A Prosthetically Driven Approach for Immediate Dental Implant Reconstruction of a Maxillary Free Fibula Flap with the Aid of Virtual Three-Dimensional Planning and Intra-Operative Navigation

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Received: 10 August 2022; **Accepted:** 05 September 2022

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ABSTRACT

Objective: To describe a prosthetically-driven reconstruction of an edentulous atrophic maxilla and mandible using 3D surgical planning and intra-operative navigation.

Methods: A twenty-eight-year-old male presented for reconstruction with fixed dental prostheses after a gunshot wound caused severe atrophy of the jaws and nasal deformity. His dentition was non-salvageable with insufficient maxillary bone for dental implant placement. To restore his midfacial deformity, reestablish upper lip support, and provide adequate bone, his maxilla was reconstructed using a free fibula flap. Dental implant placement is dictated by the planned prosthetic tooth position, and therefore the design of the maxillary reconstruction considered the necessary prosthetic space and the location of the planned prosthetics via Virtual Surgical planning. Intra-operative navigation confirmed the correct placement of the flap using surgical probe guidance.

Results: Using our precise and prosthetically driven method, we were able to place dental implants to support fixed dental prostheses and correct the skeletal deformity in a single surgery.

Conclusion: Traditional dental prosthetic design principles were applied to optimize functional and esthetic outcomes in a complex case of simultaneous maxilla-mandibular reconstruction. The use of 3D surgical planning and intra-operative navigation allowed us to shorten the treatment time providing a predictable and accurate outcome.

Keywords: *Free Tissue Flaps, Bone Transplantation, Surgery, Computer Assisted, Maxillofacial Injuries, Maxillofacial Prosthesis*

Introduction

Microvascular free fibula flap transfer has been widely utilized in tumor ablative surgery in the maxillofacial region. It provides ample bone length and bulk to reconstruct any defect with minimal donor site morbidity (Hidalgo, 1989). One of the main benefits of the use of vascularized bone over non-vascularized bone for reconstruction is the ability to achieve dental rehabilitation sooner as a result of a more rapid and reliable healing (Urken *et al*., 1989). Traditionally, the fibula is allowed to form bony union with the native skeleton prior to proceeding with dental implant placement and prosthetic fabrications, (Qaisi *et al*., 2016) however some investigators have reported shortened treatment times and success with immediate dental implant placement at the time of the fibula reconstruction (Levine *et al*., 2013; Rude *et al*., 2014).

Three-dimensional surgical planning allows for coordination between the various surgical teams prior to entering the operating room. At our institution, the multi-disciplinary approach involves the expertise of the oral and maxillofacial, plastic, and head and neck surgery teams as well as the restorative dentist. Virtual surgical planning with patient specific data allows the reconstruction to be planned backwards based on the desired aesthetic and functional outcomes. The stereolithographic models, stents, and cutting guides fabricated based on the three-dimensional surgical planning decrease treatment times and increase the likelihood of obtaining suitable prosthetic results. In one of the largest retrospective reviews of immediately placed dental implants in free fibula flap reconstruction with virtual surgical planning, Avraham et. al. reported no difficulty with denture placement caused by implant malposition in fourteen patients (Avraham *et al*., 2014).

Surgical navigation allows the surgeon to transport the pre-operative plan into the operating room. The pre-determined virtual surgical plan can be utilized in real-time with navigation to provide guidance for accurate resection margins and placement of bone segments. When correcting complex deformities of the craniomaxillofacial skeleton, it is essential to establish facial symmetry and projection in the optimal anteroposterior, vertical, and sagittal relationships (Bell, 2011). Obtaining the correct pitch, roll, and yaw is difficult to control intra-operatively due to limited visibility. Intraoperative navigation uses the frameless stereotaxis to allow precise location of an anatomic landmark or implant with a margin of typically less than one to two millimeters (Luebbers *et al*., 2008).

This is the first known report of complex maxillary and mandibular reconstruction with a free fibula flap and immediate dental implants in a totally edentulous patient planned with virtual surgical planning working backwards from the desired prosthetic result to ensure the optimum esthetics and functional occlusion.

Case Report

Patient and Methods

A 28-year-old healthy patient presented to our institution with a chief complaint of the desire to have fixed dental prostheses. The patient had sustained trauma from a gunshot wound five years prior. His initial treatment involved open reduction internal fixation of maxillary and mandibular fractures. Physical exam at presentation revealed a concave facial profile with severe maxillary hypoplasia and nasal deformity (Fig. 1). Intraorally, there was severe atrophy of the maxilla and mandible. The remaining dentition was non-salvageable due to dental caries and failed to maintain any vertical dimension of occlusion or lip support (Fig. 2). Computed tomography (CT) demonstrated total loss of the premaxilla and pneumatized maxillary sinuses. The mandible showed moderate atrophy by loss of vertical alveolar height. There was hardware of the maxilla and mandible remaining from the prior surgeries (Fig. 3).

Figure 1: Pre-Operative Frontal and Lateral Facial Views.

Figure 2: Pre-Operative Intraoral View.

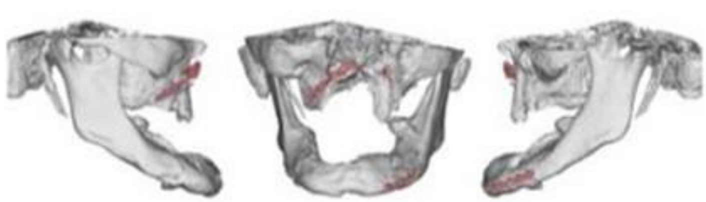

Figure 3: Three-dimensional rendering of maxillofacial CT.

Step 1: Prosthetic Planning

The patient had no pre-existing occlusion to serve as a guide for the reconstruction. We therefore utilized the steps of traditional denture fabrication to determine the proper anatomical tooth position. The steps included impressions from which casts were made, fabrication of occlusal rims to measure vertical dimension of occlusion and facial tooth position for soft tissue support and finally a wax-up with the prosthetic teeth for the maxillary and mandibular arches (Fig. 4). Following clinical try-in, the wax ups were then duplicated into a radiographic stent with radio-opaque gutta-percha marking the position of the teeth. A CBCT was then taken with the patient in centric occlusion wearing the radiographic stents. Another separate CBCT of the radiographic stents alone was then taken to aid in the virtual planning.

Figure 4: Prosthetic wax up for maxillary and mandibular arches.

Step 2: Virtual Planning

Virtual planning for the maxillary surgery was performed using 3D Systems Healthcare (Littleton, Colorado). The patient specific CBCT DICOM images and computed tomography angiography (CTA) for the lower extremities were used to plan the maxillary reconstruction with an osteocutaneous free fibula transfer flap and immediate dental implants. The fibula was positioned roughly fifteen millimeters above the occlusal plane determined by the radiographic stents to create adequate occlusal space for the planned prosthetic rehabilitation. The virtual plan dictated the necessity to perform a partial maxillectomy to provide the adequate space for inset of the free fibula flap. The three-dimensional radiographic guide could be added and subtracted during the planning to aid in implant positioning. Cutting guides with predictive holes and positioning guides were fabricated to aid in the maxillectomy and subsequent inset of the maxillary fibula graft (Fig. 5). A cutting guide for the fibula was fabricated to guide the osteotomies and dental implant placement (Fig. 6). Lastly, a stent was fabricated to aid in assembling the neo-maxilla which was constructed with priority to the angulation of the dental implants and desired position of the planned prosthesis.

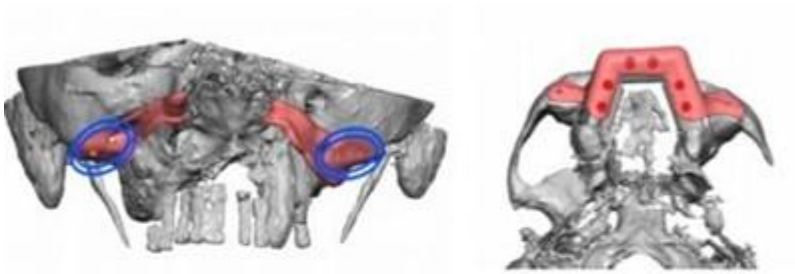

Figure 5: Cutting guide for maxillectomy and positioning guide for the neo-maxilla with predictive holes to dictate the inset of the fibula.

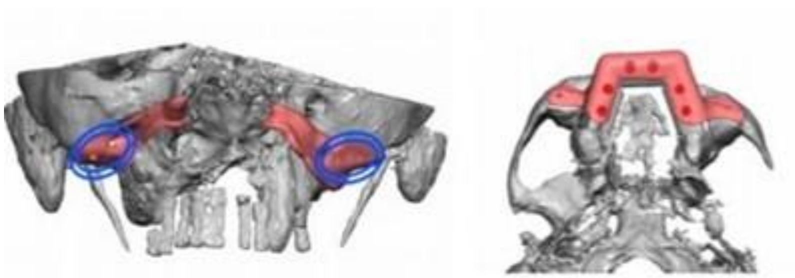

Figure 6: Fibula cutting guide with dental implant stent.

The mandibular dental implant treatment planning was performed with the assistance of virtual planning from Simplant® (Dentsply Implants, Belgium). Similar to the maxillary treatment planning, the patient specific data and scanned radiographic guide were used to design a fully-guided and bone borne implant stent compatible with the Nobel Active® guided implant surgery system (Nobel Biocare™, Yorba Linda, California). The stent was designed to guide the placement of four implants between the mental foramina due to insufficient vertical bone height in the posterior mandible above the inferior alveolar nerve. The posterior implants were angled to increase the anterior-posterior spread to limit the cantilever effect.

Step 3: Surgery

The surgery was performed in the operating room under general anesthesia via tracheostomy (the patient had a previous tracheostomy during his initial trauma). The BrainLab (Feldkrichen, Germany) skull reference array was attached to the forehead and intraoperative registration was completed. A maxillary alveolar crestal incision was made intraorally to deglove the maxilla. Cutting guides were secured to the zygomaticomaxillary prominence and the maxilla was resected according to the guides. Predictive holes were made into the zygomaticomaxillary prominence to later aid in the inset of the three-piece free fibula flap into its planned location. The partial maxillectomy was completed. A stereolithographic model of the neo-maxilla was inset and confirmed in the appropriate location with intra operative navigation using surgical probe guidance in conjunction with the BrainLab (Fig. 7). Interferences were eliminated between the stereolithographic model and the remaining maxilla to limit ischemia time when the fibula flap was ultimately transferred.

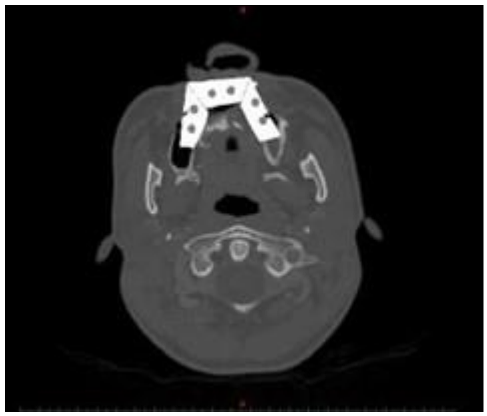

Figure 7: Surgical plan used with intra-operative navigation.

The mandibular dental implants were placed using the guidance of the bone-borne Simplant® dental implant surgical stent. A crestal incision was placed across the remaining mandibular alveolus. A full-thickness mucoperiosteal flap was reflected to facilitate the seating of the stent. The implant placement proceeded in the standard sequential manner using the Nobel Active® guided kit. Four dental implants were placed with good primary stability and cover screws were applied in standard fashion.

The fibula flap was harvested in the usual fashion. The fibula guide was secured in place and implant placement proceeded in the standard sequential manner using the Nobel Replace Select guided kit. Six Nobel Replace Select® Tapered dental implants with conical internal connection were placed with good primary stability. 5mm healing abutments were placed over the implants in the standard fashion. Osteotomies were made into the fibula through the cutting jig and the fibula segments were assembled into a stent. The three fibula segments were then plated against one another in a fashion that preserved the proper dental implant positioning (Fig. 8). The osteocutaneous flap was then moved to the head and the stent was secured using the predictive holes on the zygomaticomaxillary complex. The positioning on the inset fibula was confirmed with the use of the navigation probe in the anterior/posterior, lateral, and sagittal planes. The inset fibula was then plated to the native maxilla in the planned location using miniplates. The micro-vascular anastomosis was then completed in the standard fashion. The soft tissue paddle was seated intraorally to increase depth of the maxillary vestibule and cover the fibula with the implants. The remaining harvested fibula was buried in a subcutaneous pocket in the abdomen for later use in nasal reconstruction. The surgery was completed in 9 hours.

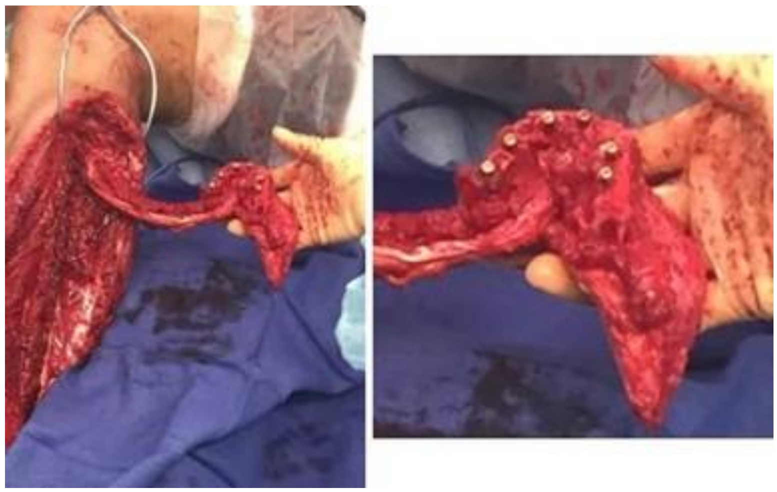

Figure 8: Neo-maxilla with immediate implant placement and vascular pedicle.

Post-Operative Course

Upon emergence from surgery, the patient was transferred to the surgical intensive care unit for hourly flap monitoring and ventilator support. He was administered appropriate anti-platelet therapy. On post-operative day 3, he transitioned to the step-down unit. On post-operative day 6, his tracheostomy was decannulated. The patient underwent uneventful post-operative course. Subsequent surgery was delayed for 5 months to establish collateral circulation to the skin paddle and osseointegration of the dental implants. The patient returned to the operating room for reconstruction of the saddle nose deformity using the banked fibula bone stored in the abdominal soft tissues as a cantilevered graft. The patient also underwent intraoral flap revision with second stage surgery of the maxillary and mandibular dental implants. All dental implants passed the reverse torque test of 35ncm. The cover screws were removed and replaced with healing abutments.

Complications

The patient sustained no complications as a result of the procedure. Due to geographic circumstances, the patient's treatment was terminated, and the patient was lost to follow-up prior to fabrication of the fixed dental prostheses. Post-operative maxillofacial CT rendering shows the reconstructed neo-maxilla with dental implant placement (Fig. 9).

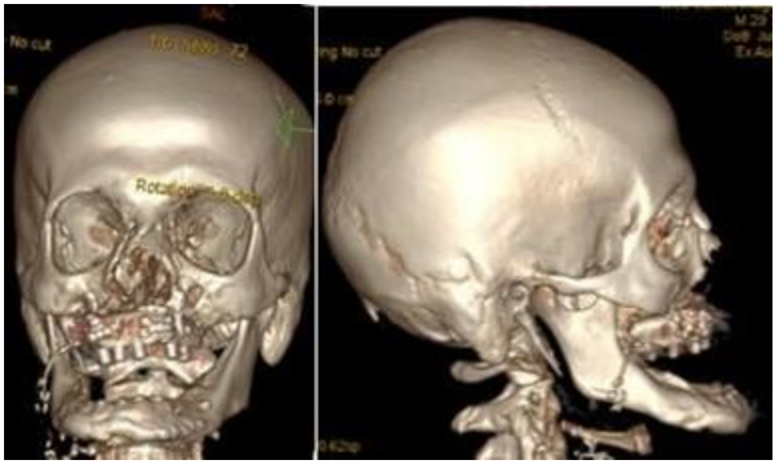

Figure 9: Final treatment outcome prior to fixed prosthodontics.

Discussion

Tooth, arch and jaw characteristics possessed by those with naturally optimal occlusions and balanced faces make up the six elements of orofacial harmony that are the optimal treatment goals in maxilla-mandibular facial reconstruction. These six areas are the 1) tooth position and shape and arch width, depth, and length, 2) anterior-posterior jaw positions, 3) jaw widths, 4) jaw heights, 5) chin prominence, and 6) occlusion (Andrews, 2000). These standard concepts and generally accepted numerical ranges can be applied to cosmetic and orthognathic surgery as well as to dentistry to produce desirable cosmetic and functional outcomes. In this case, the six elements of orofacial harmony were applied to plan and execute a complex maxillofacial reconstruction involving the nose, midface, mandible, and associated dentoalveolar structures.

The patient described in this report had severe class IV atrophy of the maxilla and mandible. The patient had a pre-existing angle Class III jaw relationship and no functional occlusion as a result of the gunshot wound trauma. In order to obtain the desired facial harmony and function, traditional dental prosthetic and orthognathic elements were employed in the surgical plan. The planning involved working backwards from the desired tooth position, which in turn, dictated the position and angulation of the dental implants. The position of the dental implants and the necessary prosthetic space then dictated the position of the fibula, which was chosen to reconstruct the midface due to its abundant length and bone stock.

Atrophy of the alveolar ridges often requires timely and complicated hard and soft tissue grafting procedures. Due to the treatment time constraints for this case, the patient was not in acceptance of traditional hard and soft tissue grafting to facilitate dental implant placement. An alternative graft-less technique of anchoring a dental prosthesis onto four zygomatic implants ("quad zygoma") was considered, but ultimately, it was felt that the anterior-posterior spread obtainable through quad zygoma implants would not be adequate to support the cantilever effect of a fixed prosthetic in the anterior maxilla. It was felt that the bulk of the prosthesis necessary to restore upper lip support would not be adequately supported by quad zygomas.

Immediate dental implant placement in a fibula for total maxillary reconstruction in a fully edentulous patient is a very complex case. Traditional dental rehabilitation following fibula placement and osseointegration is a process that can take up to twelve months (Qaisi *et al*., 2016). Meticulous three-dimensional virtual surgical planning and intra-operative navigation permitted the reconstruction of the midface and immediate dental implant placement to be performed in a single surgery for this patient. Immediate dental implant placement into fibulas in patients with non-malignant maxillofacial defects is an accurate and fast way to restore facial harmony and function with shorter treatment times.

Proceeding without this careful planning would have likely resulted in a poor jaw/tooth relationship, improper facial projection or lip support, errors in dental implant angulation, or inadequate prosthetic space for dental reconstruction. The complexity of this case stems from the lack of teeth/occlusion and the existing angle class III skeletal relationship, which would have posed significant uncertainty in positioning of the neomaxilla and dental implants if traditional denture making principles were not employed during the early pre-surgical planning phase. Tooth arch and jaw characteristics are critical in development of facial harmony and the function of the masticatory system supporting the importance of involvement from an oral and maxillofacial surgeon and dental prosthodontist as a part of a complex head and neck reconstruction team in the initial diagnosis and planning phases as well as the surgical phase.

This case report did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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