Patient Specific Mandibular Reconstruction using CAD/CAM Procedures – A Case Report

Neuhaus M*, Zeller A, Steigenberger C, Gellrich NC and Rana M
Department of Oral and Maxillofacial Surgery, Hannover Medical School, Germany

Abstract
Mandibular reconstruction today is still one of the larger challenges in cranio maxillofacial surgery. Quality of life can be extremely reduced by tissue defects in the mandible region, whether caused by trauma or tumour; it is a central concern of all CMF surgeons to improve mandibular reconstruction. Over the last few years rapid progress in CAD/CAM techniques were made. Patient specific reconstruction has become a standard procedure. In the now presented case a young patient underwent ablative surgery of a keratocystic odontogeneous tumour resulting in loss of mandibular continuity. Reconstruction was performed with a patient specific mandible implant. For the first time the donor site of the iliac bone graft was also supplied with a patient specific implant in order to reduce postoperative morbidity and risk of spontaneous pelvic fractures.

ABBREVIATIONS
CAS: Computer Assisted Surgery; CAD: Computer Aided Design; CT: Computed Tomography; CBCT: Cone Beam Computed Tomography; DICOM: Digital Imaging and Communications in Medicine (international open standard); KCOT: Keratocystic Odontogeneous Tumour, OPG: Panoramic Radiograph; PSI: Patient Specific Implant; PSMP: Patient Specific Mandible Plate; SCC: Squamous Cell Carcinoma

INTRODUCTION
Tissue defects in the mandible region can be disfiguring and disabling depending on its extent. Social participation and quality of life are compromised dramatically by loss of mandible function. Diseases, which lead to those defects, following partial or total resection of the mandible, are most commonly malignancies, such as SCC. Other benign lesions are ameloblastomas, keratocystic odontogeneous tumours or bone necrosis due to radiation or bisphosphonate therapy.

Though the huge improvements in microvascular surgery in the 1970’s and 80’s and continuously further enhancements of free tissue transfer lead to success rates up to 99% throughout the literature [1], mandibular reconstruction always was and still is challenging. However, the focus has moved to increasing function and aesthetics after tissue lost. Essential for future function are both, bony and soft tissue reconstruction. There will be no success in hard tissue reconstruction without a well vascularized soft tissue surrounding [2,3]. Restoring of mandibular continuity has to meet some challenging requirements: The patient’s own dentition should remain in a proper occlusion; the neomandible should provide a sufficient bony implant base and a structure that allows transmitting the masticatory forces.

In order to achieve these aims the pre-operative computerized planning (CAD/CAM), using DICOM data sets, generated via CT, with a patient specific titanium reconstruction plate became the Gold-Standard in recent years [4-6]. Formerly a stereo lithographic model of the planned neomandible was produced in order to prebend the titanium plate. Presently the PSSIs are industrially milled according to the pre-operative planning with higher accuracy than the manual prebended plates [7,8].

As Essig and Rana et al. explained, it is necessary to take the future implant position in consideration during pre-operative planning to reach the prosthodontic needs, the so called “Backwards Planning” [3]. The limited dimensions of bone grafts inevitably lead to an insufficient implant base if the inner part of the reconstruction plate is shaped according to the outer contour of the mandible. To avoid this autologous bone graft is being placed in a more medial position and the titanium implant is designed accordingly. The combination of a “backwards planned” bony reconstruction with a sufficient soft tissue envelope and proper dental implantation [9] leads to satisfying results in function and aesthetics.

A keratocystic odontogeneous tumour is a benign neoplastic intraosseous uni- or multilocular tumour of the jawbone with its origin in the remains of the dental lamina. Currently it is rated, by the World Health Organization, as a tumour, due to its potential...
for local aggressive and infiltrative growth. Clinically the cysts are often inapparent and incidentally found during dental routine examinations, even those of progressed extent [10]. All areas of the jaws can be affected; however, most commonly it is located in the posterior part of the mandible body and the ascending ramus. It is the third most common differential diagnosis of cystic jaw lesions in the adult population. The recurrence rates reaches up to 60%, depending on the type of treatment, as there are resection, enucleation and marsupilation [11]. Surgery is the treatment of choice concerning jaw cysts. Their constant growth can lead to severe damage of surrounding tissue like atrophy, jaw fractures and teeth deviation [12,13].

CASE PRESENTATION

A 39 year old, male patient reported to our clinic with an incidental found, cystic lesion of his left mandible corpus. Already 12 years ago a cyst in his jaw had been surgically removed in exactly the same area. The panoramic X-ray in synopsis with a computed tomography and the anamnesis lead to the suspected diagnosis of a keratocystic odontogenic tumour (Figure 1A). Due to extent of the cyst a preservation of the mandibular continuity could not be guaranteed. Therefore a “backwards planned” PSI was pre-operatively planned and manufactured: For computerized 3D segmentation, using the DICOM data set of preoperative CT, iPlan 3.0 software platform (Brainlab®, Feldkirchen, Germany) was used. With an atlas based auto segmentation function the original mandible was segmented and the resection margins were determined by the surgeon himself (Figure 2A). The mandible continuity defect was 8.2 cm long. This data set was send as STL-file to the manufacturer (DePuy/Synthes®, Zuchwil, Switzerland) in order to produce a PSMP and cutting and drilling guides (Figure 2B,D).

After ablative surgery and implantation of the PSMP the patients remaining dentition had a proper occlusion as before (Figure 1C,D). Mastication and deglutition were not significantly affected. During wound healing there were no complications, so that the following reconstruction with a non-vascularized iliac bone graft took place five months after ablative surgery.

A segmentation of the iliac crest, using a pelvic CT, was performed and an area of the left iliac crest, suitable to form the entire left body of the neomandible, was selected (Figure 3A). For pre-operative planning of this complex operation the software Geomagic®-Freeform (Geomagic®, Rock Hill, USA) was used (Figure 3A,B). Previously segmented bone parts were exported via iPlan 3.1 (Brainlab®, Feldkirchen, Germany) as STL files. STL is a file format that defines the three-dimensional structure of an object, commonly used for CAD/CAM procedures.

The novel technique in this case was performed during the second surgical intervention: According to the procedure mentioned above, for the donor site a cutting and drilling guide was manufactured, following the same procedure as above mentioned (Figure 3E). As well as for the mandible, a PSI for the iliac crest was planned and manufactured (Figure 3C,E,F). This titan PSI was planned in Geomagic®-Freeform and

![Figure 1](A) - OPG at initial diagnosis (B) - Occlusion at initial diagnosis (C) - OPG after resection (D) - Occlusion after resection (E) - OPG after reconstruction (F) - Occlusion after reconstruction.
Figure 2 (A) - Segmented mandible with determined resection margins (B) - virtually planned cutting and drilling guide (C) - Continuity defect in postoperative DVT (D) - Virtually planned PSMP (ALL) - Software: Brainlab® iPlan 3.0.

Figure 3 (A) - Iliac bone graft virtually fitted into resection defect, in Geomagic® Freeform (B) - Preoperative planning of pelvic PSI in Geomagic® Freeform (C&F) - Iliac titan PSI (D) - Iliac PSI covering the whole donor site (E) - cutting and drilling guide for donor site (G) - Bone graft exactly fitted to PSMP.
manufactured by selective laser melting (KLS Martin Group®, Gebrüder Martin GmbH, Tuttlingen, Germany). The pelvic PSI did cover the whole defect on the donor site, so the outer contour of the iliac crest could be restored (Figure 3D). It was designed in a manner to carry and withstand the static stress of the pelvic ring. The fixation was carried out with 8 40mm x 2,4mm cortical screws. After raising the autologous bone graft, according to the cutting guide, the graft was shaped with a milling cutter to fit the inner contour of the previously inserted PSMP. As expected the bone graft could be accurately fitted into the resection defect (Figure 3G). No complications during wound healing after second surgical intervention were seen. The patient’s occlusion was not affected (Figure 1F). The mobilization on crutches started 5 days after surgery. Full load on the left leg could be applied early, after 2 weeks.

During surgical removal of the PSMP in a third procedure, 5 month after reconstruction and 10 month after ablative surgery, a fully integrated bone graft, nearly without any signs of resorption, was seen. As a next step oral rehabilitation and dental implantation will now be approached.

DISCUSSION

The use of PSMP, as well as cutting and drilling guides, offers a satisfying way for accurate reconstruction of mandibular continuity defects. Risks of postoperative complications do not differ from those, reconstructed with a conventionally shaped prebend plate [8]. The postoperative occlusion can be obtained more accurately with a PSMP, as the implant can be designed according to original mandible position.

Consecutive bony reconstruction is widely seen as Gold-Standard in mandibular reconstruction [14]. In this case however, the patient already had a recrudescence of a KCOT, so the surgeon decided for a subsequent bony reconstruction to be certain of tumour free resection margins, verified by a pathologist, in order to minimize risk of recurrence.

The pelvic PSI led to a shorter convalescence and a quicker full load of the leg on the donor side than usual in patients with extended iliac bone grafts. Another advantage is the non-compromised outer contour of the iliac crest and lower risk of postoperative spontaneous fractures of the pelvic ring can be expected. Critically is to be mentioned, that yet another foreign material is placed into the patient’s body as a potential source of infection. Also the effort put into planning as well as increased material is placed into the patient’s body as a potential source of infection.

In conclusion it can be said; that our patient took benefit from reconstruction with a CAD/CAM designed and manufactured PSMP as well as the pelvic PSI.

REFERENCES