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Surgical planning and microvascular reconstruction of the mandible with a fibular flap using computer-aided design, rapid prototype modelling, and precontoured titanium reconstruction plates: a prospective study

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Abstract

The standard of mandibular reconstruction has increased since the introduction of computer-assisted design (CAD) and rapid prototype modelling (RPM) for surgical planning.

Between 2008 and 2013, a prospective pilot study of 20 patients was planned to compare the outcomes of patients treated by mandibular reconstruction who had CAD and RPM-guided operations using a precontoured titanium plate, with the outcomes of patients treated conventionally. We recorded the time taken for reconstruction, total operating time, and whether this type of planning could improve the results of mandibular reconstruction. We found significant differences in the incidence of dental malocclusion ($p = 0.03$) and exposure of the titanium plate ($p = 0.009$). The mean operating time for reconstruction in the preoperative planning group was 135 (37) min compared with 176 (58) min in the conventional group ($p = 0.04$).

Preoperative planning using CAD and RPM can increase the accuracy of microvascular mandibular reconstruction and reduce the operating time for reconstruction.

Keywords: Microvascular; Mandibular reconstruction; Rapid prototyping; Operative time; Surgical planning; Fibula flap; Computer assisted surgical planning

Introduction

The objective of mandibular reconstruction is to restore the aesthetic and functional aspects of the jaw. Free flaps should be a suitable shape and dimension to restore the 3-dimensional configuration of the mandible. Until the advent of rapid prototype modelling (RPM), including stereolithography and 3-dimensional printing, titanium reconstruction plates were bent, and bony flaps were contoured during the operation,[1–3] which led to increased operating times and insufficient accuracy in contouring of the plate.

The use of RPM, that precisely reproduces the patient's anatomy, helps to guide the procedure, contour the titanium plates, calculate the level of the mandibular osteotomies, and better understand the shape and measurements of the bony

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flap that will be required to reconstruct the defect. By using these techniques it is possible to reduce the operating and ischaemic time, and improve overall results.[4–8]

Here we describe our preoperative planning using computer-assisted design (CAD), rapid prototype models, cutting guides, and precontoured titanium plates for mandibular reconstruction with fibular flaps. Our main hypothesis was that the operating time for reconstruction (defined as the time from raising the initial flap and excision of the mandible to the final osteosynthesis of the flap and the titanium plate within the mandibular defect, but before the microvascular suture) can be reduced, thereby reducing total operating time.

To test this hypothesis we prospectively compared the outcomes of patients treated for mandibular reconstruction using a fibular flap after CAD and RPM over the mandible using cutting guides and a precontoured titanium plate, with the outcomes of patients treated without 3-dimensional modelling and with a titanium plate that had been conventionally and intraoperatively bent.[9]

Patients and methods

Data from axial computed tomography (CT) with cuts of 1.5 mm or less were required.

Mimics software (Materialise NC, Leuven, Belgium) was used for the segmentation of 3-dimensional CT images. The project was fine-tuned and the STL-format file was imported into 3matic-software (Materialise). A mandibular or a skull model and guides were built out of acrylic resin with the help of RPM.

The mandibular resection and evaluation of the defect were guided using CAD and accounted for the extent of the lesion seen on CT images and during the clinical examination of the patients.

Cutting guides, which were used to guide the osteotomies of the mandible, were designed during the preoperative computed assisted planning. RPM technology was used to obtain a solid and highly accurate 3-dimensional model. Rapid prototyping is based on either layer-by-layer deposition of a liquid polymer that is cured by laser or ultraviolet light, or on a starch powder that is bonded with glue, depending on the type of printer, and produced as a solid model with a reported range of accuracy from 1.5 to 0.0016 mm.[2,10,11]

In the preoperative planning group, 2.7 or 2.4 mm Mondeal BMR-System titanium plates were precontoured to match and reproduce the precise contour and 3-dimensional aspects of the mandible. The preoperatively contoured, custom-made titanium plates were used to model the segments of the fibular flap to the plate while the flap was still attached to the pedicle. The flaps were then placed on the titanium plate to fit the mandibular defects.

When the mandible cannot serve as the correct reference because the lesion is expanding or there is a pathological fracture, the plate cannot be contoured to match the vestibular aspect of the mandible. In this case, a second rapid prototype model was printed using the mirror image of the opposite hemimandible.[12] Finally the RPM and the titanium plate were sterilised for use during the operation as a reference for the surgical team.

In the control group the 2.0 mm Osteomed MFX-System titanium plates were bent during the operation, and shaped conventionally to best maintain their centric occlusion.[9]

Fibular flaps were raised with a cutaneous paddle to cover soft tissue defects intraorally, extraorally, or both. Even for a small defect, a cutaneous paddle was used to monitor the flap.

The decision whether to harvest a left or right fibular flap was made preoperatively. A vascular CT scan was used to study the vessels in the lower extremities in both groups and the choice was made depending on the site of mandibular reconstruction, the soft tissue defect, and the cervical vessels available.

Analysis of data

Between 2008 and 2013, a pilot study was planned to study prospectively 2 groups of patients who had microvascular reconstruction with a fibular flap after segmental mandibular resection. The minimum follow up was 6 months, and Ethics Committee approval was obtained.

In the group that had the planning protocol as detailed above, the mandibular reconstruction was guided by RPM with the support of Mondeal BMR precontoured titanium reconstruction plates to shape the fibular flap on to the plate.

The patients in the control group had mandibular reconstruction without RPM or specific software support. In these cases, the Osteomed MFX titanium plates were bent intraoperatively, and the plates shaped to the contour of the mandible. When the mandible was destroyed, poorly-positioned, or substantially distorted in this group, the plate was bent to best maintain the previous occlusion.[9]

A total of 26 patients had their mandibles reconstructed with fibular flaps, and 20 were included in the study, 10 in each group. We could not randomise the patients and they were included if they followed the criteria of the New Technologies Committee, as economical approval for RPM planning was required for each case.

Exclusion criteria comprised the absence of consent, a different surgical protocol used from the one defined for the study, or the need to use other flaps including the double-barrel fibular flap.

The operations were done by the same two teams of surgeons using a simultaneous double-field approach. The operating time for reconstruction was defined as the time from the beginning of the raising of the flap and excision of the mandible to the final osteosynthesis of the flap before microvascular suture. The amount of time taken for reconstruction and the total operating time were measured for both groups.