Current Concepts in Mandibular Reconstruction By Microsurgical Free Flaps

NORMAN WEINZWEIG, M.D., F.A.C.S.
ASSISTANT PROFESSOR OF PLASTIC SURGERY & ORTHOPEDIC SURGERY
DIVISIONS OF PLASTIC SURGERY & DEPARTMENTS OF ORTHOPEDIC SURGERY
UNIVERSITY OF ILLINOIS AT CHICAGO & COOK COUNTY HOSPITAL, CHICAGO, ILLINOIS

JEFFREY WEINZWEIG, M.D.
RESIDENT IN PLASTIC SURGERY
DEPARTMENT OF PLASTIC SURGERY
RHODE ISLAND HOSPITAL
BROWN UNIVERSITY SCHOOL OF MEDICINE
PROVIDENCE, RHODE ISLAND

Restoration of form and function after composite oromandibular resections, especially those of the symphysis, is one of the greatest challenges facing the reconstructive surgeon. Loss of the anterior mandibular arch results in serious impairment of oral competence, speech, deglutition, and mastication producing the striking cosmetic disfigurement characterized by the "Andy Gump" caricature of the 1930s (Fig. 1).[1,2] The pathomechanics of this deformity are due to anterior and medial deviation of the lateral mandibular segments by the residual mylohyoid muscles and superior displacement by the medial pterygoid, masseter, and temporalis muscles. In comparison, these deforming forces are relatively absent following lateral mandibulectomy. Prevention of the "Andy Gump" deformity and its sequelae is paramount and often mandates composite replacement of bone, skin and mucosa. Additionally, through-and-through lateral or posterior defects requiring trilaminar replacement of skin, bone and mucosa or long bone gaps crossing the midline with massive soft tissue losses pose formidable reconstructive challenges.

With the advent of microvascular free tissue transfer, the feasibility of reliable, one-stage, complex oromandibular reconstruction is now reality. Currently, several free flaps enjoy popularity in mandibular reconstruction including the radial forearm, iliac crest, scapula, and fibula. Additional options include the combination of a reconstruction plate with free vascularized soft tissue or muscle and sequential free flaps combining the best individual flaps for bone and soft tissue components, such as the fibula for bone and the radial forearm for soft tissue. Each of these options possesses relative advantages and disadvantages (Table 1). None of these flaps is universally applicable to all mandibulectomy defects.

TABLE 1

Free Flap Options

Radial Forearm

Advantages	Disadvantages
* Up to 14 cm straight unicortical bone	* Donor radius fracture
* Multiple osteotomies	* Skin graft loss with tendon exposure
* Thin, pliable, abundant, relatively hairless skin	* Prolonged extremity immobilization
* Excellent intraoral lining	* Osseointegration not possible
* Three-dimensional orientation of tissue components	
* "Sensational"-reinnervation possible	

Iliac Crest

Advantages	Disadvantages
* Up to 14 cm thick corticocancellous bone	* Extremely bulky soft tissue
* Best bone stock for osseointegration	* Poor intraoral, chin and submental contour
* Natural bone curvature	
* Least three-dimensional flexibility	
* Delayed ambulation	
* Contour deformity at donor site	

Scapula

Advantages	Disadvantages
* Up to 14 cm straight corticocancellous bone	* Bulky soft tissue
* Independently vascularized bone and skin paddle(s)	* Two-team approach not possible
* Excellent three-dimensional flexibility	
* Good external skin coverage	
* Osseointegration possible	
* Minimal donor site morbidity	

Fibula

Advantages	Disadvantages
* Up to 25 cm straight bicortical bone	* Unreliability of skin paddle (no longer a problem)
* Multiple osteotomies	* Limited amount of skin available
* Osseointegration possible	* Delayed ambulation
* Minimal donor site morbidity	

Reconstruction Plate and Vascularized Soft Tissue or Muscle

Advantages	Disadvantages
* No donor bone morbidity	* Plate loosening, fracture or extrusion
* Easy to contour	* No bone stock for osseointegration
* Reduced operative time	
* Condylar replacement	
* Reconstruction of extensive bony defects in elderly and infirm	

Sequential Free Flaps

Advantages	Disadvantages
* Combines the best qualities of bone and soft tissue of individual flaps	* Prolongs operative time
	* Adds complexity to case
	* Increases donor morbidity

However, the objective is to select the best flap for a particular oromandibular reconstruction rather than using one flap to accomplish all reconstructions.

Choosing the particular flap to be used in a patient must be individualized and depends upon numerous factors. These include the experience and personal preference of the surgeon, extent of the defect with respect to bone and soft tissue requirements, need for intraoral lining and/or external skin coverage, three-dimensional orientation of the various tissue components, candidacy for osseointegration, prognosis, considerations for donor site morbidity, and overall medical condition of the patient. This can often be an extremely difficult decision-making process even for the experienced microsurgeon.

HISTORICAL PERSPECTIVE

Over the years, various techniques for mandibular reconstruction have evolved with poor or, at best, unpredictable results largely due to the variability of the recipient bed. These procedures have included the use of free bone grafts; alloplastic materials such as metallic implants and metal or Dacron trays packed with cancellous bone; freeze-dried, autoclaved or irradiated bone allografts; and pedicled flaps. These conventional methods of mandibular reconstruction encountered limited success when employed in traumatized, irradiated, or avascular recipient beds. Furthermore, these reconstructions often required multiple-staged procedures and long hospitalizations with the patients often succumbing prior to completion of the reconstruction.

INDICATIONS

With the introduction of microsurgical free flaps to the armamentarium of the plastic surgeon, the indications for oromandibular reconstruction have been liberalized. Patients previously deemed unresectable because an extensive defect was anticipated are now in the operable category. Complex soft tissue and bony defects can now be corrected with a single operation at the time of the initial resection with excellent success rates. Microsurgical free flaps, by facilitating one-stage reconstruction, can tremendously improve the quality of life and should be considered even in patients with very limited life expectancies as long as they can medically tolerate the operation.

TIMING

The ability to reliably transfer well-vascularized composite tissue at the time of resection has revolutionized head and neck surgery.[3] Currently, immediate reconstruction is the preferred approach to mandibular reconstruction. Primary reconstruction can be performed in the face of extensive soft tissue loss, oral contamination, dense scarring, and preoperative

irradiation. This avoids the permanent aesthetic and functional problems associated with soft tissue scarring, fibrosis and contracture that can never be fully corrected with a delayed procedure. Primary wound closure, early oral rehabilitation, and immediate restoration of body image are the benefits of this advance.

INTRAOPERATIVE CONSIDERATIONS

Mandibular reconstructions are lengthy procedures. Whenever possible, a two-team approach should be taken. Simultaneous tumor ablation and flap harvest can significantly reduce operative time. Once composite tissue requirements are established, flap harvest can begin. If necessary, an excess of tissue should be harvested. Flap ischemia time can be minimized by performing the osteotomies and shaping the bone segments prior to transfer to the neck. The specimen is taken to a back table and used as a template to fashion the mandibular arch. The neck vessels should also be isolated and prepared for anastomosis prior to flap transfer. The use of vein grafts and multiple flaps should be avoided whenever possible by careful selection of the donor site and recipient vessels since they increase the incidence of complications.

FREE FLAP SELECTION

Microvascular free tissue transfer has revolutionized mandibular reconstruction. Skin, soft tissue, and bone can be transferred to hostile recipient beds that are heavily contaminated by oral secretions, densely scarred, or irradiated with excellent functional and aesthetic outcomes. The ideal flap should incorporate a bony component that is well-vascularized, is easily shaped by osteotomies without vascular compromise, is of sufficient length, width, and height to conform to all defects, has a contour similar to the mandible, has minimal donor site morbidity, and can be harvested by a two-team approach. The soft tissue should be well-vascularized, capable of providing both intraoral lining and external skin coverage, thin, pliable, hairless, abundant, capable of being reinnervated, have minimal morbidity, and can be harvested by a two-team approach. Currently, no single free flap can meet all of these qualifications. We have developed an algorithm that can be useful in choosing the most appropriate flap for a specific clinical situation depending on bone and soft tissue requirements (Figs. 2,3).

Figure 1. Clinical example of "Andy Gump" deformity.

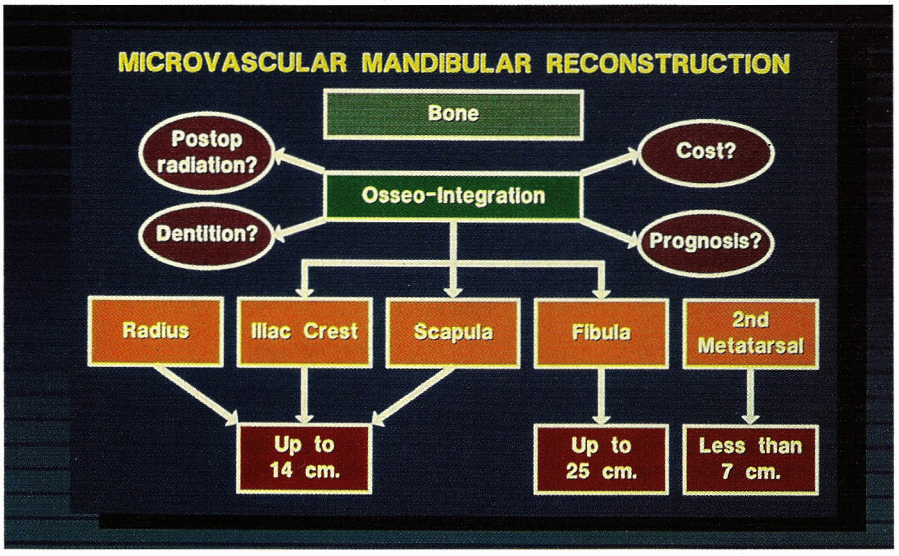

Figure 2. Algorithm for mandibular reconstruction: Bone component.

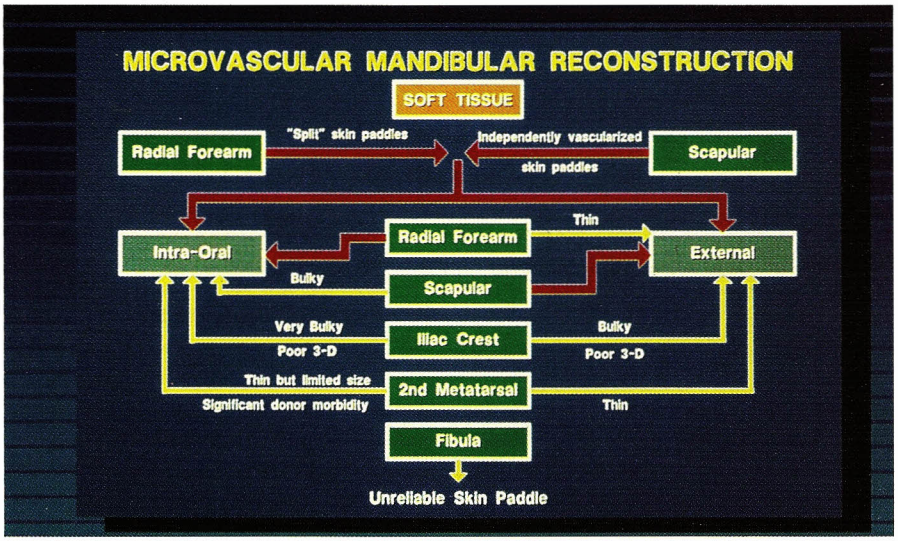

Figure 3. Algorithm for mandibular reconstruction: Soft tissue component.

Figure 4a. 32-year-old woman after shotgun blast to the face with loss of the anterior mandible, floor of mouth, chin soft tissue, and 80 percent of the lower lip.

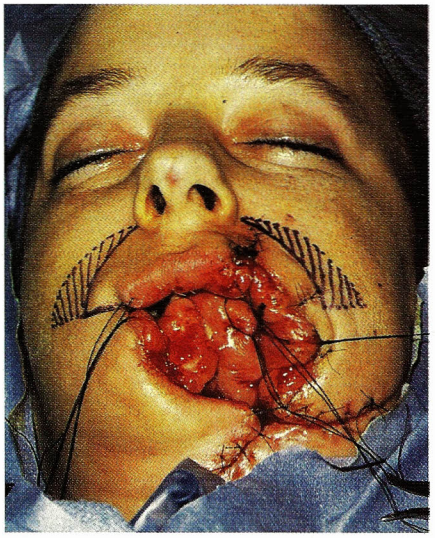

Figure 4b. Several conservative debridements have been performed and the patient is ready for definitive reconstruction. A Webster modification lip repair is designed.

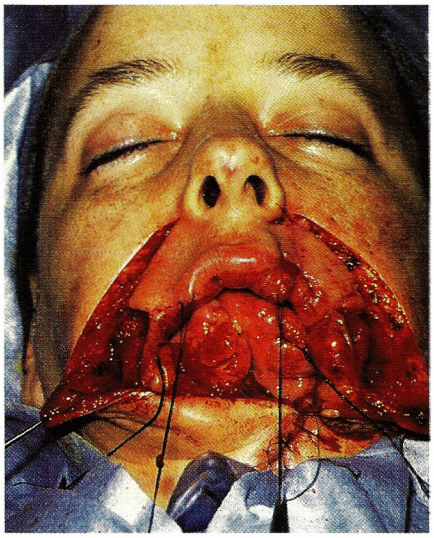

Figure 4c. Triangular wedges of skin and subcutaneous tissue are excised from the nasolabial folds to facilitate medial advancement of the cheek and lateral lip remnants which are extensively undermined. The neurovascular supply to the orbicularis oris muscle is preserved.

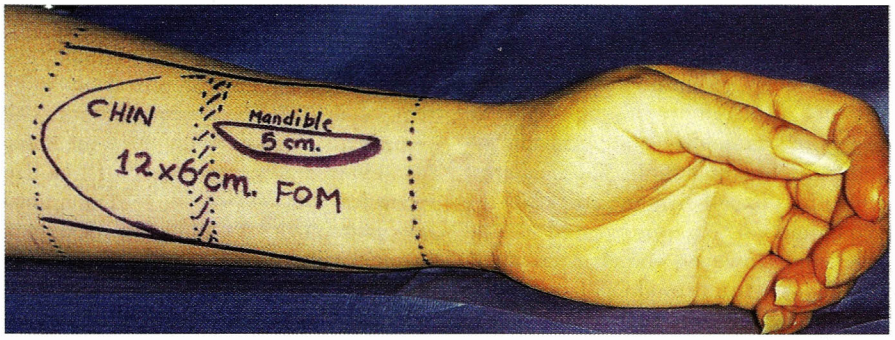

Figure 4d. A neurosensory osteocutaneous radial forearm flap is designed. A segment of radius and "split" skin paddles are incorporated for reconstruction of the anterior mandible, floor of mouth and chin soft tissue.

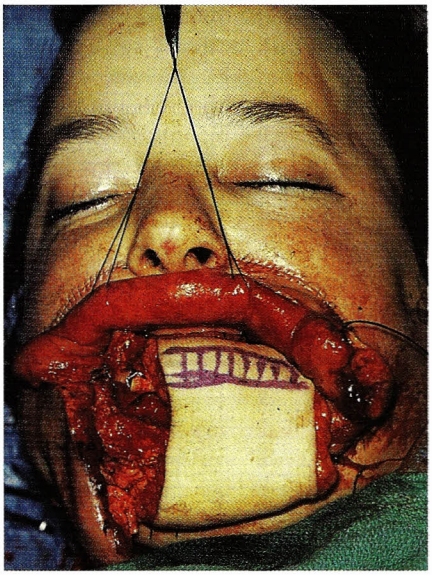

Figure 4e. Flap inset. The radius is fixed to the native mandible by interosseous wires. The distal skin paddle is placed at the base of the tongue to recreate the floor of mouth. The proximal skin paddle is used to reconstruct the chin soft tissue as a single aesthetic unit. The bridge between the "split" skin paddles will later be deepithelialized to allow medial advancement of the lower lip remnants.

Figure 4f. Flap inset is completed. The lower lip remnants are advanced medially over the deepithelialized bridge. The lip, oral mucosa and orbicularis oris muscle are approximated.

RADIUS

The radial forearm osteocutaneous flap can provide up to 14 cm of straight unicortical bone that can be recontoured by one or two closing wedge osteotomies since it receives a "segmental" blood supply from the radial artery to create an anterior mandible or hemimandible. The thin forearm skin conforms extremely well to the contours of the oral cavity to re-establish the sulci and prevent tethering of the tongue.[4-7] When needed, it can be "split" into two separate paddles permitting simultaneous reconstruction of both intraoral mucosal lining and external skin coverage.[8] There is significant flexibility in the three-dimensional orientation of the bone segments and the accompanying skin paddle(s). Donor vessels are consistent in location, provide a long pedicle (up to 10 cm), and are large caliber vessels (2-3 mm) with dual venous drainage.

The suitability of the radial forearm flap for oral lining is unmatched by other free tissue transfers in its potential for cutaneous reinnervation facilitating oral rehabilitation, including lip competence, speech, swallowing, and mastication. Neural coaptation of the greater auricular, lingual, or mental nerve to the lateral or medial antebrachial cutaneous nerve is possible with restoration of sensibility and two-point discrimination.[9,1]

Potential drawbacks include donor radius fracture, skin graft loss with tendon exposure, displeasing appearance of the

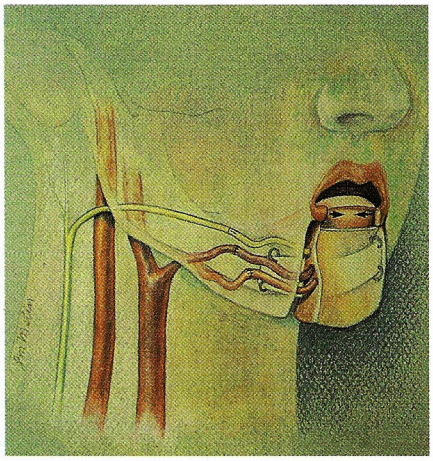

Figure 4g. Schematic representation of one-stage reconstruction od anterior mandible, floor of mouth, chin soft tissue and subtotal lower lip. The composite flap is revascularized by anastomosis of the radial artery and one of the venae comitantes to the facial vessels. The flap is reinnervated by coaptation of the lateral antebrachial cutaneous nerve to an anterior twig of the greater auricular nerve.

Figure 4h. Preoperative and postoperative photographs. At 14 months, the patient has a satisfactory appearance, intelligible speech, excellent sensory recovery, good aperture and excursion, and no problems with drooling or mastication.

skin grafted donor forearm, and inadequate bone stock for osseointegration.[11-13] Reasons for donor radius fracture include: (1) harvesting an excessive thickness of bone, (2) perpendicular osteotomies with cross-cutting or weakening of the radius, (3) lack of or short period of postoperative immobilization, and (4) failure to prevent pronation and supination by an above-elbow cast. Removal of a unicortical segment of distal radius results in significant weakening of the donor bone, however, by employing a keel-shaped modification of the radial forearm osteocutaneous flap, donor radius fracture can be prevented.[7]

The radial forearm cannot provide sufficient bone stock for placement of osseointegrated dental implants and should not be employed in patients where dental rehabilitation is a consideration. Use of the thin radial forearm skin, however, can allow restoration of the normal sulci and provide a satisfactory buttress for denture-fitting. This flap is best indicated for short lateral mandibulectomy defects with extensive intraoral lining or external skin requirements. It can also serve well for anterior mandibular and hemimandibulectomy defects in which osseointegration is not considered (Fig. 4).

ILIAC CREST

The iliac crest osteocutaneous flap has been promulgated by Taylor[14,15] and others[16-21] for mandibular reconstruction where considerable bone and soft tissue replacement is required. Based on the deep circumflex iliac vessels, the iliac crest can provide up to 14 cm. of curved bone. Its unique shape resembles a hemimandible. The iliac crest also offers excellent bone stock for the placement of osseointegrated dental implants. However, the iliac crest has significant functional and aesthetic drawbacks. The soft tissue is often too bulky for intraoral lining unless a glossectomy has been performed and may even compromise the airway. When used for external skin coverage, it is difficult to create good chin and submental definition owing to the extreme bulk of this flap. The nature of its blood supply mandates close apposition of the bone and skin paddle with minimal flexibility in spatial orientation. Moreover, the flap skin reliability is unpredictable. Potential donor site problems include contour deformities especially when a large segment of bone is harvested, abdominal wall weakness or even herniation, injury to the lateral femoral cutaneous nerve, delayed ambulation and gait disturbances. Modifications of this flap have been described including the use of the internal oblique muscle and skin graft for intraoral lining and split inner cortex bone harvest.[20,21] This flap is best indicated in cases where osseointegration is planned or only bone reconstruction required.

SCAPULA

The scapula flap, based on the circumflex scapular vessels, can provide up to 14 cm. of straight lateral scapular bone with separate skin paddles for intraoral lining and external skin coverage. This free flap provides the greatest three-dimensional flexibility of the flap options with respect to orientation of independently vascularized bone and skin paddle(s). However, the skin paddles can be quite bulky limiting their usefulness. The bone stock is not as substantial as the iliac crest but is suitable for osseointegration. Osteotomies can devascularize the bone segments. The major drawback is that a two-team approach is not possible; simultaneous tumor resection and flap harvest is not possible and intraoperative repositioning is necessary. This can significantly increase the operative time of these already lengthy procedures. This flap is best indicated for extensive combined intraoral and extraoral soft tissue defects.

FIBULA

The fibula can provide by far the largest amount of bone (up to 25 cm.) for mandibular reconstruction. The uniformly shaped bicortical bone can be remodeled by multiple osteotomies due to its segmental periosteal blood supply. Additionally, the bone stock is adequate to support osseointegrated implants. Early on, the septocutaneous blood supply appeared to be unreliable to support a skin island and the fibula was considered to be most useful in "bone-only" reconstructions or in conjunction with a separate pedicled

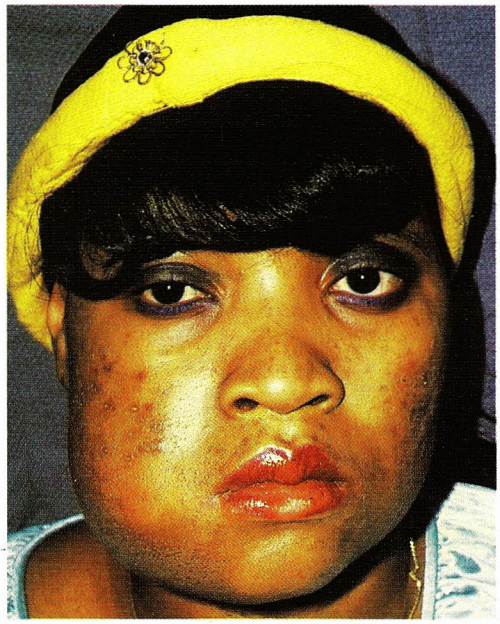

Figure 5a & b. 23-year-old woman with extensive osteogenic sarcoma involving the entire right hemimandible.

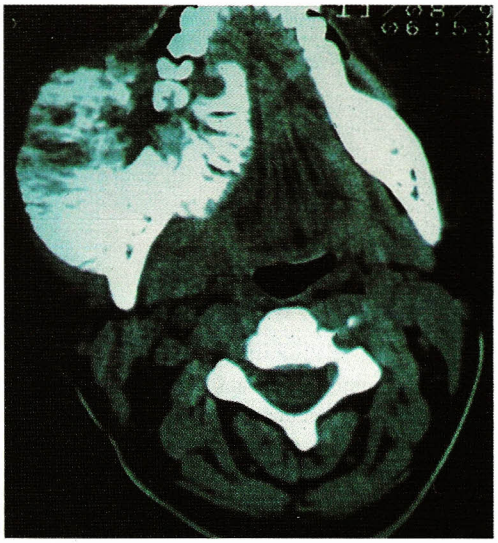

Figure 5c. CT scan demonstrates extent of tumor involvement.

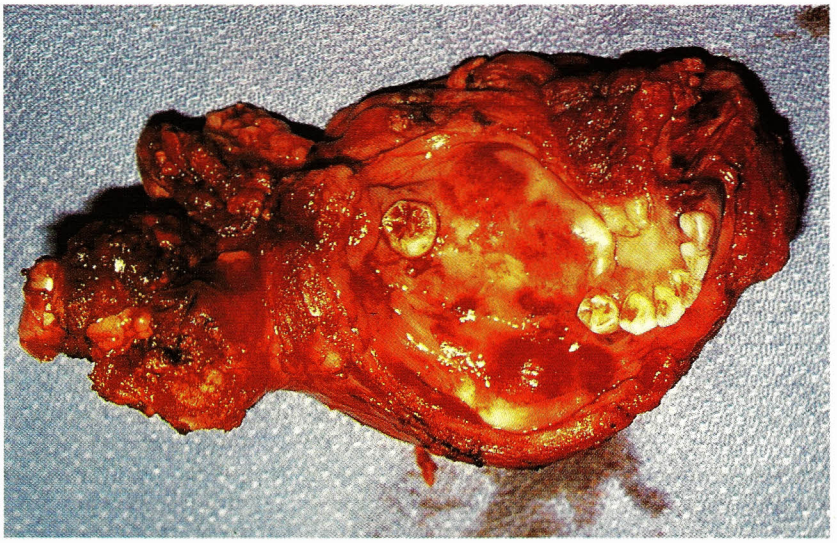

Figure 5d. Resected specimen.

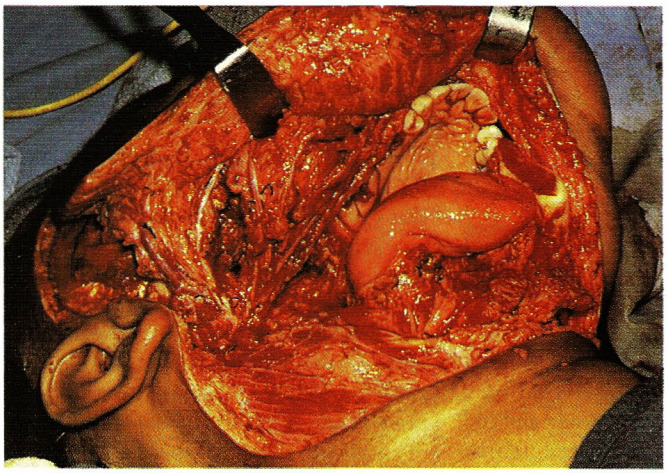

Figure 5e. Composite oromandibular defect involves the entire right hemimandible including the condyle.

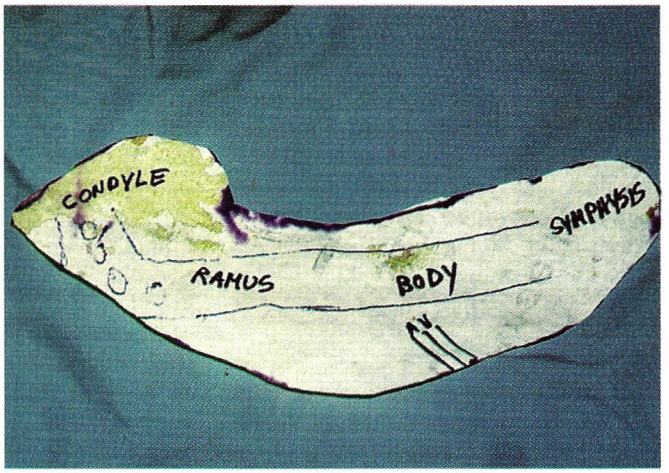

Figure 5f. Template for oromandibular reconstruction.

Figure 5g. Howmedica reconstruction plate with condyle.

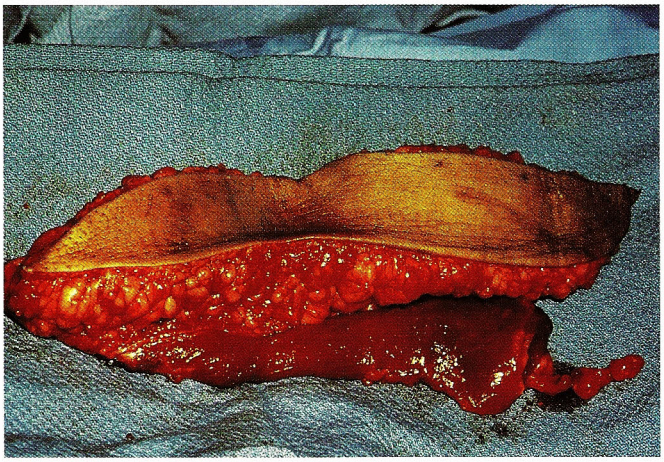

Figure 5h. Rectus myocutaneous free flap is harvested.

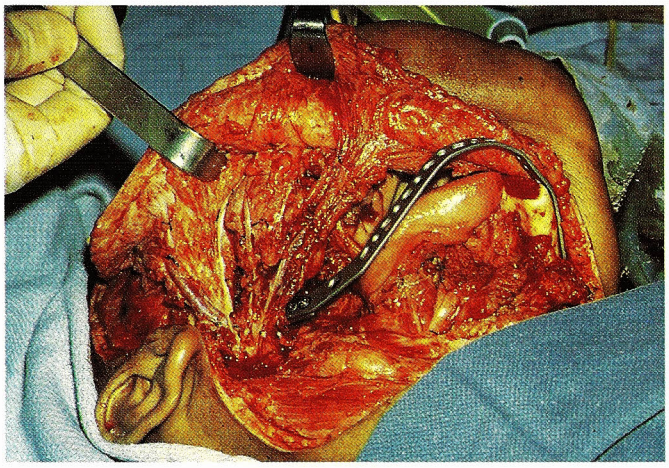

Figure 5i. Reconstruction plate with condyle is placed.

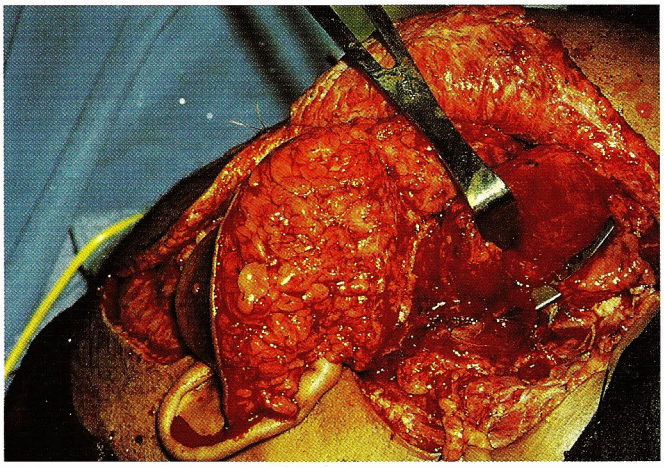

Figure 5j. Rectus myocutaneous free flap is inset.

or free flap for soft tissue coverage. More recently, however, several papers testify to the reliability of the skin paddle.[25,26] Drawbacks include the limited amount of available donor skin, objectionable appearance of the skin grafted donor site, and delayed ambulation. The fibula free flap is an extremely versatile option for oromandibular reconstruction especially in cases of extensive bony defects in which osseointegration is considered. It is also well-suited for short-segment "bone-only" defects, hemimandible defects with adjacent lateral floor of mouth or buccal mucosa loss, and symphyseal defects requiring both floor of mouth replacement and external skin coverage.

METATARSAL

Duncan proposed the use of the metatarsal osteocutaneous flap for anterior mandibular reconstruction in the radiated patient. The second metatarsal osteocutaneous flap is only suitable for small defects, i.e., less than 7 cm. The skin territory reliably supplied by this flap is only approximately 6x10 cm. Additional disadvantages of the metatarsal flap are the difficulty of dissection and management of the donor site. The anatomy of the first dorsal metatarsal artery is variable and dissection of this artery can be extremely tedious as it penetrates the interosseous muscle. The donor site has been problematic with significant cosmetic deformity due to skin graft loss. All factors considered, the metatarsal osteocutaneous may only be indicated for small symphyseal defects requiring a small segment of bone and a solitary skin paddle.

RECONSTRUCTION PLATE WITH SOFT TISSUE OR MUSCLE FREE FLAPS

The combination of a reconstruction plate with vascularized soft tissue or muscle has proven extremely useful in cases involving the mandibular condyle and for extensive defects in elderly and infirm patients, thus reducing operative time and minimizing donor site morbidity.[29-32] The major drawback of this technique is that the absence of bone stock makes future dental osseointegration impossible. Other potential complications include plate loosening, fracture, or extrusion. While the role of this method of reconstruction for the mandibular symphysis has recently been questioned,[31] our experience with the AO plating system has been favorable (Fig. 5).

SEQUENTIAL FREE FLAPS

Sequential free flaps should be reserved for extensive bony and soft tissue defects that cannot be satisfactorily reconstructed by a single free flap. This method combines the best qualities of bone and soft tissue of the individual flaps as well as the concomitant morbidities. However, it is technically more demanding than more traditional approaches. While this method can be functionally and aesthetically superior to that of a single free flap, its specific role in microvascular mandibular reconstruction has yet to be elucidated.

Figure 5k & l. Postoperative appearance at 18 months. The patient has a satisfactory appearance, intelligible speech, and excellent aperture and excursion.

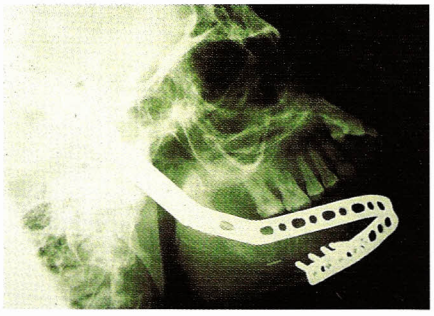

Figure 5m. Radiograph of reconstruction plate and condyle.

DENTAL REHABILITATION BY OSSEOINTEGRATION

One of the key considerations in flap selection for bony mandibular reconstruction is the suitability of the bone stock for osseointegration.[35,36] Osseointegration of vascularized bone is the ideal rehabilitative end-goal in mandibular reconstruction maximizing functional and aesthetic results. Living bone provides an excellent bed for osseointegrated dental implants. In cases where donor bone may not be suitable for osseointegration, such as the radius, the adjacent native mandible may occasionally be successfully osseointegrated. Unfortunately, many patients with advanced intraoral malignancies are poor candidates for this procedure for several reasons. It is difficult to justify osseointegration which requires several stages over six to nine months in patients with very poor prognoses (approximately 50% of these patients will be dead within 1.5 to 2 years). Many of these patients were edentulous or had poor dentition prior to tumor ablation. Furthermore, there is significant cost associated with this procedure which may not be covered by the insurance companies. Lastly, the fate of osseointegrated dental implants in the face of postoperative radiation is uncertain at this time. Despite all discussion about the meritorious role of osseointegration in mandibular reconstruction, very few mandibular reconstructions have actually undergone this novel approach.

CONCLUSIONS

Microsurgical free flaps have revolutionized oromandibular reconstruction. Restoration of form and function can be accomplished with various types of free flaps, each with its unique advantages and disadvantages. Primary complex mandibular reconstructions such as those involving the anterior mandibular arch, trilaminar lateral or posterior defects, and long bone gaps crossing the midline with massive soft tissue losses are now possible with excellent success rates and tremendous improvement in the quality of life. STI

REFERENCES

1. Steckler RM, Edgerton MT, Gogol W. "Andy Gump". Amer J Surg 1974; 138: 545.
2. Millard DR, Maisels DO, Batstone JHF. Immediate repair of radical resection of the anterior arch of the lower jaw. Plast Reconstr Surg 1967;37:15.
3. Millard DR. Interim report of immediate mandibular repair. Am J Surg 1969;118:726.
4. Timmons MJ. The vascular basis of the radial forearm flap. Plast Reconstr Surg 1986; 77(1):80.
5. Cormack GC, Duncan MJ, Lamberty BGH. The blood supply of the bone component of the compound osteo-cutaneous radial artery forearm flap-An anatomical study. Br J Plast Surg 1986;39:173.
6. Soutar DS, Widdowson WP. Immediate reconstruction of the mandible using a vascularized segment of radius. Head Neck Surg 1986; 8:232.
7. Weinzweig N, Jones NF, Shestak KC, et al. Oromandibular reconstruction using a keel-shaped modification of the radial forearm osteocutaneous flap. Ann Plast Surg 1994;33: 359.
8. Boorman JG, Green MF. A split Chinese forearm flap for simultaneous oral lining and skin cover. Br J Plast Surg 1986;39:179.
9. Dubner S, Heller KS. Reinnervated radial forearm flaps in head and neck reconstruction. J Reconstr Microsurg 1992;8:467.
10. Weinzweig N, Chen L. Lower face reconstruction using a neurosensory osteocutaneous radial forearm flap and Webster modification lip repair. Plast Reconstr Surg 1994;94:685.
11. Timmons MJ, Missotten FEM, Poole MD, et al. Complications of radial forearm flap donor sites. Br J Plast Surg 1986;39:176.
12. Boorman G, Brown JA, Sykes PJ. Morbidity in the forearm donor arm. Br J Plast Surg 1987;40:207.
13. Swanson E, Boyd JB, Manktelow RT. The radial forearm flap: Reconstructive applications and donor-site defects in 35 consecutive patients. Plast Reconstr Surg 1990;85:258.
14. Taylor GI, Townsend P, Corlett R. Superiority of the deep circumflex iliac vessels as the supply for free groin flaps. Plast Reconstr Surg 1979;59:646.
15. Taylor GI. Reconstruction of the mandible with free iliac bone grafts. Ann Plast Surg 1986;9:361.
16. O'Brien BMcC, Morrison WA, MacLoed AM, et al. Microvascular osteocutaneous transfer using the groin flap and iliac crest, the dorsalis pedis and second metatarsal. Br J Plast Surg 1979;32:188.
17. Rosen IB, Bell MSG, Barron PT, et al. Use of microvascular flaps including free osteocutaneous flaps in reconstruction after composite resection for radiation-recurrent oral cancer. Am J Surg 1979;138:544.
18. Duncan MJ, Manktelow RT, Zuker RM, et al. Mandibular reconstruction in the radiated patient: The role of osteocutaneous free tissue transfers. Plast Reconstr Surg 1985;76(6):829.

19. Jewer DD, Boyd JB, Manktelow RT, et al. Orofacial and mandibular reconstruction with the iliac crest free flap: A review of 60 cases and a new method of classification. Plast Reconstr Surg 1989;84:391.
20. Shenaq SM, Banis J, Taylor T. The split inner cortex iliac crest microvascular free flap: A new refinement for mandibular reconstruction. Presented at the Annual Meeting of the American Association of Plastic Surgeons, San Antonio, Texas, 1991.
21. Shenaq SM, Klebuc MJA. The iliac crest microsurgical free flap in mandibular reconstruction. Clin Plast Surg 1994;21:37.
22. Teot L, Bosse JP, Maffaregz R, et al. The scapular crest pedicled bone graft. Int J Microsurg 1981;3:257.
23. Swartz MM, Banis JC, Newton E. The osteocutaneous scapular flap for mandibular and maxillary reconstruction. Plast Reconstr Surg 1986;77:550.
24. Hidalgo DA. Fibula free flap: A new method of mandible reconstruction. Plast Reconstr Surg 1989;84(1):71.
25. Hidalgo DA. Aesthetic improvements in free-flap mandible reconstruction. Plast Reconstr Surg 1991;88:574.
26. Schusterman MA, Reece GP, Miller MJ, et al. The osteocutaneous free fibula flap: Is the skin paddle reliable? Plast Reconstr Surg 1992; 90:787.
27. Bell MSG, Barron PT. A new method of oral reconstruction using a free composite foot flap. Br J Plast Surg 1982;35:239.
28. Macloed AM, Robinson DW. Reconstruction of defects involving mandible and floor of mouth free osteocutaneous flaps derived from the foot. Br J Plast Surg 1982;35: 239.
29. Sako K, Manchetta FC. The use of metal prostheses following anterior mandibulectomy and neck dissection for carcinoma of the oral cavity. Am J Surg 1962;104:715.
30. Wenig BL, Keller AJ. Rigid fixation and vascularized bone grafting in mandibular reconstruction. Clin Plast Surg 1989;16:125.
31. Shusterman MA, Reece GP, Kroll SS, et al. Use of the AO plate for immediate mandibular reconstruction in cancer patients. Plast Reconstr Surg 1991;88:588.
32. Davidson J, Boyd B, Gullane P, et al. A comparison of the results following oromandibular reconstruction using a radial forearm flap with either radial bone or a reconstruction plate. Plast Reconstr Surg 1991;88:201.
33. Sanger JR, Matloub HS, Yousif NJ. Sequential connection flaps: A logical approach to customized mandibular reconstruction. Am J Surg 1990;160:402.
34. Wells MD, Luce EA, Edwards AL, et al. Sequentially linked free flaps in head and neck reconstruction. Clin Plast Surg 1994;21:59.
35. Lukash FN, Sachs SA. Functional mandibular reconstruction: Prevention of the oral invalid. Plast Reconstr Surg 1989;84(2):227.
36. Zlotolow IM, Huryn JM, Piro JD, et al. Osseointegrated implants and functional rehabilitation in microvascular fibula free flap reconstructed mandibles. Am J Surg 1992;164: 677.