23 Microsurgical Jaw Reconstruction

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Introduction: Mandibular Defects

The loss of continuity caused by trauma, defects following tumor disease, or inflammation (i.e., osteonecrosis or osteomyelitis) significantly impairs functions such as chewing, swallowing, speaking, and breathing. Microsurgery allows restoring mandibular continuity through free bone grafting, microvascular grafts, or reconstruction with allogeneic and alloplastic materials. Technological advancements in computer-assisted surgery (CAS) provide the foundation for sustainable procedures. Depending on the localization as well as the extent of mandibular defects, there are considerable functional and aesthetic deteriorations.

Defects located in the lateral mandible or in the area of the ascending mandibular branch heavily impact the ability of chewing and swallowing. Due to a loss of continuity around the chin, the tongue loses its support. Along with issues of chewing and swallowing, patients are endangered due to possible obstruction of the upper respiratory tract. Furthermore, psychological as well as social consequences frequently occur, which might negatively influence social life and interactions. Thus, a functional and aesthetically appealing result using CAS represents an indispensable component for mandibular reconstruction.

The introduction of microvascular surgery in the 1970s completely changed the therapeutic concept. This technique allows different bone grafts, also possible in combination with soft tissue, which might be harvested from areas distant from the defect and transplanted into the head and neck region. Here, primary or secondary reconstruction is possible. Depending on the underlying diagnosis, primary osseous reconstruction is preferred in the case of fractures or chronic osteomyelitis as well as in the case of resections due to benign lesions. In the case of malignant underlying diseases, temporary fixation by means of a reconstruction plate and secondary reconstruction is rarely performed. Through CAS, the size and extent of the tumor, the safety distances, the resection margins, as well as the reconstruction can be planned preoperatively, visualized, and further implemented intraoperatively.

Unlike reconstruction in the maxilla, the option of an obturator in the sense of a defect prosthesis [1] is not possible. The continuity of the mandible can be restored using microvascular grafts from different donor regions. Besides the quality, quantity, and shape of the bone, the variability and volume of the required soft tissue, the length of the pellicle, and the morbidity of the

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donor region are of particular relevance when selecting the appropriate graft. For the reconstruction of the mandible, donor regions such as the fibula, the scapula, as well as the iliac crest [2] are highly suitable for clinical and surgical demands. Along with the restoration of continuity, masticatory rehabilitation following reconstruction is also of great importance.

Virtual Planning

Three-dimensional virtual surgical planning (3D-VSP) uses three-dimensional imaging datasets from computed tomography (CT) and magnetic resonance imaging (MRI) of the defect site as well as CT angiography of the graft harvest site. Depending on the underlying disease, CT scans provide high resolution of both hard and soft tissues in the case of bony defects or bone erosion. In the case of soft tissue tumors and inflammatory diseases such as osteomyelitis, MRI scans can further enhance soft tissue imaging. For improving the overall image quality, the strengths of the imaging modalities can be exploited by fusing and combining CT and MRI datasets using new software programs. After merging the desired datasets, the mandible and adjacent structures are initially segmented. Intelligent software segments are semiautomatically based on algorithms, which simplifies planning and shortens the overall duration [3]. In the context of virtual planning, the size and extent of the tumor, the resection margins, and the desired reconstruction can thus be planned preoperatively, visualized, and then implemented intraoperatively. For the planning of the intraoperative navigation, special dental splints are manufactured and placed or screws are inserted before the preoperative imaging. Intraoperatively, the digital planning and the clinical situation are merged via a navigation tripod temporarily attached to the skull. During the operation, navigation can be used to directly verify the targeted resection and the correct positioning of the patient-specific implants (PSI) and graft [4]. In addition to intraoperative navigation, preoperative planning can also serve as a basis for postoperative performance monitoring. By merging the pre- and postoperative CT scans, the accuracy of fit can be validated [5]. For a functional and aesthetically appealing reconstruction, the opposite side can be used as reference or template for achieving a symmetrical result. Besides the intersegmental cutting and visualization of the microsurgical reconstruction, the dental and prosthetic rehabilitation can also be considered, simulated, and planned [6]. If the prosthetic rehabilitation is already addressed at an early stage, the procedure is referred to functional or prosthetically oriented backward planning. Thereby, the condylar position and intermaxillary relationship are reproduced, visualized preoperatively, or planned. Thus, the entire functional and dental rehabilitation is achievable. Virtual planning further allows visualization of different reconstruction possibilities enabling a completely individualized treatment concept for the patient without invasive procedures. However, not only surgeons should benefit from the possibility of visualizing the surgical site in the future. The development of virtual reality devices will also provide access to the planned operation for patients. Regarding patient education, the operation is presented in a more illustrative and tangible way, increasing the transparency of the treatment concept [7].

Patient-Specific Implants (PSIs)

Advancements in CAS, particularly regarding computer-aided design/computer-aided manufacturing (CAD/CAM) technology, are superior to more traditional methods of mandibular reconstruction with hand-bent plates [8–15]. CAD/CAM or selective laser melting (SLM) plates achieve higher accuracy compared to manually bent reconstruction plates. These plates provide greater results in terms of strength and intraoperative positioning [16]. Decisive factors for this procedure are anatomical and symmetrical bone shaping, restoration of a stable dental occlusion, and condylar repositioning into a centric relation [9, 17–20].

In the conventional technique, in contrast to CAS, the plates are bent intraoperatively or preoperatively manually before their adaptation. Depending on the complexity of the case and the skills as well as experience of the surgeon, this procedure might be very time consuming. The standard plates offered by manufacturers do not always possess the required size and number of holes for the intraoperative situation. PSIs do not need to be bent to fit the patient's mandible and do not require predefined bending points as with conventional reconstruction [21, 22]. With improvements of CAD/CAM, it is possible to accurately plan the reconstruction of craniofacial defects preoperatively, manufacture precise PSI, and place them in less complex surgeries with shorter operating times [12, 23–25]. The implant can be designed and shaped by the surgeon according to the defect size, shape, and morphology [26, 27]. By selecting the appropriate design method, manufacturing process, and implant material, it is possible to perform a precise surgical procedure and reduce complications [28–35]. The integration of this technology in the pre- and intraoperative workflow has simplified the production of cutting guides and has been shown to shorten the operation time and the length of stay and to improve osseous consolidation, symmetry, and morphology [34, 36, 37]. Recent research demonstrated additional advantages, for instance, minimized interoperator variability caused by the surgeon's experience and improved teaching possibilities for younger colleagues involved in the planning procedures/sessions with a senior consultant and/or biomedical engineer [38].

Computer-Assisted Reconstruction of the Mandible Using Microvascular Grafts

After continuity resections of the lower jaw in case of carcinoma, osteonecrosis, osteomyelitis, or trauma, a mandibular reconstruction is essential to restore function and aesthetics [6, 39]. The size of the defect is determined by the preoperative extent, the entity of the pathology, and the resulting radicality of the resection.

Defects of the mandible are reconstructible using either a reconstruction plate without bony reconstruction or immediately with a combination of reconstruction plate and primary bone flap. Despite the considerable progress in microvascular surgery, complications such as tissue necrosis, failure of the graft, infections (donor site or recipient), prolonged hospital stay, and long recovery process occur [40–42].

Fibula, scapula, or iliac crest grafts are suitable for the clinical requirements for reconstruction of the mandible, in the sense of a free tissue transfer.

Fibula-Tx

The microvascular fibula graft ingests a major role in computer-assisted reconstruction of the mandible and in dental rehabilitation. It provides a similar cross section as an atrophied mandible, shows good corticoid bone quality and special vascularization, and can be harvested up to a length of 20–25 cm [43].

Nevertheless, not every patient can undergo fibular grafting as in 6% of cases a nonunion of the anterior or posterior tibial artery is present [22]. In more than 1% of cases, the peroneal or fibular artery is the only vessel supplying the entire lower leg making microsurgical fibular transfer impossible. Angiography of the donor region is used to check whether transplantation is advisable, where the perforators are located, and how the graft can be obtained in an individualized manner. During virtual planning, the harvesting templates including drill holes are individually designed so that the number and position of the perforators are considered along with the planned osteotomy lines. This also facilitates the removal of a suitable skin transplant. Due to the digital and visualized planning as well as the facilitated handling, ischemia and operation time can be shortened, and an optimal aesthetic and functional result is achievable.

Scapula-Tx

The microvascular scapula graft is highly appropriate for reconstruction of the mandible [44], especially if a fibula graft is not possible due to peripheral vascular arteriopathy [45]. The lateral scapula edge with the maximal length of 14 cm can be used for bony reconstruction [46]. The circumflex scapular artery supplies the lateral scapula as the terminal branch of the subscapular artery and equips the soft tissue above the scapula via two other vascular branches. This special vascular anatomy allows two independent fasciocutaneous flaps, the scapular and the parascapular flaps, to be harvested simultaneously for soft tissue reconstruction with one pellicle [45]. Therefore, this transplant can be primarily used for the reconstruction of combined defects where intraoral and extraoral soft tissue reconstruction is necessary as well as bony reconstruction. Compared to the removal of the fibula graft, a change of position must be performed intraoperatively. When harvesting the scapula graft, it is not possible to operate in two teams and save operating time.

Iliac Crest-Tx

The iliac crest transplant is further suitable for microsurgical reconstruction of the mandible. Supplied via the circumflex ilium profunda artery, the iliac crest graft is a valid graft because of the good bone quality, the slightly curved contour, and the bone volume. The special bone structure can facilitate the desired dental rehabilitation [47]. Nevertheless, the special vascular supply (short pellicle) makes microsurgical anastomosis difficult. Thus, strict indication and concrete preoperative planning are advisable.

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