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Accuracy of secondary maxillofacial reconstruction with prefabricated fibula grafts using 3D planning and guided reconstruction

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ABSTRACT

Background: We compared the pre-operative 3D-surgical plan with the surgical outcome of complex two-stage secondary reconstruction of maxillofacial defects using inserted implants in the prefabricated fibula graft.
Methods: Eleven reconstructions of maxillofacial defects with prefabricated fibulas were performed using a 3D virtual planning. Accuracy of placement of the fibula grafts and dental implants was compared to pre-operative 3D virtual plans by superimposing pre-operative and post-operative CT-scans: we first superimposed the CT-scans on the antagonist jaw, to represent the outcome of occlusion, and then superimposed on the planned fibula segments.
Results: Superimposing the CT scans on the antagonist jaws revealed a median deviation of the fibula segments and implants of 4.7 mm (IQR:3–6.5 mm) and 5.5 mm (IQR:2.8–7 mm) from the planned position, respectively. Superimposing of the CT scans on the fibula segments revealed a median difference of fibula and implant placement of 0.3 mm (IQR:0–1.6 mm) and 2.2 mm (IQR:1.5–2.9 mm), respectively.
Conclusions: The final position of the fibula graft is determined by the occlusion of the denture, which is designed from the 3D plan. From a prosthodontic perspective, the accuracy of 3D-surgical planning of reconstruction of maxillofacial defects with a fibula graft and the implants allows for a favorable functional position of the implants and fibula graft.

1. Introduction

Functional reconstruction of large maxillofacial defects has long been a surgical challenge. In the past decade, the free vascularized fibula flap (FFF) has become the most popular choice for reconstruction of defects (Cordeiro et al., 1999). Moreover, for optimal prosthodontic rehabilitation it is widely accepted that dental implants are part of the treatment planning, as implant-supported prosthetics enhance the masticatory and speech function in patients (Zlotolow et al., 1992). Fibula bone has favourable conditions for inserting dental implants due to its high quality of cortical bone (Chiapasco et al., 2006).

Correct positioning of the FFF and the implants to support an implant-retained prosthesis is often difficult (Virgin et al., 2010). If implants are positioned in an unfavourable position, post-operative function and aesthetics may be impaired, thereby negatively affecting the patient's quality of life (Zlotolow et al., 1992). In planning these complex reconstructions it is therefore important to not only plan the fibula bone in the preferred anatomical location to optimally reconstruct the defect, but also to 'topographically' plan the position of the implants in the fibula for optimal support of the superstructure.

Rohner described a method to prefabricate a FFF using dental implants and split skin grafts for complex rehabilitations (Rohner et al., 2003). This approach can provide optimal support of the prosthesis and can create stable peri-implant soft tissues. Prefabrication of a FFF enables functional placement of bone in a defect by using backward prosthetic planning. The Rohner technique essentially is a two-step approach. The first surgical step starts with planning the desired prosthetics (position of the teeth) in the jaw

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defect using stereolithographic models of the maxillo-mandibular complex. Next, backward planning for the placement of the fibula bone graft and the desired location of the dental implants is done based on the prosthetic design. Based on this planning, a drilling guide for inserting the dental implants at the preferred position location in the fibula can be produced. This drilling guide is sterilized and used in the first surgical procedure for placing the dental implants in the fibula bone after exposing the anterior side of the fibula. The first surgical step is completed by taking impressions of the implants inserted into the fibula to register their position in the lower leg, followed by a split thickness skin graft covering the part of the fibula to be implanted. This impression is used to finalize the design of the superstructure and dental prosthesis before the second surgical step of harvesting of the fibula. Also, because the position of the dental implants is known, cutting guides fitted on the implants can be produced for the subsequent fibular osteotomies. During the second surgical step, usually 6–8 weeks after the first one, the superstructure and/or dental prosthesis fixed to the inserted dental implants acts as a guide for correctly positioning the fibula segments in the craniofacial defect. Thus, during the second surgical step, the prosthetics and fibula graft are placed as one complete entity. The prosthesis is placed in occlusion and as a result the bone is automatically placed in a functional position.

A disadvantage of the conventional Rohner technique is the extensive planning procedure, which requires extensive vast laboratory work by experienced dental technicians, especially in manufacturing the drilling and cutting guides. For instance, Rohner utilized laser-welding techniques in the preparation of his drilling and cutting guides (Rohner et al., 2003). To facilitate the laborious work and to use the advantage of detailed anatomical insight, a method using 3D-software and 3D-printing techniques was developed (Schepers et al., 2013, 2012). 3D planning also allows for mathematically evaluating the surgical result when a post-operative (Cone beam) CT is superimposed over the 3D-plan. Several publications provide data on the mathematical accuracy of fibula-based craniofacial reconstructions using 3D-printed cutting guides and pre-bend plates or CAD-CAM reconstruction plates (Roser et al., 2010; Schepers et al., 2015; Hanken et al., 2014). For instance, it was shown that 3D-virtual planning could be performed within 4 mm of accuracy (Modabber et al., 2014; Metzler et al., 2014). In prefabrication, however, the occlusion of the prosthesis determines the placement of the complete graft during surgery, which is not included in the 3D plan. Dentures are made based on the information of the 3D plan fixed in the articulator. However, the denture is traditionally made in central occlusion and through articulation can maintain occlusion in the articulation movement. This allows for slight freedom of positioning of the graft without causing occlusion problems. Theoretically, this could lead to a different level of accuracy regarding the surgical outcome, because the fibula graft and denture are fixed and then placed in the defect guided by the occlusion. Therefore, the aim of this study was to determine the accuracy of the surgical outcome of the fibula graft and the implants inserted in a two-stage reconstruction of secondary maxillofacial defects, compared to the pre-operative 3D-surgical plan.

2. Materials and methods

2.1. Patients

We assessed the accuracy of the fibula segments, and implants inserted in these segments of 11 consecutive patients who received reconstruction of a maxillofacial defect, including the maxilla or mandible with a free vascularized fibula flap. The reconstructions were carried out between January 2011 and May 2015 at the University Medical Center Groningen, University of Groningen, the Netherlands. The inclusion criteria were (1) secondary reconstruction of the maxilla or mandible using a free vascularized fibula graft, (2) use of a prefabricated fibula with dental implants, and (3) positioning of the graft into the defect using a bar retained denture or fixed superstructure supported by the implants in the graft. The patients needed a reconstruction due to a preexisting craniofacial defect resulting from tumour surgery (N = 8) or osteoradionecrosis (N = 3). Two to four weeks after reconstruction, conebeam CT (CBCT) scans to check the position of the transplanted fibula segments provided with dental implants were made.

The institutional review board (IRB) of our university hospital approved the study design and requirements for patient anonymity under reference number M15.176617.

2.2. Virtual planning

The 3D virtual treatment plan started with a CBCT scan of the maxillofacial region and mandible (i-CAT, Imaging Sciences International, Hatfield, USA). The patients were seated in an upright position using a chin rest and headband for fixation. Upper and lower dentition were in maximal occlusion, and in case of an edentulous or partially dentulous jaw, the denture was worn. Scanning settings used were: 120 KV, 5 mA, 0.4 voxel with a field of view of 23 × 16 cm to capture the maxillofacial region. A high-resolution CT angiography scan from the lower legs was acquired (Siemens AG Somatom Definition Dual Source, Forchheim, Germany). A digital subtraction arteriogram (DSA) of the lower leg was made with a 0.6 mm collimation and a 30f kernel (medium smooth). Images were stored in an uncompressed DICOM format. Both scans were imported into ProPlan CMF 1.3 (Synthes, Solothurn, Switzerland and Materialise, Leuven, Belgium) to plan the reconstruction of the jaw defect in a virtual environment. The 3D-models of the jaw-defect and the fibula were created and the fibula was virtually cut and planned in the defect.

To plan the antagonist dentition and the implants, the virtual reconstruction file was converted to Simplant Pro 2011 (Materialise Dental, Leuven, Belgium), virtually the antagonist dentition was added in the proper occlusion. This was done in two ways: the first was to scan the antagonist denture separately (if present) using the CBCT (120 KV, 5 mA, 0.3 voxel) and create a 3D model of the dentition in Simplant pro 2011. If there was no denture or setup, the second possibility to determine the best implant position was to use the virtual teeth in Simplant Pro 2011. Next, virtual implants (Nobel Speedy, Ø: 4.0 mm, length: 10–13 mm; Nobel Biocare AB, Götenborg, Sweden) were planned in the optimal position supporting the virtual antagonist dentition, thus creating a total reconstructive plan of fibula graft and implants (Fig. 1). Then a

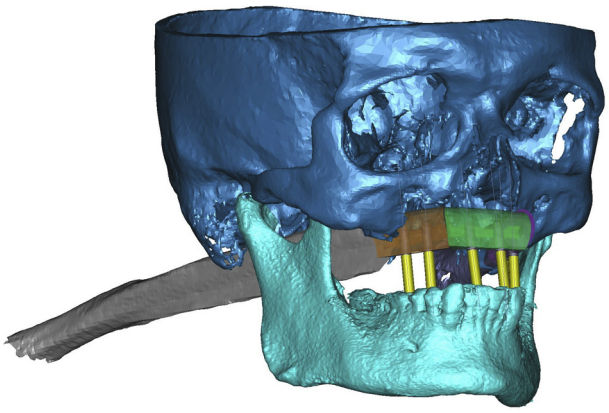

Fig. 1. Planning of implants in a segmented fibula to reconstruct a bony defect of nearly the entire maxilla. In yellow, virtual implant direction tubes are visualized that help to plan the implant angulation.