

**TITLE: Mandibular Reconstruction: Special Considerations in TMJ and Condyle Reconstruction**

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## **Introduction**

The mandible is a unique bone in the head and neck and is very important for a number of reasons. The mandible is important to airway stability as it supports the tongue base. The mandible is important in speech, deglutition, and mastication. It must be able to withstand significant forces during mastication. It has been found that the maximal molar occlusal forces average 4346 Newtons. The mandible is very important in defining the features and shape of the lower face. Many authors talk about the "Andy Gump" deformity. Based on a caricature from a cigar advertisement, the "Andy Gump" deformity refers to patients without a mandible. Mandible reconstruction must address each of these functions. The unique anatomy of the temporomandibular joint and the condyle have made reconstruction controversial. The anatomy is located near the skull base and complications of the reconstruction can be devastating. Return of form and function of the joint can be very difficult.

## **History**

Prior to recent advancements in surgical and medical treatment, mandible reconstruction saw very disappointing results. Many studies found that vascularized bone grafts failed in 50% of all cases. However, the recent advances of free tissue transfer especially involving osteocutaneous free flap reconstruction have revolutionized the practice of mandible reconstruction. The first successful mandible reconstructions were performed in 1976 by Panje and colleagues. Panje and his colleagues utilized free groin tissue transfer to reconstruct the mandible. As free tissue transfer has advanced, so has the involved hardware. Most initial hardware was composed of Vitallium which is an alloy composed of cobalt, chromium and molybdenum. This alloy was quickly replaced by stronger, less reactive alloys. Presently, mandible hardware consists mostly of titanium. Initial combinations of soft tissue reconstruction and reconstruction plates significantly improved short-term results. However, long term results remained poor. Plate extrusion, plate fracture and screw loosening all contributed to the poor long term results.

## **Anatomy**

The mandible is the strongest of the facial bones. It is a u-shaped bone with a horizontal section called the body which contains the alveolar process. The alveolar process contains dental sockets which support the teeth. Changes to the alveolar process occur throughout adult life and are most noticeable after dental extractions

where most patients lose alveolar height. It is also composed of two vertical segments known as the rami. The bilateral rami articulate with the skull through the temporomandibular joints. The rami are composed of broad, thin plates of dense bone and form the coronoid and condylar processes. The Inferior Alveolar Nerve passes through the Mandibular Foramen into the alveolar nerve where it provides sensation to the mandibular dentition. The nerve then exits the mental foramen found between the inferior border and upper edge of the alveolar process at the level of the second premolar tooth. The mandible has a dense cortical structure with a small core of spongiosa containing nerves, blood vessels and lymphatic vessels.

Mandibular movement depends primarily on 2 groups of muscles. The muscles are divided based on function into the depressor-retractor group and the elevator group. The Geniohyoid and the digastrics muscle compose the depressor-retractor group while the masseter, medial pterygoid and temporalis muscle compose the elevator group. The mandible is held into place by the masseteric-ptyergoid sling. The Medial Pterygoid inserts into the inner surface of the mandible while the masseter inserts on the outer surface creating a sling or cradle for the mandible. While the masseter muscle in most people is larger and more powerful, the medial pterygoid's attachment is more favorable. This causes the medial pterygoid to overpower the masseter in cases of segmental defects. This creates the typical displacement inward that is seen. There are two other muscles involved in mandibular movement. The lateral pterygoid and mylohyoid muscle have minor influences on the movement of the mandible. The lateral pterygoid, in particular, pulls the neck the mandible anterior and medially.

### Indications

Mandible resection is indicated in a number of cases. It is most often indicated in ablative surgeries involving benign or malignant neoplastic tumors. These ablative surgeries often involve soft-tissue defects. It is also indicated in certain traumas, osteoradionecrosis, bisphosphonate-induced osteonecrosis, and osteomyelitis.

### Classification

One of the first goals in mandible reconstruction is the accurate classification of the defect and an understanding of likely functional deficits (Mehta 2004). There are several classification schemes available today. Boyd and colleagues developed the HCL classification scheme. H defects refer to lateral defects of any length up to the midline which include the condyle. L defects refer to defects involving the lateral segment excluding the condyle, and C defects involve the central segment which contains 4 incisors and 2 canines. There are also 3 lower case letters to describe the soft tissue component. These are as follows: o, s, m, and sm. The lower case "o" signifies no skin or mucosa. The lower case "s" refers to defects involving the skin. The "m" refers to mucosa involvement, and "sm" involves the skin and mucosa.

Urken et al developed a similar classification scheme that is based on the functional considerations caused by detachment of the various muscle groups and difficulties with cosmetic restoration. The classification is broken into the letters: "C", "R", "B", "S", and "SH." The "C" stands for condyle, "R" stands for ramus, "B" stands for body, "S" stands for total symphysis, and "SH" stands for hemisymphysis.

### Goals of Reconstruction

As stated earlier, the accurate classification and understanding of functional deficits is one of the most important goals in mandible reconstruction. It is important to understand how best to restore form and function to the mandible. Mandible reconstruction should strive to restore the bony contour of the native mandible.

Reconstruction should work toward the restoration of mastication. With ablative surgeries, this is often most dependent of the amount of tongue volume taken. Generally, the greater the tongue volume loss, the more negative the impact upon recovery of oral function is. Mandibular reconstruction should allow for deglutition, articulation and most importantly, maintenance of the airway.

### **Current Techniques in Mandible Reconstruction**

Currently, there are three main techniques in mandible reconstruction. These include the use of alloplastic implants, vascularized free tissue transfer, and adjuvants to vascularized osseous free tissue transfer. Each will be discussed further.

#### **Alloplastic Implants**

There are several implantable devices used in mandible reconstruction. The bone plate and screw are the most common used implants. Often times, these implants are indicated in patients with poor performance status or when the soft-tissue defect is more extensive than the bony mandibular defect. Many improvements in these implants including self-drilling, self-tapping screws and locking miniplates have become an invaluable adjunct to micro vascular reconstruction.

The Titanium Hollow Screw Osseointegrating Reconstruction Plate System, also known as THORP, is the first reconstruction plate with a mechanism for osseointegration at the bone-to-screw interface. The plating system also creates a locking mechanism at the screw-to-plate interface. Studies showed that the THORP system has been superior to solid steel screws and titanium plates. It's adjuvant in micro vascular surgery has shown great promise in the future of mandible reconstruction

#### **Vascularized Free Tissue Transfer**

Micro vascular surgery has revolutionized oral and mandibular reconstruction. Taylor as well as Sanders and Mayou described the utilization of the iliac bone and overlying skin as a free tissue transfer in the 1980's. Also, in 1986, Swartz et al. introduce the scapular osteocutaneous free flap. In 1989, Hidalgo became the first to report transfer of the fibular bone for mandible reconstruction. Microvascular surgery allows for the ability to transfer substantial bone with soft tissue to the head and neck. While there are many different reconstructive tissue transfers available, the most important in mandible reconstruction are as follows:

- fibular free flap,
- scapular free flap,
- iliac crest free flap,
- radial forearm free flap, and
- double flap reconstruction.

#### ***Fibular Free Flap***

The fibular free flap, first utilized by Hidalgo in 1989, has become the workhorse of mandible reconstruction. The fibular free flap can be utilized to reconstruct bony defects as long as 30 cm in length. The length of the fibular free flap is unique in free tissue transfer as it is the only donor site that allows for total mandibular defects. It has a relatively long vascular pedicle which can be 6-10cm in length. This length becomes advantageous in reconstruction after ablative surgery when recipient vessels may be distant from the defect.

The free flap is based on the peroneal artery and vein. The flap is harvested with the flexor hallucis longus muscle, and its skin island can be used both intraoral and externally. When harvesting the flap, up to 27 cm of bone can be taken. The flap receives both segmental and intraosseous blood supplies. This allows for multiple osteotomies to the bone. This allows for improved contouring of the bone prior to reconstruction. The positioning of the flap allows for simultaneous dissection of the fibular free flap and resection. It is generally believed that small defects less than 5 cm in width can be closed primarily.

The fibular free flap is a wonderful choice for mandible reconstruction. However, there are definite limitations in its use. The flap is limited in the amount of soft tissue that can be recruited and the skin island is often thought to be unreliable in reconstruction. The bone does not recreate the alveolar height of native dentate mandible. Closing the defect often requires a secondary skin graft donor site. This can often be very painful for patients. It is important to preserve 7-8 cm of bone at the ankle and 3-4 cm of bone at the knee to reduce donor site morbidity. After harvesting, most patients will return to full ambulation in 2 months.

Pre-operative evaluation is very important in the decision to utilize the fibular free flap. Patients need evaluation of lower extremity vasculature to assess for disease precluding transfer. Current recommendations call for MR angiography. MR angiography has started to replace conventional angiography. CT angiography is also currently being utilized.

Kim et al. set to address the concerns of a secondary skin graft donor site by creating a cohort study involving 30 patients. The closure of fibular free flap donor sites remains controversial. The split-thickness skin graft adds pain and additional morbidity. The study set to examine taking the split-thickness skin graft in reconstruction from the cutaneous paddle of the fibula. The study recruited patients from September 1, 2006 to March 30, 2007 and included 30 patients from two institutions. All patients in the study underwent fibular free flap harvest with split-thickness skin graft. The average skin graft thickness of the study was 0.04cm. The results of the study found 87% (26 patients) with viable skin grafts at follow-up. 13% (4 patients) had partial loss of the skin graft ranging from 15-50% of the graft. No skin grafts were completely lost in the study. Results of the skin paddles were promising. One skin paddle required surgical debridement due to necrosis after a post-operative Streptococcus infection. 2 patients developed orocutaneous fistulas which were conservatively managed with dressing changes. 1 patient developed adhesions between the base of the tongue and the tonsillar defect which required adhesion lysis with placement of a split-thickness skin graft. 57% of the patients (17 patients) required post-operative radiation therapy of which 1 patient formed an orocutaneous fistula. In discussing the technique the authors recommended in defects involving opposing surfaces, epithelialized tissue should be used.

### *Scapula Free Flap*

Another adjunct in the repertoire of reconstruction is the scapula free flap. The scapula flap is often thought to be the most versatile of the flaps for mandible reconstruction. The anatomical basis for this flap is the circumflex scapular artery and vein. Generally, these vessels are of good length and diameter for anastomosis to native vessels. While the scapula free flap can provide up to 14 cm of bone for reconstruction, it is often of poor quality. The scapula provides a large, well-vascularized skin island with a moderate amount of bulk. The thoracodorsal artery can be included for transfer of the latissimus dorsi muscle. This ability makes the scapula free flap useful in salvage surgery after chemoradiation as the latissimus dorsi muscle can be used to cover vital vascular structures in the neck. The bone of the scapula can be safely osteotomized to contour into a new mandible during reconstruction. The flap is a good choice for through and through defects involving facial skin, bone, and mucosa. Many authors recommend its use in recurrent parotid malignancies requiring cheek skin and ascending ramus resection. The scapula free flap can accept osseointegrated dental implants. The flap

is also useful in the geriatric patient due to its ability to get patients to ambulate early after surgery. There are several limitations to the scapula free flap. First of all, the scapula free flap cannot be raised at the same time as the ablative procedure making operative times longer. Patients also complain of decreased range of motion to the shoulder affected by surgical resection.

### ***Iliac Crest Osseocutaneous Free Flap***

The iliac crest osseocutaneous free flap was, at one time, the workhorse of mandible reconstruction. However, with the advent of the fibula free flap, the iliac crest has fallen out of favor. The morbidity of the iliac crest harvest is the main reason for this fallout. The blood supply of the flap is based on the Deep Circumflex Iliac Artery. The vessels are generally short and of small diameter. A large amount of bicortical bone can be harvested. The iliac crest flap offers bone with height comparable to native dentate mandible. This helps to improve oral competence by supporting the lower lip. The iliac crest osseocutaneous free flap can be contoured to fit most segmental mandible defects. By including the ascending branch of the DCIA, the surgeon is able to harvest the internal oblique muscle. As mentioned, the donor site morbidity can be a limiting factor in the use of the flap. Patients generally complain of numbness to the anterior hip region. There is rehabilitation required to achieve ambulation. One of the major challenges is reconstruction of the anterior abdominal wall as hernia of the internal oblique muscle is a known complication.

### ***Long-term Follow Up for Free-Flap Reconstruction***

Hidalgo et al. completed a 10 year follow up study involving free flap reconstruction of the mandible. The study found acceptable aesthetic outcomes in 90% of patients involved. The authors also found that 70% of patients were eating a regular diet while the rest of the patients in the study were on a soft diet. This study is often cited most for its efficacy for free-flap reconstruction of mandible defects.

### ***Adjuncts to Vascularized Osseous Free Tissue Transfer***

There are several tools that the reconstructive surgeon uses to assist during placement of the osseous free flap. The temporary intraoperative external fixation device is used to aid in maintaining the preoperative three-dimensional relationships of the mandible. Most surgeons use bridging reconstruction bars or arch bars with intermaxillary fixation. Often, however, the native mandible has been changed secondary to neoplastic processes and the original three-dimensional relationships cannot be recreated. Another adjunct often used in iliac crest corticocancellous autografts is the periosteal free flap. The most often used flap is the fascioperiosteal radial forearm free flap. This flap is used to enhance the survival of the iliac crest autograft. Kelley et al. found that the periosteal tissue in the radial forearm flap had osteogenic capacity. As discussed, one of the goals in many reconstructions is the ability to place osseointegrated dental implants. Dental implants require bone height of approximately 6 to 7mm. Studies have shown that dental implants placed in osseous free flaps work identically to those placed in native bone. It is important to know that at least 6 months are needed between placement and post-operative radiation.

### ***Nonvascularized Bone Grafts***

The nonvascularized bone graft is used to reconstruct partial mandible defects from small segmental resections. It is not useful when soft tissue defects are present, which is often the case in mandible reconstruction especially with squamous cell carcinoma. The nonvascularized bone graft is often composed of cancellous bone chips. Autogenous bone chips are taken from the iliac crest. The major limitation of the

nonvascularized bone graft is that it cannot be utilized in patients undergoing radiation. Many of these patients have poor outcomes with many different complications.

### Posterior Mandible Defects

Most reconstruction techniques involving the condyle are controversial. With condyle reconstruction, oral competence, tongue, and laryngeal mobility are not significantly affected. Studies continue to show poor outcomes in TMJ and condyle reconstruction. Often, reconstruction does not improve function, and the complications from reconstruction can be devastating. Hanasona et al. performed a study of 74 patients undergoing microvascular free flap reconstruction in 2010 to delineate whether vascularized bone flaps or soft tissue free flap reconstructions were better in posterior mandible defects. In this study, posterior mandible defects were defined as those including at least the condyle and the ramus up to the mandible angle. There was a wide range of data collected in the study including mouth opening and cross-bite. Furthermore, patients were divided upon ASA and Kaplan-Feinstein classification.

Between the two groups studied, the most significant factors compared were mean age, ASA classification, Kaplan-Feinstein score and hypertension. Surgical factors including defect size were similar between groups and the only other factor differing in the two groups was length of reconstructive surgery. Complications were similar among the two groups. Functional outcomes, surprisingly, were also very similar. Time to oral intake, postoperative diet and mouth opening were similar. The only function outcome to show a difference was degree of cross-bite. The soft-tissue free flap group averaged from 0 to 16mm in cross-bite while the vascularized bone flap group averaged 0 to 6mm in cross-bite. Oncologic prognosis did not affect reconstructive technique or outcome. The study showed that patients with natural or prosthetic teeth were able to return to regular diet over soft or pureed diet.

### Condylar Prostheses

With regards to the condyle, disarticulation can result in complex deformities that can affect facial appearance and oral function. IN many cases the options are very limited. There are several options that have been used in the past. These will be discussed in further detail and include: reconstruction plates with attached metallic condylar prostheses, autogenous rib grafting, cadaveric mandible, and vascularized tissue transfer.

The temporomandibular joint is a complex synovial joint that allows for both hinge action and sliding action. As described previously, there are several muscles that create motion of the mandible. The lateral pterygoid muscle is directly attached to the condyle.

In condyle reconstruction, Gordon first reported the use of alloplastic materials in 1955. Gordon felt that using implants would maintain function mandibular ramus height, avoid malocclusion, and prevent hypomobility. Gordon also felt that condylectomy without reconstruction would result in facial deformity, pain, and limitation to movement of the face.

A case series by Patel in 2001 demonstrated 4 patients who underwent condylar reconstruction with metallic condylar prostheses after hemimandibulectomy. OF these patients, 3 required reconstruction for squamous cell carcinoma and 1 required reconstruction for Ewing's sarcoma. Of the 4 patients, 1 was found to have transient facial nerve paralysis. This patient was found to have migration of the prosthesis into the epitympanum causing otorrhea, profound sensorineural hearing loss due to destruction of the cochlea and transient facial nerve paralysis. 3 patients who underwent radiation therapy had exposure or extrusion of the prosthesis. The authors of the case series concluded that metallic condylar prosthesis in the setting of tumor resection and

reconstruction involves significant risks and potential complications. Often times, they do not offer satisfactory results after reconstruction. The authors suggest that vascularized bone grafting is the best option when available.

Condyles can be resected in many cases and fixed to the end of a free-flap bone graft. Studies have shown that these condylar reconstructions can functionally last for over a decade. Hidalgo et al. suggest that nonvascularized grafting should be considered when transections are planned at the midramus or higher. Hidalgo et al. also found that shaping the end of a graft, in particular the fibula free flap or placing a prosthetic condyle is a superior alternative to not reconstructing the condyle or the TMJ.

### **Condylar Prosthesis Materials**

There are many materials currently available in the reconstruction of the condyle. There are currently two metallic implants available for reconstruction. Those include the Christensen implant and the THORP. The Christensen implant has been used for over 25 years. It is composed of a metal fossa and a metal condyle with an articulating dome of polymethylmethacrylate. The implant has been successfully used in treating severe TMJ disorders. The implant can be made to create patient-specific prosthesis using CT imaging. The polymethylmethacrylate has been known to cause fibrosis, neo-ossification or heterotrophic bone formation.

Discussed earlier, the Titanium-Associated Hollow-Screw Reconstruction Plate or THORP has been used often in reconstruction of the mandible. Raveh et al. reported 2 successful reconstructions with the THORP in condyle reconstruction. The authors noted 2 major advantages to the THORP. They noted that the stable anchorage of the carrier plate to the mandible by hollow screws allowed for osteointegration of the plate and reduction in risk of hardware loosening. They also noted that the three-dimensional adaptability of the condylar prosthesis was beneficial in placement and later articulation. Kim and Donoff reconstructed 13 patients using reconstruction plates. They found that the majority of patients with plate loss were secondary to patients undergoing irradiation. This is unfortunate as many patients undergoing reconstruction will require irradiation due to advanced stage cancers.

Lindqvist et al. examined 23 TMJ arthroplasties using metallic condylar prostheses. They used both clinical and radiographic studies for follow up with an average of 25 months of follow up. Of the 23 patients, 3 patients required removal of the plate secondary to infection or necrosis of the pectoral flap. 1 patient required plate exchange secondary to plate fracture. They found that the neo-condyle had become displaced in 4 cases, and that 2 patients had bony erosion of the prosthesis into the skull base. The authors concluded that some tumor patients can benefit from condylar reconstruction. However, the complications can be devastating. They note that special anatomical and function conditions of the TMJ prescribe using autogenous materials whenever possible.

### **Implants**

There are several implantable materials in condyle reconstruction. However, these implants have many complications associated and are currently no longer indicated. They include Proplast, polytetrafluoroethylene (Teflon), and Silastic. Each of these materials can cause severe foreign body giant cell reactions. They can cause soft tissue and bony destruction. Microparticulate debris of these implants has been shown to migrate to other areas causing foreign body reactions.

## **Autogenous Materials in Condylar Reconstruction**

Free bone grafts, especially the osteochondral rib graft, are susceptible to unpredictable resorption. They are often insufficient for reconstruction of the mandible ramus and body. Vascularized bone grafts have been effective in reconstruction. They are resistant to infection and extrusion. They can survive in poor recipient beds after radiation therapy. The fibula free flap and the iliac crest have the best functional and aesthetic results of the vascularized bone grafts. These grafts, with overlying skin islands, can restore both bony and soft tissue defects in one procedure.

In reconstruction of the condyle with the fibula free flap, there are 3 major options. The first is the addition of a condylar prosthesis to the flap. The second involves the addition of the resected condyle to the flap, and the third option involves placement of the distal portion of the flap into the glenoid fossa. Condylar prostheses have many complications as discussed above. Often, the resection of a neoplastic process renders recovery of the condyle impossible. Hidalgo found that the free graft of a condyle to a fibula flap was a viable alternative in reconstruction. The fibula is well-suited for reconstruction secondary to its tubular shape and cortical density. The narrow shape of the fibula allows for placement into the soft tissue tunnel with minimal dissection around the facial nerve.

Several authors have reported good outcome with these patients. Guyot et al. followed 11 patients over 6 years and found good oral function preservation with no cases of ankylosis.

## **Conclusions**

Mandible reconstruction poses a specific challenge in both functionality and aesthetics. There are many options available to the reconstructive surgeon. As demonstrated, each option has its own risks and benefits. No two patients are the same and each presents their own challenge in reconstruction. Knowing the options available and their complications, allows for open conversation in reconstructive techniques and potential outcomes with the patient. The fibula free flap has quickly become the workhorse of mandible reconstruction overtaking the iliac crest flap. The condyle and temporomandibular joint remain challenges in mandible reconstruction. Authors have proven that vascularized free flaps are now the best option in reconstruction.

Radiation, both pre-operatively and post-operatively, increases the risks involved in mandible reconstruction. However, there is limited evidence in radiation and TMJ reconstruction.

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