



Patient-specific reconstruction plates are the missing link in computer-assisted mandibular reconstruction: A showcase for technical description



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ARTICLE INFO

Article history:

Paper received 15 July 2014

Accepted 19 February 2015

Available online 2 March 2015

Keywords:

Computer-aided design (CAD)

Computer-aided manufacturing (CAM)

Computer-assisted mandibular

reconstruction

Craniofacial reconstruction

Patient specific Mandibular reconstruction

plate (PSMP)

Virtual surgery

ABSTRACT

Introduction: Preoperative planning of mandibular reconstruction has moved from mechanical simulation by dental model casts or stereolithographic models into an almost completely virtual environment. CAD/CAM applications allow a high level of accuracy by providing a custom template-assisted contouring approach for bone flaps. However, the clinical accuracy of CAD reconstruction is limited by the use of prebent reconstruction plates, an analogue step in an otherwise digital workstream.

Technical report: In this paper the integration of computerized, numerically-controlled (CNC) milled, patient-specific mandibular plates (PSMP) within the virtual workflow of computer-assisted mandibular free fibula flap reconstruction is illustrated in a clinical case. Intraoperatively, the bone segments as well as the plate arms showed a very good fit. Postoperative CT imaging demonstrated close approximation of the PSMP and fibular segments, and good alignment of native mandible and fibular segments and intersegmentally. Over a follow-up period of 12 months, there was an uneventful course of healing with good bony consolidation.

Conclusion: The virtual design and automated fabrication of patient-specific mandibular reconstruction plates provide the missing link in the virtual workflow of computer-assisted mandibular free fibula flap reconstruction.

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1. Introduction

Preoperative planning of reconstructive surgery on the mandible has moved from mechanical simulation by use of dental model casts or physical stereolithographic models into an almost completely virtual environment. The clinical feasibility of CAD/CAM-based procedures providing a custom template-assisted contouring approach for bone flaps has been demonstrated in several studies (Hirsch et al., 2009; Leiggenger et al., 2009; Sharaf et al., 2010; Antony et al., 2011; Zheng et al., 2012a; Mazzoni et al., 2013; Seruya et al., 2013). The placement of implants into a

virtually planned neomandible with simultaneous provision of an implant-supported prosthesis was recently reported (Levine et al., 2013; Schepers et al., 2013).

A reasonably high level of accuracy was achieved in CAD/CAM-based template-assisted mandibular reconstructions (Roser et al., 2010; Zheng et al., 2012b). However, a factor, which may limit the accuracy of virtually planned reconstructions, is the shift back to analogue mode necessitated by the use of manually prebent reconstruction plates halfway through the workflow to clinical implementation (Roser et al., 2010).

The following showcase demonstrates how the use of an innovative computerized, numerically-controlled (CNC)-3D milled and drilled patient-specific mandibular plate (PSMP) can provide the missing link in the digital workflow of computer-assisted mandibular reconstruction and preclude potential deficiencies inherent to prebent reconstruction plates.

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2. Technical report

A 70-year-old male patient suffered from a squamous cell carcinoma of the right lateral floor of the mouth infiltrating the pre-angular alveolar process and the buccal soft tissues (T4N0M0). The treatment plan included a continuity resection of the mandible with primary free fibula flap reconstruction of the segment and a selective neck dissection (level I to III).

2.1. Preoperative preparations

In addition to routine head and neck staging procedures, which included a high-resolution CT scan of the craniofacial skeleton, high-resolution CT-angiography of the lower extremities was made according to a standard protocol to confirm a regular three-vessel supply of the lower limb. DICOM files with an axial slice thickness of 0.6 mm were forwarded to the medical engineering partners (Materialise, Leuven, Belgium). The datasets were converted into three-dimensional virtual bone models of the upper and lower jaws and the left fibula using Synthes ProPlan CMF software (De Puy Synthes Maxillofacial, Paoli, USA/Materialise, Leuven, Belgium).

In an interactive web session between surgeons and engineers the clinical treatment concept was entered into the workflow of the design and manufacturing process.

As a first step the boundaries of resection needed determination (Fig. 1, above left, above right) and bony safety margins of at least 15 mm were set. The posterior resection line had an angulated course vertically in the mid ramus and horizontally below the condylar process. The anterior vertical resection border was placed just in front of the mental foramen.

The neomandibular segments of the fibula were then aligned within the defect to replace the crestal border of the mandible with a particular view to a future dental implant insertion. By contrast restoration of the basal contours of the mandibular body was not undertaken due to its minor role in functional repair. The reconstruction of the mandibular angle required a single in-plane wedge osteotomy of the fibula (Fig. 1, centre right, below left). The lingual shift position of the posterior alveolar process was not accounted for in this case (Chen et al., 2012).

Once the bony framework consisting of the native jaw and the fibular segments was prepared, the blueprint of a reconstruction plate was moulded to the geometry of the lateral surface of the hybrid mandible (Fig. 1, below left). In the software program the

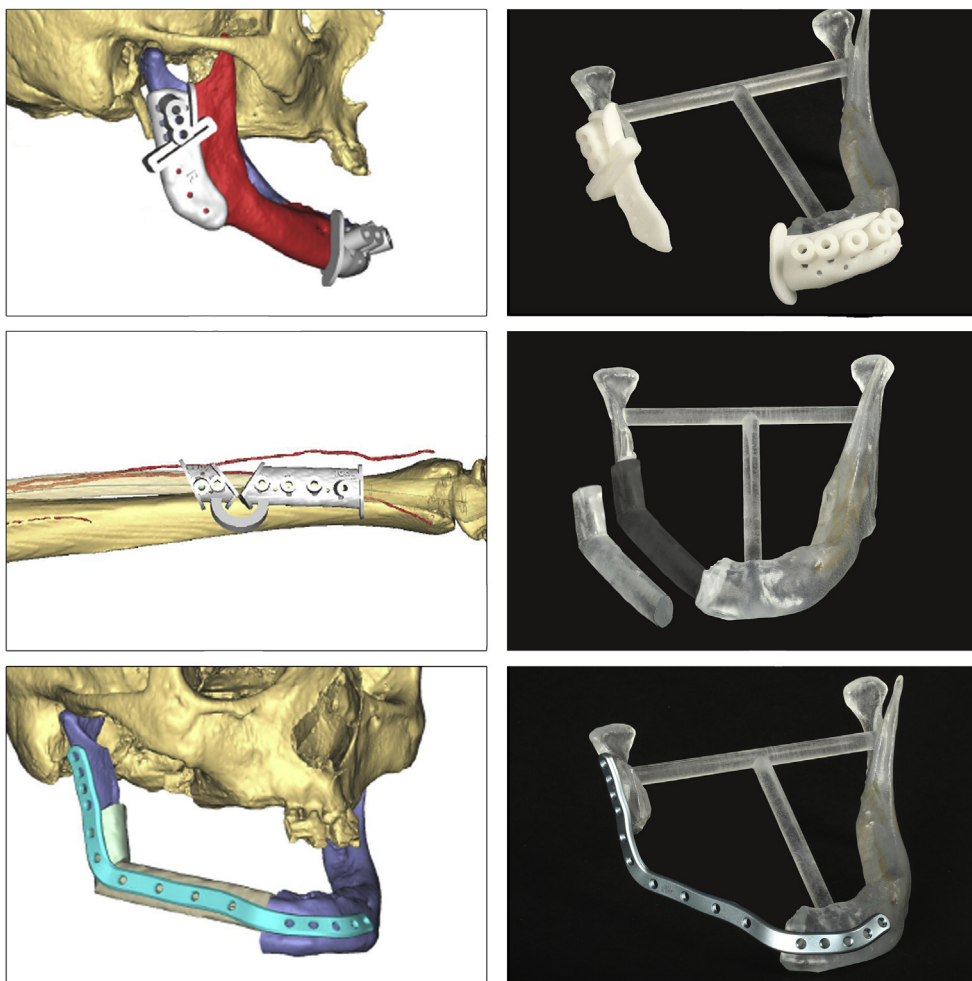


Fig. 1. Virtual planning (Synthes ProPlan CMF) patient-specific mandibular plate (PSMP) and auxiliary tool kit. (Above left) Planned removal of mandibular body and ramus (red), outline of resection guides equipped with fixation holes and hollow targeting cylinders marking the boreholes for PSMP fixation. (Above right) Stereolithography (STL) model of the entire mandible displaying the resectional defect as planned. Selective laser sintering resection guides in place, delineating the margins with its slots and flanges. (Centre left) Virtual plan of the fibula cutting guide. (Centre right) STL models of the mandible and the neomandibular fibular segments. Photographic superimposition shows the hybrid shape. (Below left) Planned reconstruction with fibular segments at the vertical height of former alveolar crest. PSMP flush with the lateral bone surfaces of the hybrid. (Below right) Milled PSMP spanning the defect of the STL mandibular model.

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