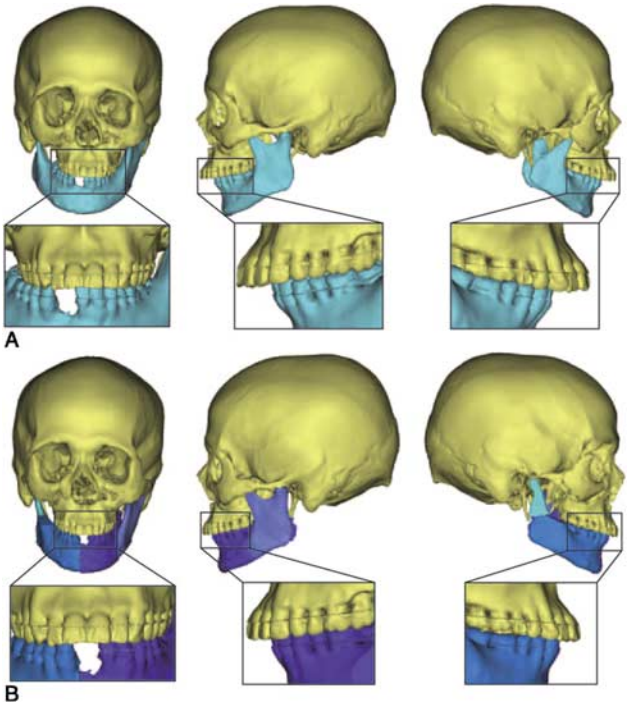

FIGURE 2. Occlusal relationship. (A) Preoperatively, the patient was diagnosed with deep overjet and overbite as well as a unilateral crossbite on the right. (B) Terminal occlusion.

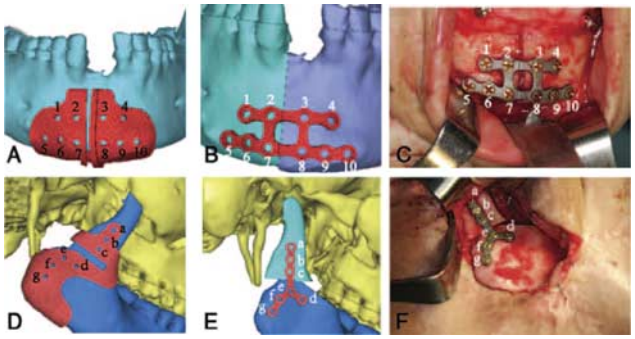

FIGURE 3. (A and D) Design of the resection and reconstruction guide on the chin and mandibular angle. (B and E) The design of the corresponding titanium plate. (C and F) The mandible is combined with the 3D-printed titanium plate.

then performed fixation of mandible by titanium plate (Fig. 3A-C).

Determination of the coronoid process position is vital for TMJ reconstruction. First, we cut the right coronoid process anterior to the glenoid fossa and medial to the zygomatic arch. Then, the top of the coronoid process was placed in an appropriate location below the glenoid fossa while the distal end was placed close to the mandible body. In order to achieve accurate virtual surgical planning, we designed a surgical template for locating screw holes from the inferior margin of the mandible to the coronoid process. The holes on the titanium plate matched the holes on the surgical template to assist with positioning and connecting (Fig. 3D-F). Finally, the terminal occlusion template, mandible model, and surgical templates were printed in 3D based on the virtual surgical planning and were used to guide the surgery.

Due to the multiple surgical areas, the surgical procedure was first performed on the unaffected side followed by the condylar-defect side. After general anesthesia and intubation, unilateral SSRO was performed on the left (Fig. 4A). Then, mandibular symphysis osteotomy was performed to remove excess bone, guided by the template, and fixation was performed (Fig. 4B). Then, the left mandibular body was fully freed. Next, the terminal occlusion template was placed and intermaxillary fixation was performed. After that, the titanium plate was used for rigid internal fixation. A straight four-hole titanium plate was fixed to the left distal end of the mandible body while the trapezoidal titanium plate was fixed to the chin.

For right condyle reconstruction, the open transcutaneous approach was cut along the original surgical scar from the inferior edge of the mandible to the mentum on the right side of the face in order to expose the posterior border of the mandibular ramus and coronoid process. Next, the surgical template was applied at the angle of the mandible and coronoid process, and the coronoid process was cut off and contoured. After releasing the soft tissue around the glenoid fossa, the coronoid process was put in place (Fig. 4C). The final position of the titanium plate was guided by the screw holes which corresponded to those punched on the surgical template. Finally, the terminal occlusion was checked to ensure it was consistent with the presurgical design (Fig. 4D).

The patient achieved satisfactory results after the surgery. The terminal occlusion template was removed one month after surgery, and it was planned to remove the titanium plates one year later. No postoperative complications were observed during follow-up. The patient's occlusion was stable and mouth

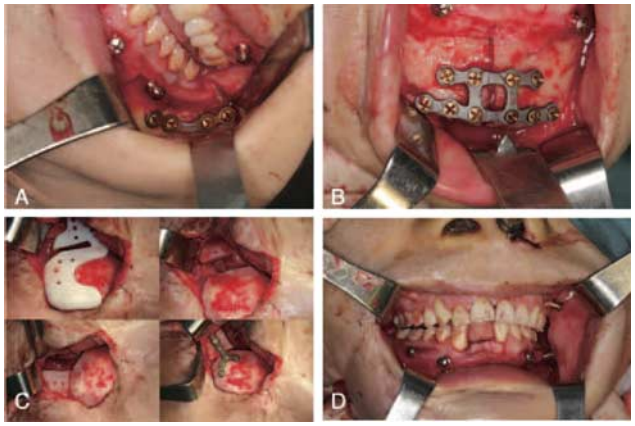

FIGURE 4. Surgical procedure. (A) Unilateral SSRO and internal fixation. (B) Mandibular symphysis splitting and internal fixation assisted by the surgical guide. (C) Procedure for the resection of the right coronoid process and condylar reconstruction. (D) Terminal occlusion.

FIGURE 5. Images of the patient at follow-up. (A) Three months after the surgery, and (B) 6 months after the surgery.

opening to almost 4 cm was achieved. Further, the facial scar contracture was released (Fig. 5).

DISCUSSION

Mandible condyle defects result in limited jaw opening, malocclusion, and facial asymmetry.[15] Either autogenous or alloplastic grafts can be used for condyle replacement. Among the autogenous grafts, mandibular coronoid process grafts and costochondral grafts (CCGs) are considered to be effective alternatives for condylar reconstruction.[7,8] Compared with CCG, coronoid process grafts have several advantages, including the avoidance of a second surgical incision, rare growth potential, and an appropriate shape and thickness.[7,11,16]

In maxillofacial plastic reconstruction surgery, precise recovery of aesthetics and function are the primary goals.[2,17,18] There were two pivotal procedures performed in this case. The first was virtual surgical planning. Both the occlusive relationship and the position of the right mandibular ramus must be taken into consideration when addressing terminal occlusion, and both are related to whether the coronoid process is smoothly in place. Moreover, in this case, the extra pieces of bone in the mandibular symphysis, as well as the subcoronoid process were resected during planning, and the final position was determined. The second procedure was the transformation of the virtual plan to the actual surgery. The presurgical CAD/CAM and screw-track transfer technique for both resection and location holes were considered to bridge the gap between virtual surgical planning and actual surgery.

Clinical experience indicates that misalignment of the teeth between the upper and lower jaws can grind down the teeth and cause TMJ problems.[19–21] In addition, cheek scaring is recognized as the main factor contributing to intermaxillary contracture.[11,14,22,23] Here, we not only reconstructed the unilateral condylar process, but also performed occlusion reconstruction and released the cicatricial contracture on the lower mandible margin. This contributed greatly to maintenance of the morphology and function of the TMJ in both the uninjured side and reconstructed side.

CONCLUSION

The application of CAD/CAM combined with the screw-track transfer technique is proposed to enhance the accuracy of coronoid process grafts when reconstructing the condylar process. This approach can be utilized for the reconstruction of both condylar process and occlusal relationship simultaneously. Meanwhile, both rebuilding the occlusive relationship and releasing cicatricial contracture are important factors in maintaining postoperative stability.

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