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# Mandibular reconstruction after cancer: an in-house approach to manufacturing cutting guides☆

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*Abstract.* The restoration of mandibular bone defects after cancer can be facilitated by computer-assisted preoperative planning. The aim of this study was to assess an in-house manufacturing approach to customized cutting guides for use in the reconstruction of the mandible with osteocutaneous free flaps. A retrospective cohort study was performed, involving 18 patients who underwent mandibular reconstruction with a fibula free flap at three institutions during the period July 2012 to March 2015. A single surgeon designed and manufactured fibula and mandible cutting guides using a computer-aided design process and three-dimensional (3D) printing technology. The oncological outcomes, production parameters, and quality of the reconstructions performed for each patient were recorded. Computed tomography scans were acquired after surgery, and these were compared with the preoperative 3D models. Eighteen consecutive patients with squamous cell carcinoma underwent surgery and then reconstruction using this customized in-house surgical approach. The lengths of the fibula bone segments and the angle measurements in the simulations were similar to those of the postoperative volume rendering ($P = 0.61$). The ease of access to 3D printing technology has enabled the computer-aided design and manufacturing of customized cutting guides for oral cancer treatment without the need for input from external laboratories.

Key words: oral cancer; computer-aided design; mandibular reconstruction; fibula free flap; cutting guides.

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The surgical management of cancers extending from the upper aero-digestive tract results in complex tissue injuries with subsequent significant disability. The use of the free vascularized fibula flap remains the gold standard for the restoration of large mandibular and oral defects after cancer treatment.[1] The main objectives of such reconstructions are the restoration of bone continuity and cutaneous facial contouring, closure of the oral mucosa, and dental rehabilitation.[2]

This surgery remains technically demanding because of the need to transform the fibular bone into a three-dimensional (3D) structure with specific angulations, different for each patient. Many teams around the world have proposed the use of software to design, improve, and correct mandibular reconstructions. Studies using preoperative virtual planning along with prefabricated cutting jigs for precise contouring and positioning of microvascular fibula free flaps have shown better results with the use of these techniques than for conventional techniques regarding flap ischemia and dental rehabilitation.[3–5]

It appears that virtual planning technologies are becoming the criterion standard in mandible reconstruction.[6,7] Surgeons have already evaluated the use of computer-designed osteotomy guides for reconstruction of the mandible with the fibula technique.[8,9] Over the past 10 years, many authors have published the results of mandibular reconstruction cases in which a model based on rapid prototyping technology has been used to assist in the accurate contouring of plates and/or planning of bone graft harvest geometry before surgery.[10] Moreover, the surgical team of Hanasono and Skoracki has used rapid prototyping to help shape the fibula flap for reconstruction in their practice.[11] They concluded that computer-assisted design (CAD) and rapid prototype modelling have the potential to increase the speed and accuracy of mandibular reconstruction. Other authors have proposed a protocol based on virtual preoperative surgery with a planned bone resection that allows the engineering of a specific implant to accurately fit the defect during surgery.[12,13] However, all of these cases have required the help of a laboratory team specialized in CAD.

The main objective of the present research was to evaluate an in-house technique that integrates all the processes of CAD and rapid prototyping and that does not require the input of an external laboratory.

## Materials and methods

Eighteen patients who underwent a segmental mandibulectomy for oral cavity squamous cell carcinoma (SCC) during the period July 2012 to March 2015, and who required a fibula osteocutaneous free flap reconstruction with one or two skin paddles,[14] were included in this study. All patients were informed about the procedure and signed the preoperative consent for care and the recording of data, in accordance with the recommendations of the clinical research unit. The surgical technique was not modified by the guide manufacturing protocol. Postoperative radiological data were obtained from the computed tomography (CT) scans that were done during radiotherapy.

The bone resections for the mandibular lesions and the reconstructions were completed in the same one-step procedure using the customized cutting guides and jigs.[15] The same surgeon performed all fibula flap virtual reconstructions, 3D printing of the osteotomy guides, and surgical reconstructions of the mandibles. A maxillofacial surgeon performed the surgical oral tumour excisions.

### CT scan acquisition, virtual resection, and 3D process

Computed tomography angiography (CTA) studies of both the head and the legs were performed by means of a 16-detector row CT scan after intravenous administration of 100 ml of iodinated contrast solution. No supplementary radiological examinations were done, except Doppler ultrasonography of the inferior limb to ensure that there was no venous thrombophlebitis before surgery.

The CT scan DICOM slides (1-mm intervals) were transferred to volume rendering software (Ayra, Ikeria SARL, Sevilla, Spain; OsiriX, Pixmeo SARL, Bernex, Switzerland; 3D Slicer, http://www.slicer.org) . An accurate delineation of the mandibular and fibular bone was performed. The 3D volume rendering models of the fibula and the mandible were used to define the surgical bony resection margins. A safety margin of 10 mm for the SCC bone resection was decided on during multidisciplinary medical board meetings, in which the patient clinical examination findings, diagrams of the lesions, biopsy results, and CT scan or magnetic resonance imaging (MRI) analysis were assessed. Thus, the required resection was defined and the planned cuts designed on the 3D virtual volume, to create the definitive virtual 3D model with bone resection (Fig. 1).

The virtual 3D volume was exported in .stl file format (standard tessellation language) and imported into CAD freeware (Meshmixer, Autodesk, Inc., http://meshmixer.com/; Blender, Blender Foundation, https://www.blender.org). The planned cuts on the virtual 3D volume were used as a scaffold to virtually design the cutting guides. To obtain a perfect fit, the cutting jigs were virtually drawn by performing subtractions from the virtual 3D volume of the mandibular bony structures for each patient. Specific spherical holes were then virtually drawn through the cutting guides to fix them within the bony structure. These holes were drawn with consideration of the nerve anatomy and dental structures, to avoid the risk of injury to the tooth roots during osteotomy sawing or screw fixation (Fig. 1).

The virtual fibula osteotomies were performed with the aim of saving the maximum bone length and providing bone fragments of $\geq$2 cm in length (Fig. 2A) using the same step-by-step approach. Angle measurements were calculated to ensure the best possible overlay between fibular bone fragments. Distal and proximal step osteotomies were designed to ensure the maximum congruency between the remaining mandibular bone and the fibula bone flap (Fig. 2B). When the thickness of the fibula bone was insufficient, reconstruction of the lower margin of the mandible bone was favoured to allow a more stable and robust reconstruction, simpler future bone implantation, and the use of dental prosthetic devices (Fig. 2C).

At the end of the virtual design process, a virtual prototype of the reconstruction was performed to ensure that reconstruction with the bony fragments matched the original mandibular conformation as closely as possible (Fig. 2D).

### Printing of the cutting guide

Computerized files were exported in .stl format to a 3D printer (Stratasys Objet30 Pro, Stratasys Ltd, Eden Praries, United States; Zortrax M200, Zortrax SARL, Olsztyn, Poland). After printing and before use, the surgical guides were washed manually by ultrasonography process and then sterilized using a low-temperature hydrogen peroxide plasma technology (STERRAD; Advanced Sterilization Products, Division of Ethicon US, LLC). The guides were then assigned to the patient (identity number) and stored in sterile boxes until surgery; the classical sterilization procedure was used at that time.

Titanium mesh plates were manually cut and pre-shaped on the 3D printed model of the reconstructed mandible (Fig. 3A).

At the end of the design process, preshaped titanium mesh plates and three virtual cutting guides (two for the mandibular resection and one for the fibula osteotomies) were obtained for each patient (Fig. 3B).

All patients received perioperative antibiotic treatment with cefazolin, as well as heparin for 3 weeks postoperative as prophylaxis for thromboembolism.