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CASE REPORT

Pre-operative virtual planning followed by fabrication of patient-specific guiding instruments for mandibular deformity after fibula free flap reconstruction

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ABSTRACT :

Corrective osteotomy for secondary mandibular reconstruction is complex, and it is extremely difficult to achieve desirable three-dimensional positioning. The authors present a case for repositioning the mandibular segments of mandibular deformity after fibula free flap reconstruction using computer-assisted surgical simulation and patient-specific guiding instruments. A 69-year-old man developed severe mandibular deviation after segmental mandibulectomy and reconstruction with fibula free flap for basal cell carcinoma of the mental region. A virtual osteotomy was performed between the mandible and fibula on a 3D virtual model using simulation software. The proximal mandibular segments were placed in the ideal position using a 3D virtual model. The original contour of the mandible before the primary resection was used as a reference for repositioning. Patient-specific guiding instruments were fabricated for the pre-osteotomy and intraoperative positioning of the osteotomized mandible, enabling bone fragments to be repositioned and fixed using the pre-operative plan. Post-operative CT showed that the mandibular segments were precisely repositioned. In this case, virtual planning and patient-specific guiding instruments were useful in corrective surgery for mandibular deformity after fibula free flap reconstruction.

Key Words : CAD/CAM, Virtual surgical planning, Corrective Osteotomy, Patient-specific guiding instrument, Secondary mandibular reconstruction

Introduction

Managing mandibular deformity after mandibular reconstruction is a complex and demanding task[1, 2]. The accurate placement of osteotomized proximal bone segments is a technical challenge.

The original contour of the mandible is extremely difficult to achieve after mandibular osteotomy, and the precise placement of the osteotomized proximal bone segments requires careful surgical planning.

This paper presents a case in which virtual simulation was used to plan the repositioning of the mandible and computer-aided design/computer-aided manufacturing (CAD/CAM) technology was used to create and adapt patient-specific guiding instruments (PSGIs) that positioned the mandible as planned. Finally, the patient's mandibular function and natural mandibular contour were completely restored.

Case report

A 69-year-old man underwent right neck dissection and tumor resection with segmental mandibulectomy, followed by reconstruction with a fibula free flap for recurrent basal cell carcinoma of the skin in the mental region. Before surgery, a 3D model was created, and model surgery was performed for reconstruction. During the surgery, no intermaxillary fixation was performed

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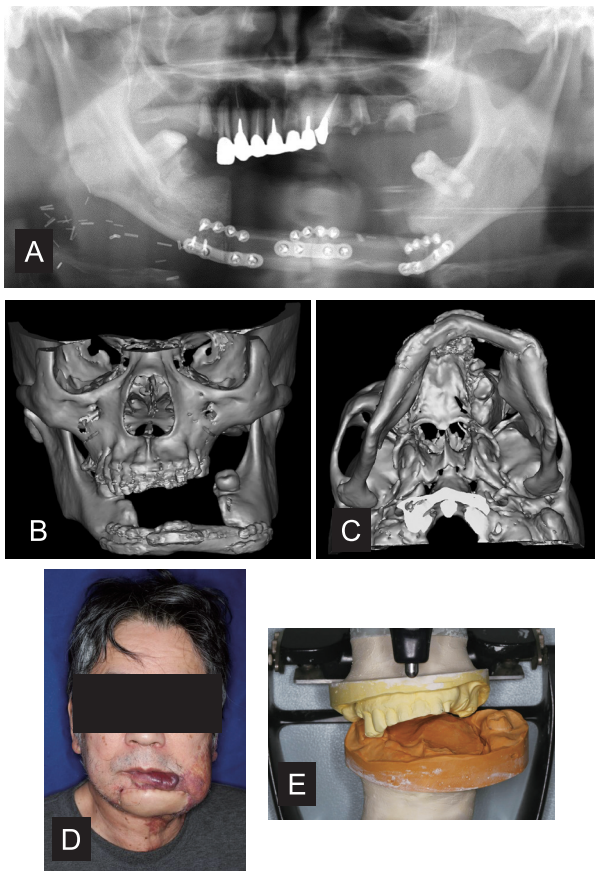

Fig. 1 Images at initial examination.
(A) Panoramic radiograph.
(B) and (C)
Severe deviation to the left of the mandible identified on the 3D CT image. (B) Front view (C) Inferior view.
(D) Extraoral view.
(E) Occlusal relationship.

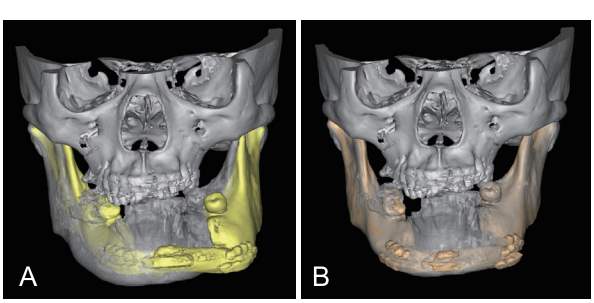

Fig. 2 Virtual surgical planning of the mandible bone.
(A) Pre-mandibulectomy (gray) vs. actual situation before corrective osteotomy (yellow).
(B) Pre-mandibulectomy situation (gray) vs. planned restoration (brown).

due to the large number of missing teeth. Based on the model surgery, mandibular reconstruction was performed, and the surgery was concluded by fixation of the fibula and mandible using six plates. Initial healing was uneventful. However, the patient was referred to our department 10 days post-surgery because the remaining mandibular teeth hit the right maxillary gingiva during mastication. On examination, severe deviation to the left of the mandible was observed, and discordance between the maxillary and mandibular dentition was prominent (Fig.1).

To improve this situation, we repositioned the proximal mandibular segments using computer simulation and fabricated PSGIs, and repositioned the bone segments as per the initial plan.

Virtual surgical planning

Computed tomography (CT) data in Digital Imaging and Communications in Medicine (DICOM) format before mandibulectomy and the current state were prepared and analyzed. The CT data before mandibulectomy were used to obtain a reference model of the original contour of the mandible. The DICOM format was uploaded into Mimics® version 24.0 software (Materialise, Leuven, Belgium) and converted to the STL format after segmentation of the skull and mandible. DICOM and STL file formats were imported into ProPlan® CMF version 3.0 software (Materialise, Leuven, Belgium). The pre-and post-reconstruction mandibles were superimposed on a computer software using the pre-operative skull as reference. The deformed mandible was then virtually osteotomized between the mandible and fibula, and the osteotomized proximal segment was repositioned into the pre-operative mandible (Fig.2). The fibula was repositioned to the proper position.

Design and manufacture of PSGIs

Pre-osteotomy and repositioning PSGI were designed using 3-matic® version 16.0 software (Materialise, Leuven, Belgium), based on the pre-and post-translation positions of the proximal fragment segment, respectively. PSGIs consisted of a plate and a connecting rod. The plate was designed to accurately fit the bone surface profile with a thickness of 3 mm at the inferior margin of the mandible. Three screw holes were provided for intraoperative PSGI fixation. The position and orientation of the plate and screw holes were set to match the pre-osteotomy and repositioning conditions (Fig.3). Pre-osteotomy and repositioned PSGI were fabricated with Biocompatible Photopolymer Resin (BioMed Clear®; Formlabs, Tokyo, Japan) using a 3D printer (Form3B®; Formlabs, Tokyo, Japan).

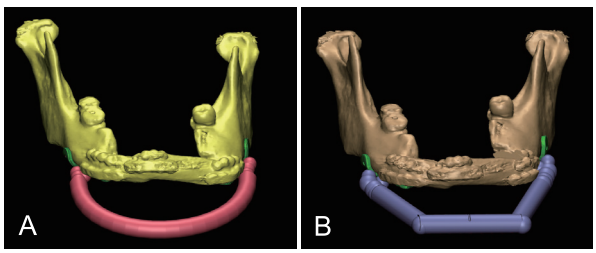

Fig. 3 Computer-aided design of patient-specific guiding instruments.
(A) Pre-osteotomy guide.
(B) Repositioning guide.

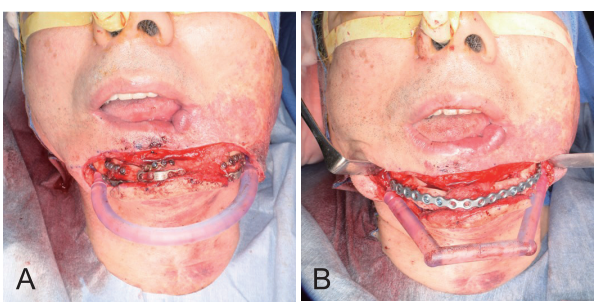

Fig. 4 Surgery
(A) Before osteotomy, pre-osteotomy patient-specific guiding instruments (PSGI) are applied to the mandible bone.
(B) Fixation of repositioning PSGI guides the displaced mandible back to its original position.

Repositioning of the proximal mandibular segment during surgery

After 17 months of the initial surgery, a secondary corrective procedure was performed extra orally with wide exposure of the mandible (Fig.4). Osteosynthesis between the fibula and mandible was fine. Pre-osteotomy PSGI was applied to the inferior margin of the mandible, and screw holes were formed and fixed in the planned positions. After confirming a desirable fit, the PSGI was removed. After osteotomy between the mandible and the fibula, the PSGI was repositioned. The proximal mandibular segments were positioned using a repositioning PSGI that precisely fitted the bone. The positioned PSGI was fixed to the bone using the same holes with which the pre-osteotomy PSGI was fixed. The proximal mandibular segments and fibula were fixed with osteosynthesis material, and the PSGI was removed. Osteosynthesis material was bent during surgery. Post-operative CT images showed improved deviation and harmonious form. The patient was able to wear a removable partial denture six months after surgery. The match between the 3D model of the virtual plan and the

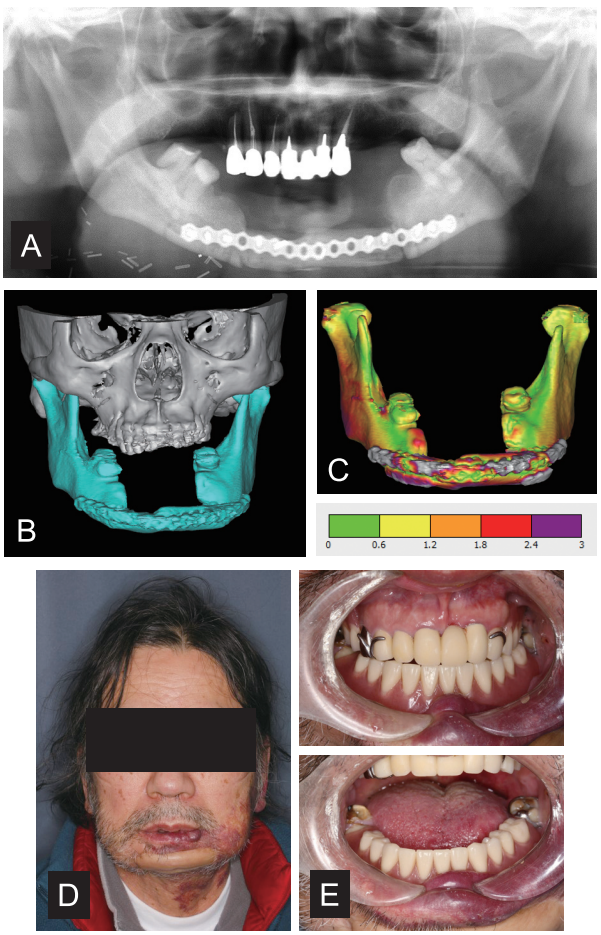

Figure 5 Post-operative images.
(A) Panoramic radiograph.
(B) 3D CT image (frontal view).
(C) Comparison of deviations between the planning and post-operative 3D CT with color mapping showed a deviation of <3 mm.
(D) Extraoral view.
(E) Intraoral view at 6 months after surgery.

3D model after corrective surgery was evaluated with surface deviation analysis, and the discrepancies were less than 3 mm (Fig.5).

Discussion

Mandibular reconstruction requires restoration of the three-dimensional positioning of the separated proximal mandibular segments to restore occlusal relationships and facial contours. However, it is not always possible to reposition separated proximal mandibular segments while maintaining their three-dimensional relationships. In primary surgery, a reconstructive plate can be bent to fit the mandible[3]. Alternatively, a temporary extracapsular fixation device can be created to conform to the mandible

to reproduce the pre-operative position[4]. However, in the case of secondary surgery, the original mandibular contour is lost, making it difficult to plan reconstruction using a three-dimensional model.

In virtual surgical planning, the displaced proximal mandibular segments can be easily repositioned to their original position with reference to the mandibular contours before the primary surgery. Furthermore, CAD/CAM technology enables surgeons to fabricate patient-specific instruments that reflect the virtual surgical plan. The PSGI can easily guide displaced mandibular segments to their original positions intraoperatively.

There are many advantages to our method of pre-drilling with pre-osteotomy PSGI followed by accurate 3D positioning with repositioning of the PSGI. Intermaxillary fixation (IMF) is usually used to maintain the relationship between the proximal segments after mandibulectomy. Most patients undergoing mandibulectomy have many teeth removed, making IMF difficult. This technique is expected to be applied to cases without an IMF. We did not require a navigation system or intraoperative CT imaging to confirm repositioning during surgery. Therefore, we require less intraoperative effort, and this contributes to shorter operating times. In addition, the PSGI is fixed to the mandible, which makes it much easier to conform and fix the osteosynthesis material to the bone, thus contributing to a reduced operative time[5].

The method presented herein requires special software and training. Despite the reduction in operative time, considerable time is required for pre-operative virtual simulation and the design and fabrication of PSGIs. In accordance with the learning curve, the time required for the simulation is expected to be reduced.

Conclusion

This report describes the treatment of mandibular deformity after fibula free flap reconstruction with virtual planning and PSGIs. This surgical technique, based on three-dimensional computer simulation, has advantages and may be a useful treatment option for patients with severe deformities after mandibular reconstruction.

Conflict of Interest

The authors have no conflicts of interest to declare.

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