Principles of Implant-Based Reconstruction and Rehabilitation of Craniofacial Defects

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ABSTRACT

The final stages of reconstruction following craniofacial trauma or tumor resection often involve the fitting of prostheses. Development of osseointegrated implants for retention of prostheses has improved function and aesthetic outcome. Placement of osseointegrated implants requires coordinated care from multiple specialists and a lifetime commitment of the patient. The workup and surgical treatment algorithms for placement of intraoral compared with extraoral implants are discussed. The quality and quantity of bone available are the most important factors influencing design and placement. The long-term retention of implants is influenced by implant site, local tissue bed preparation, and hygiene. Osseointegrated implants are a part of the complete rehabilitation of patients with craniomaxillofacial defects. Although final fitting and maintenance of prostheses is completed by prosthodontists and patients, successful placement and preservation of implants is affected largely by the plan set forth by the reconstructive surgeon.

KEYWORDS: Craniofacial defects, craniofacial reconstruction, osseointegrated implants

PRINCIPLES OF FUNCTIONAL AND AESTHETIC REHABILITATION WITH OSSEOINTEGRATED IMPLANTS

The successful rehabilitation of patients with craniofacial defects due to trauma, tumor ablation, or congenital deformity depends on the motivation of the patient, careful preoperative planning, interdisciplinary cooperation, and adequate surgical and prosthodontic techniques. Ideally, all treatment options for aesthetic and functional rehabilitation including implant-based reconstruction should be discussed with the patient. If osseointegrated implants and rehabilitation with a prosthesis are considered, for example, before tumor resection, an impression of the teeth can be taken and used for the modeling of the prosthesis. If possible, bone can be preserved or reconstructed in areas crucial for later

placement of osseointegrated implants or immediate reconstruction and implantation can be considered. Furthermore, the tissue bed can be prepared for implants during ablative and reconstructive surgery without omitting the necessary radicality. In all cases of traumatic, congenital, or tumor-related craniofacial defects, the topographic positioning of the implants and the treatment plan, including the timing and need for bone replacement, should be discussed by the surgeon and the maxillofacial prosthodontist prior to surgery.

Preoperative Planning

Assessment of the bone available for implantation is most important in preoperative planning. For complex craniofacial defects, computed tomographic (CT) scan

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Craniomaxillofac Trauma Reconstruction 2010;3:33–40. Copyright © 2010 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA. Tel: +1(212) 584-4662.

Received: August 10, 2009. Accepted: September 24, 2009. Published online: March 11, 2010.

DOI: <http://dx.doi.org/10.1055/s-0030-1249372>. ISSN 1943-3875.

allows the best assessment of bony structures available for placement of osseointegrated implants. Axial scans of the relevant parts of the craniofacial skeleton should be performed in 1 to 2 mm slices. The patient's head should be positioned such that the scans are parallel to the surface of the upper teeth or the upper alveolar ridge to allow for the best results for reconstructed images in coronal planes.^{1,2} For intraoral dental rehabilitation, a cone beam CT can be performed that allows visualization of the alveolar, maxillary, or mandibular bone defect in preparation for implant surgery (Fig. 1).³ In selected cases, computer-aided design/computer-aided manufacturing (CAD/CAM) evaluation and planning can be used for image-guided implant placement and immediate loading with a prefabricated denture in one surgical step (Fig. 2).⁴

Special care needs to be taken in patients who underwent or will undergo radiotherapy because bone healing and osteogenesis are depressed. There is still insufficient clinical and biological information to suggest an established timetable for the implantation of osseointegrated implants in irradiated bone. A time interval of 12 months is recommended between termination of treatment and installation of implants.⁵⁻⁸ Perioperative hyperbaric oxygen (HBO) can be considered as adjuvant therapy. The long-term survival of osseointegrated implants placed in irradiated bone in patients treated with HBO was improved dramatically compared with that of implants placed in patients who were not treated with HBO.⁹

Prosthetic Techniques

The prerequisite for implant-based restoration and retention of dental, orbital, auricular, or midface prostheses is the establishment of osseointegration. For replacement of teeth and stable anchorage of intraoral and extraoral prostheses, specially designed titanium implants are available in different shapes and lengths. In extraoral implants, a flange is designed to avoid dislocation into interior compartments (Fig. 3). With osseointegrated implants, many of the former limitations of defect dentures and prostheses designed to cover defects after tumor ablation in the face have been eliminated. A prosthesis can now be directly anchored to the underlying bone with excellent functional and aesthetic improvements and long-lasting results.

General prosthetic requirements of treatment are difficult to establish because of the great differences in defect size and location, amount of bone available, bone quality, and the thickness and mobility of the soft tissue in any given patient. Whereas two implants may be sufficient for retention of an auricular prosthesis, as many implants as possible should be placed in extended maxillomandibular defects to distribute the load.¹⁰

Prosthetic assessment of the implantation sites has to take several fundamental principles into account. First, the retention and support for the prosthesis has to fall within the peripheral extension of the device. Preferably, the margins of the prosthesis should extend in areas of limited mobility of the adjacent tissue bed. Overextension of a prosthesis in the midface is therefore limited. The anchorage system also needs to be

Figure 1 NEWTOM cone beam X-ray for implant planning following subtotal resection of the maxilla.

Figure 2 CAD/CAM planning of image-guided implant placement with immediate restoration with the denture in one surgery. A computed tomographic (CT) scan is taken with a model denture in place, and the implant size and position are planned on the computer (upper left). A surgical stent is fabricated (upper middle) and the denture is prefabricated based on the computer model. The surgical stent is used for flapless surgical placement of the implants according to the preoperative plan (upper right), and the prefabricated denture is inserted in the operating room at the end of surgery (below: preoperative and postoperative pictures of the patient).

placed deep enough to allow for sufficient thickness of the prosthetic material. The support system is for the prosthesis to be designed such as to avoid stress concentration and distribute forces uniformly to ensure long-time survival of the implants. Whereas this does not pose much problems in auricular, orbital, or simple midface prosthesis, difficult design problems can occur in combined intraoral and/or combined intraoral/extraoral defects. Individually designed open bar systems fulfill these engineering requirements.

Long-term success of a dental, facial, orbital, or auricular prosthesis depends on the maintenance of anchorage function.¹¹ Soft tissue inflammation and ingrowth of soft tissue may lead to the loss of an implant and can be avoided in most cases by proper preparation of the implant site and adequate postoperative care.

There also appears to be a direct correlation between the level of hygiene and inflammatory soft tissue reactions of the skin at extraoral implantation sites.¹²

The survival rates of osseointegrated implants depend on the site of implantation and range from 77.2% to 95.7% after 5 years. Implants placed in the orbit, the midface, and the frontal bone have three to four times higher failure rates compared with implants in the mastoid area.¹³ Survival rates for implants in the floor of the nose have been similar to those for the auricular sites. The failure rate of extraoral implants placed into irradiated bone seems to be even higher.¹⁴ The time of the second-stage surgery—when the skin penetrating abutments are attached to the implant—needs to be adjusted accordingly to allow for sufficient bone healing.

Figure 3 In general, osseointegrated implants are made of titanium and have a screw design. Different lengths and widths are available to accommodate different clinical situations (A). Special extraoral implants with a limited length of 3 or 4 mm and a flange for retention have been designed, which can be used in the skull without the risk of intracranial or sinus dislocation (B).

IMPLANTATION OF OSSEOINTEGRATED IMPLANTS FOR INTRAORAL DENTAL REHABILITATION

Prosthetic rehabilitation of maxillomandibular defects after trauma, tumor resection, or congenital deformities can significantly improve patients' function and quality of life.¹⁵ For the planning of the prosthesis and

positioning of the implants, it is helpful to fabricate a model prosthesis and surgical guide that can be used as a template for surgery (Fig. 4A and B). The location of the implants is determined based on the surgical template and the availability of bone in the intended area of implantation. If bone replacement is necessary, free bone grafts can be used successfully for augmentation

Figure 4 Reconstruction of a maxillary defect status post trauma. (A) Model of the defect. (B) Waxup of the final dentition and bone graft model. (C) Bone graft from iliac crest and placement of osseointegrated implant 3 months later. (D) Abutment placement 3 months after implant placement and final restoration.

Figure 4 (Continued) (D) Abutment placement 3 months after implant placement and final restoration.

or reconstruction of defects of up to 5 cm in the mandible if the soft tissue bed is sufficient and no irradiation is planned (Fig. 4C).¹⁶ The implants can be placed immediately at the time of reconstruction or 3 months after bone grafting. In general, a two-stage procedure is used with exposure of the implants and restoration after a healing interval of 3 to 4 months to allow for osseointegration (Fig. 4D). Dentoalveolar bone and soft tissue defects, for example, in clefts, can also be addressed successfully with distraction osteogenesis prior to placement of osseointegrated implants for dental rehabilitation (Fig. 5).

If the recipient area after tumor ablation does not provide adequate soft tissue to incorporate a free bone graft, for example, due to scarring, or the patient has been treated with irradiation, free vascular bone and tissue grafts are indicated. Vascularized bone flaps for reconstruction of bony defects are mostly harvested from the iliac crest, the scapula, or the fibula. Primary implantation of osseointegrated implants into vascularized bone flaps is successful, but influenced negatively by radiation therapy (Fig. 6).¹⁷⁻¹⁹ Problems in autologous bone grafting are the limited availability of the material

and the morbidity in the donor region. Therefore, transplantation of allogeneic bone, bone substitutes, and tissue-engineered replacements are discussed.²⁰⁻²² Until now there is no alternative to autologous bone in the installation of osseointegrated implants.

In microvascular free flaps, the most important step in the second-stage implant exposure is the reduction of the subcutaneous tissue. Subdermal margins can lead to inflammation and loss of the implants.²³ Vestibuloplasty in combination with split thickness skin grafts and keratinized gingiva grafts can be used to rebuild periimplant tissue and avoid periimplantitis in these cases.²⁴

EXTRAORAL PROSTHESIS

Auricular Prosthesis

The auricle can be reconstructed autologously using cartilage, local flaps, and skin grafts over multiple stages. In comparison, osseointegrated implants for an auricular prosthesis can be done in one or two stages. Both treatment alternatives should be discussed with the

Figure 5 Alveolar distraction in a cleft-lip and palate case, status post multiple bone grafts. Note that the newly formed bone is not yet visible on the X-ray at the time of distractor removal (lower middle).

patient.²⁵ CT is usually not necessary after ablation of the auricle alone, but it is the method of choice for studying the anatomic situation when more extensive bone defects in the mastoid have been created during tumor surgery or the bony anatomy is changed due to a congenital deformity. Intraoperative navigation can be used in these selected cases for guided placement of the implants (Fig. 7).²⁶

For fixation of an auricular prosthesis, two to three implants are inserted in a semilunar fashion as a basis for a bar retained prosthesis. The fitting of the

prosthesis can be performed 6 to 10 weeks after implantation in a one-stage procedure. No difference has been shown in the establishment of osseointegration between these one-stage and two-stage surgical techniques in implants placed in the mastoid process for the retention of bone-anchored hearing aids or auricular prostheses.²⁷

Orbital Prosthesis

An implant-based orbital prosthesis becomes an option if the eyelids cannot be preserved during tumor resection and an eye prosthesis alone cannot rehabilitate a patient. The primary locations for the insertion of osseointegrated implants for orbital prostheses are the lateral orbital and infraorbital rims because the bone is sufficiently thick and wide in these areas. Successful osseointegration of periorbital implants is significantly lower than anywhere else in the craniofacial, therefore surgery is performed in two stages with a 6 to 12-month healing interval after implant placement.^{28,29} In general, a minimum of three implants are placed for retention.

Figure 6 Resection of a recurrent ameloblastoma and immediate reconstruction with a microvascular iliac crest bone graft and osseointegrated implants.

Nasal and Midfacial Prosthesis

The aesthetic results of nasal or midface prosthesis depend on the extension of the defect into areas of higher motility in the face, where gapping can occur and reveal the margins of the prosthetic device. It can become necessary especially in cases of partial defects to remove tissue, for example, alar rims, to improve the aesthetic outcome. The adjacent skin is fixed to the

Figure 7 Auricular prosthesis.

underlying periosteum. The residual frontal bone and the zygomatic arches can be used for implantation. Long implants are available for insertion into the zygoma, which provide excellent stability.

In large defects, it may be desirable to decrease the size of the lesions and create a barrier to the gastrointestinal tract to enable the regular intake of food. The maxillary tuberosity and the posterior palatal rim are crucial for the establishment of a posterior peripheral seal of any prosthetic device. It is especially important to preserve or reconstruct the upper lip to minimize the extension of the prosthesis and to retain lip function.

The size of the lesions can be reduced with free tissue transfer, though the aesthetic results may be limited by the different skin color and texture of the donor skin. If extraoral implants are planned, areas of potential implant installation should not be obliterated with myocutaneous flaps. In addition, access has to be possible for placement and maintenance of a prosthetic bar system.

CONCLUSION

Craniofacial trauma, surgical resections of head and neck tumors, and congenital deformities can create large defects accompanied by dysfunction and disfigurement. In malignant tumors, radiation therapy produces signifi-

cant additional tissue management problems. For functional dental rehabilitation and in cases where autologous reconstruction is not possible, osseointegrated implants can be used to support oral, auricular, orbital, and midface prostheses.

Restoration of craniofacial defects with a prosthesis anchored by osseointegrated implants is a difficult task that requires the close collaboration of the surgeon, prosthodontist, anaplastologist, and radiologist and a lifetime commitment by the therapists and the patient. Careful preoperative planning is essential to evaluate the individual situation and determine whether implants alone or implants in combination with tissue transfer are best suited to provide a basis for a retention system for a prosthesis. A one-stage or two-stage procedure depending on the location is used for the placement of the implants in the craniofacial skeleton. In some cases, implant-based prostheses provide the only reliable and aesthetically appealing solution for functional and aesthetic rehabilitation for a patient.

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