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Surgical navigation-assisted mandibular reconstruction with fibula flaps

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Abstract. The mandible has an important role in appearance and function. The aim of this study was to describe and evaluate surgical navigation-assisted mandibular reconstruction with the fibula flap. Patients recruited into the study had a custom dental splint fabricated to maintain the mandible in a fixed position. Later, the computed tomography (CT) scan, preoperative design, and operation on the mandible were done in the same position. At 1 week after surgery, a CT scan was done to evaluate the repeatability between the preoperative design and the postoperative result. Twenty patients were enrolled in this study. Good repeatability between the postoperative CT and the preoperative design was found. The repeatability between the preoperative plan and postoperative outcome was 79.1 ± 8.6% at within 1 mm, 87.1 ± 6.7% at within 2 mm, and 91.9 ± 5.4% at within 3 mm. From this study, it can be concluded that surgical navigation techniques can precisely transfer the preoperative design to the operation in mandible reconstruction with a fibula flap. This will assist the surgeon in achieving good cosmetic and functional outcomes.

Key words: mandibular reconstruction; surgical navigation; computer-assisted surgery; fibula flap.

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The mandible has an important role in facial harmony, mastication, speech, swallowing, support of the tongue base, and airway function. Jaw defects caused by a tumour or injury usually result in compromise of these functions, as well as facial aesthetics.[1,2] The utility of the free fibula osteocutaneous flap for mandibular reconstruction was recognized and subsequently popularized by Hidalgo in 1989.[3] The fibula flap is now used widely in mandibular reconstruction. Advantages include the ability to incorporate skin, muscle, and components of bicortical bone that can accurately reproduce the mandible. Comprehensive long-term follow-up studies assessing the cosmetic effect, speech, and deglutition have demonstrated satisfactory outcomes. Morbidity at the donor site has been described as 'mild'.[2,4,5]

Even though mandibular reconstruction with the fibula flap is now a common oral and maxillofacial surgical procedure, it is technically challenging and time-consuming. In addition to microvascular anastomoses, contouring of the flap must be precise to re-establish the form-and-function occlusal relationships of the mandible.[6]

To improve precision and simplify the surgical procedure, computer-assisted surgery (CAS) involving preoperative virtual planning and computer-assisted intraoperative navigation has evolved. Computerized navigation was first indicated for the resection of tumours in the

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craniomaxillofacial skeleton.[7] Based on identification of the tumour on computed tomography (CT) scans and the planned resection margins, the navigation probe is used intraoperatively to provide real-time feedback to the surgeon. Several studies have demonstrated the value of this technology in improving the precision with which tumours can be resected with safe margins while reducing the morbidity of unaffected tissues.[8,9]

The application of computerized navigation in surgery to the mandible is complicated due to its mobility. Unlike the rest of the craniomaxillofacial skeleton (which acts as one solid structure), the mandible is an independently movable body, so its synchronization with the pre-acquired CT image is more difficult.[10]

The aim of this study was to describe and evaluate a straightforward method for navigation-assisted mandibular reconstruction with a fibula flap.

Materials and methods

Ethical approval of the study protocol

The study protocol was approved by the institutional ethics committee. All patients provided written informed consent to participate in the study.

Patients

From November 2011 to September 2014, 20 patients with a lesion or defect of the mandible attending the study hospital were enrolled prospectively. Inclusion criteria were the following: partial resection of the mandible was indicated; reconstruction with a fibula graft was possible; the patient could wait 3–5 days for a design to be created; the patient agreed to the surgical team using a computer-assisted navigation method. Exclusion criteria were the following: operation time had to be controlled because of the general status of the patient; the patient could not wait 3–5 days for a design to be created; the patient had an advanced malignant tumour with a poor prognosis; mouth opening was limited, so making a dental splint was difficult. A preoperative incisional biopsy was done in order to obtain a pathological diagnosis. Reconstruction was indicated for all patients.

Surgical planning

All patients underwent preoperative spiral CT (helix with a slice thickness of 1.25 mm), which was repeated at 1 week after surgery (BrightSpeed 16; GE Healthcare, Buckinghamshire, UK). CT data were processed and transferred to SurgiCase CMF version 5.0 (Materialise, Leuven, Belgium) and iPlan CMF (Brainlab, Feldkirchen, Germany) via Digital Imaging and Communications in Medicine (DICOM) files for preoperative surgical planning and postoperative evaluation. The VectorVision system (Brainlab) was used for surgical navigation.

Preoperative design

A custom-made dental splint was fabricated. Once fitted, the mandible could be maintained in a fixed position. A high-resolution CT of the skull and fibula region was taken with the dental splint in situ. Two-dimensional CT data were saved in DICOM format. DICOM data were processed in SurgiCase CMF version 5.0 to generate accurate three-dimensional rendering of the bone contours. Virtual segmentation of the skull was undertaken to separate the mandible from the remaining parts of the skull.

Following standard principles, tumour resection was planned and the precise defect defined. Virtual design of the fibula flap involved segmentation, length of segments, angulation, and orientation to achieve the 'ideal' contour of the 'neo-mandible'. If distortion of the mandible due to the tumour was evident, the 'mirror' function was used to replicate the corresponding contralateral anatomical structure. If deformation was bilateral, the neo-mandible was guided by the position of maxillary teeth and the underlying skeletal base.

Surface data for all parts were exported into stereolithography (STL) files. Three-dimensional cylindrical-shaped objects in STL format were placed in a triangular pattern for use as reference points (Fig. 1). These were placed on the unaffected mandible on the facial aspect on both sides of the anticipated ostectomy. Cylinders were 3 mm in height and 2 mm in diameter. The three cylindrical-shaped objects were separated $\geq$1.5 cm to facilitate identification.[11]

STL data of segments with surface markers were imported into iPlan CMF, and merged into one object as the surface marker-assisted navigation plan.

Intraoperative navigation

Intraoperative navigation was undertaken using VectorVision (Brainlab). Preoperative preparation included matching the STL and CT in advance on iPlan (Brainlab) and exporting the file to the navigation workstation.

Under general anaesthesia, a reference frame with three light-reflecting spheres was fixed rigidly to the skull. Registration was completed through facial-surface imaging with the infrared ray (IR) emitter and IR receiver, as per the VectorVision protocol. Registration accuracies of the surgical area were verified automatically by the software, and registration errors were $<$0.7 mm in all cases. Also, surgeons could verify the actual surgical process on the virtual plan.[11]

Intermaxillary fixation was applied with a custom-made dental splint in situ (Fig. 2a). Under the navigation plan, all surface markers were located by the tip of a navigation probe. Holes were drilled in the mandible before osteotomy (Fig. 2b).

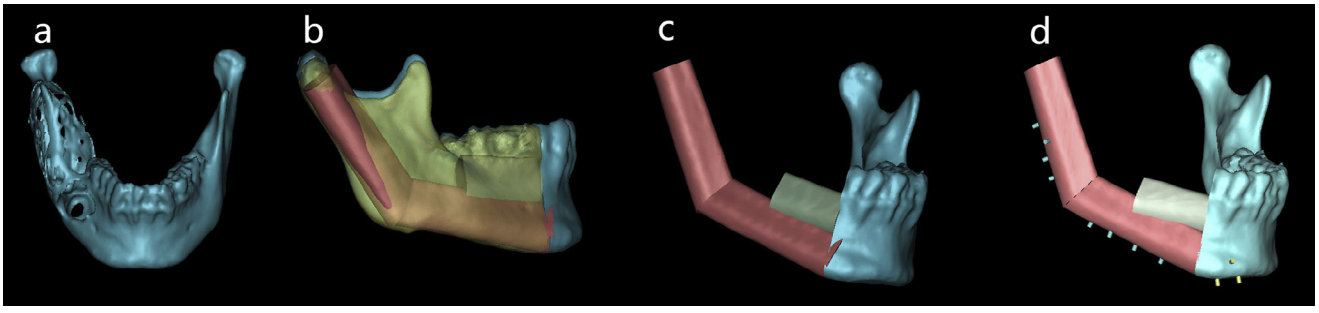

Fig. 1. Preoperative design procedure: (a) CT shows the tumour; (b) the 'mirror' function is used to replicate the corresponding contralateral anatomical structure and to design the fibula flap; (c) the fibula flap is designed; (d) cylindrical-shaped objects are placed on the residual mandible.

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