ORIGINAL ARTICLE

Oromandibular Reconstruction Using Microvascular Composite Flaps

Report of 210 Cases

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Objective: To review the experience of 1 microvascular surgeon during an 11-year period in performing 210 vascularized bone-containing free flaps for oromandibular reconstruction.

Design: Retrospective medical records review of patients who underwent primary and secondary oromandibular reconstruction with the use of vascularized bone free flaps.

Setting: Academic medical center.

Patients: A total of 201 patients underwent 210 composite free-flap reconstructions of the mandible for various disorders and with a range of bony and soft tissue defects.

Intervention: All patients underwent the microvascular transfer of vascularized bone flaps from the ilium, fibula, or scapula. In selected cases, 2 simultaneous free flaps were transferred to achieve an optimal bone and soft tissue reconstruction. Endosteal dental implants were used in 81 patients, with a total of 360 fixtures placed during these 11 years.

Main Outcome Measures: The success of microvascular free tissue transfer, dental implant extrusion, and short- and long-term complications at the recipient and donor sites.

Results: Of the 210 mandibular reconstructions that were performed, 202 were successful in reestablishing mandibular continuity. Reexploration for vascular-related complications was done in 16 patients, 8 of whom were successfully treated, yielding an overall success rate of 96%. The overall success rate for endosteal dental implants was 92%. The implant success rate was 86% when the bone in which the fixtures were placed was irradiated postoperatively. The success rate was 64% in the 14 fixtures that were placed into previously irradiated bone.

Conclusions: The success of the use of vascularized bone free flaps in restoring continuity to the mandible is clearly demonstrated in this series. There was an acceptable incidence of donor- and recipient-site complications that resulted in minimal long-term morbidity. The careful selection of a donor site(s) for oromandibular reconstruction allows for an optimal restoration of bony and soft tissue defects. Dental implants can be safely used in oromandibular reconstruction with a high level of success. Placing these implants during the initial surgery shortens the duration for achieving dental rehabilitation and enhances the success of the implants when postoperative radiotherapy is administered.

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MICROVASCULAR techniques to transfer vascularized bone to the head and neck region have been successfully applied to the problem of segmental mandibular defects. The use of these techniques for reconstruction is particularly well suited to the hazards of performing primary osseous reconstruction in the oral cavity, and its reliability has clearly surpassed that of the myriad other techniques that have been proposed for this purpose.[1] The many reports of the use of microvascular osseous mandible reconstruction that have been published from a variety of centers lend credence to the statement that primary oromandibular reconstruction with vascularized bone-containing free flaps (VBFFs) has become the standard of care. Moreover, this procedure should be offered to all patients who are medically fit and who are undergoing segmental mandibulectomies for the treatment of benign or malignant neoplasms, and for the management of stage III osteoradionecrosis (radiation-induced osteomyelitis).[2-4] The advantages of this method are that it allows the transfer of bone and soft tissue with a rich vascular supply that permits these tissues to withstand the detrimen-

PATIENTS AND METHODS

The medical records of 201 patients who underwent a total of 210 composite free-flap reconstructions of the mandible were reviewed. These patients ranged in age from 8 to 81 years (mean age, 55 years). Most patients underwent mandibular replacement surgery in the fifth and sixth decades of life (**Table 1**). Nine patients underwent 2 sequential VBFFs for a variety of reasons. One patient underwent a second VBFF because of the progression of osteoradionecrosis. Three patients underwent a second reconstructive procedure because of the need for a second ablative surgery following the development of a recurrence of the neoplasm; in 1 patient, this was a metastatic breast carcinoma, and in the other 2 it was an osteogenic sarcoma. In addition, in 1 patient a recurrent cancer developed following primary radiotherapy and the placement of a VBFF to treat osteoradionecrosis that resulted from that treatment. The recurrent neoplasm necessitated the removal and replacement of the original VBFF with a second VBFF. Three patients underwent second VBFFs following the failure of the initial reconstructive procedure. Finally, 1 patient required a delayed second composite scapular flap because of inadequate bone in the symphyseal region and a large soft tissue deficiency following an initial scapular composite free flap used to reconstruct a massive defect resulting from the resection of a hemangioma of the cheek and skull base.

Reconstructions were performed in 180 patients at the time of the ablative surgery for tumor (n=170) or for osteoradionecrosis (n=10). Of the patients undergoing mandibulectomy for tumors, 100 underwent their initial treatment for this neoplasm; the remaining 70 patients had been previously treated with 1 or a variety of modalities. The pathologic disorders that were identified in this group of patients are listed in **Table 2**. Although the vast majority of patients in this series underwent segmental mandibulectomy because of squamous cell cancer, there was an interesting array of other disorders for which a segmental defect was created. Two patients underwent resections because of metastatic cancer (1 patient underwent 2 resections when a local recurrence developed); 1 patient with a hemangiopericytoma arising from the frontal sinus and a second patient with a metastatic breast carcinoma that recurred a year after the initial surgery, requiring a second ablative or reconstructive procedure. The decision to proceed with surgery in each of these patients was made only after an extensive metastatic workup did not reveal any evidence of systemic disease.

In all cases, the need for a segmental resection of the mandible was determined by the evidence of bone erosion on preoperative radiographs or the presence of firm fixation of tumor to the mandible, which was often not determined until the time of surgery. The patients included in this series represent a subset of the total number of patients who underwent surgery for oral carcinoma; many of them were treated by marginal resections of the mandible, and are not described in this review. In this series, 68 patients had received prior radiotherapy. A curative surgical procedure was done in 70 patients with recurrent tumors, and 10 underwent segmental sequestrectomy for osteoradionecrosis. In the patients who had recurrent cancer adjacent or fixed to an irradiated mandible, the threshold for performing a segmental resection was much lower because of the greater ease with which these cancers gain access to the mandible.[6] In the later part of this series, intraoperative frozen sections were obtained from marrow specimens curetted from the ends of the resected segments of the mandible. In patients with extensive bone erosion that was evident on the preoperative imaging studies, a magnetic resonance image was obtained to evaluate the extent of the marrow involvement and to aid in determining the bony resection margins (**Figure 1**). In only 3 patients in this series was residual tumor identified in the bone margins on permanent pathologic sections.

The decision on the extent of the sequestrectomy for osteoradionecrosis was far more difficult to make, and the decision was always to err on the side of performing a wider resection to achieve clearance around this disease process. Intraoperative observation of the quality of the bleeding from the ends of the cut mandible was used as one of the guides for this determination.

In this series, 39 patients underwent secondary mandibular reconstructions with the use of VBFFs. In this subset of patients, 24 (62%) had received previous radiotherapy. Six patients underwent reconstruction with a VBFF because of extrusion or fracture of a mandibular reconstruction plate that was placed at the time of the ablative surgery to serve as a mandibular spacer. Patients who presented for secondary reconstruction underwent extensive evaluations to determine whether their expectations of the anticipated gains from the restoration of bony continuity were likely to be met from this surgery. It was often found that the functional complaints were more a product of the soft tissue problems than the defect in the mandible. These soft tissue problems were addressed either independently of bone replacement or in conjunction with mandibular reconstruction. As an example, in 1 patient who was having considerable problems with an obturator for a soft palate defect, the reconstructive strategy included a separate radial forearm flap to achieve velopharyngeal competence so as to eliminate the need for a prosthesis. Furthermore, in patients who were edentulous and thought to be good candidates for rehabilitation with dental implants, the goal was to restore the central segment of the mandible with nonirradiated vascularized bone. In patients who had defects that involved the symphysis and parasymphysis, this was

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tal effects of the normal oral flora and postoperative radiotherapy. Preserving the osteogenic potential of the transferred bone permits it to take an active role in osteosynthesis with the native mandible and to accept dental implants in the primary setting, thereby allowing complete oromandibular rehabilitation.

In the 1990s, the optimal and achievable goals in oromandibular reconstruction include the following: (1) the primary reestablishment of mandibular continuity with vascularized bone rigidly fixed to the remaining mandible; (2) the primary placement of dental implants for rapid dental rehabilitation; (3) the restoration of sensation to the lower lip along with the restoration of its normal height vis-à-vis the upper lip to preserve or restore labial competence; (4) the restoration of sensation to the lining of the oral cavity through the use of nerve grafts or sensate flaps; and (5) the introduction of thin, pliable tissues to the tongue and floor of the achieved by placing a VBFF in this region. In edentulous patients in whom the defect was lateral and the symphysis was included in the previous radiation portals, the option of replacing the central segment with the VBFF reconstruction was offered to the patients as the most effective way of achieving a stable and retentive dental prosthesis. This approach carried with it the possible hazard of a more extensive problem if the VBFF failed.

A detailed description of the bone defects and the frequency of their occurrence in this series is included in **Table 3**. The defects were classified according to the scheme that was previously described in which the different anatomic portions of the mandible are designated as follows: condyle, ramus, body, hemisymphysis to the midline, and the entire symphysis.[2] A detailed description of the soft tissue and neurologic defects of the oral cavity, as previously introduced, is beyond the scope of this article and takes on greater importance when the functional results of oromandibular reconstructions are being reported. More than 50% of the defects, however, involved at least a quarter or more of the mobile part or the base of the tongue.

Eleven patients underwent near-total or total glossectomies in combination with segmental defects of the symphysis and parasymphyseal region. The bone and soft tissue defects in these patients were reconstructed by an iliac composite flap in which the bone was placed as a horizontal platform to support the overlying soft tissue against the long-term effects of gravity.[7] The goal in these patients was to achieve permanent contact of the neotongue to the hard palate.

Thirty-seven patients had through-and-through defects involving the oral mucosa, mandible, and overlying skin. Several of these patients received an additional regional or free soft tissue flap.

Various microvascular composite flaps were used during this period. The rationale for the use of each of these flaps will be discussed in the "Comment" section. The trends in flap use during this series are shown in **Table 4**. In patients in whom the reconstruction was performed with a combination of 2 separate free flaps, 1 flap supplied vascularized bone, and the other provided a soft tissue flap for either internal or external lining. This group of patients represents a small subset of the total series (14%), and the indications for the use of this technique will be discussed as well. All flaps in this group, except for the first, were revascularized using 2 separate pedicles.

Replacement and reconstruction of the condyle were performed in 29 patients. The first choice for restoring the condyle was to mold the end of the VBFF and to place drill holes in the bone through which 0 polypropylene (Prolene) sutures were passed and secured through drill holes placed in the lateral lip of the glenoid fossa. Patients who underwent condylar replacement were put into maxillomandibular fixation for about 2 weeks to allow cicatrization to occur to assist in maintaining the position of the neocondyle in the glenoid fossa and to prevent its anterior dislocation. In selected patients where there was insufficient length of the VBFF, a costochondral graft was secured with lag screws to the end of the VBFF. When the cartilaginous component of the temporomandibular joint was not present, a temporalis muscle flap was transposed into the fossa. In patients undergoing secondary reconstruction of the ramus and condyle and, in particular, when the area had been previously irradiated, the neocondyle was placed in a more anterior position along the anterior articular eminence to try to avoid dissection within the glenoid fossa and possible trauma to the facial nerve.

In the vast majority of patients, the VBFFs were fixed into position using rigid reconstruction plates. Whenever possible, the plate was contoured to the lateral cortical margin of the native mandible before resection and then replaced and used as a template for contouring the bone through the creation of opening (iliac and scapula) or closing (fibula) osteotomies. In the case of the iliac crest, the opening V-shaped osteotomies were filled with corticocancellous bone chips. In selected cases of using the scapular flap, fixation was achieved with the use of miniplates to avoid stripping too much soft tissue from the bone or compressing the soft tissue between the plate and the bone and thus compromising the vascular supply.

Between 1989 and 1997, we have placed 360 fixtures (endosteal titanium screws and titanium plasma-sprayed press-fit fixtures) in 81 patients undergoing mandibular reconstruction, with a mean follow-up of 49 months (range, 2-121 months). Of these 360 fixtures, 81 were placed in areas that were later directly irradiated. Furthermore, 14 fixtures were placed in previously irradiated native mandibles.

A variety of adjunctive procedures were performed in this series. In patients who sustained a near-total or total glossectomy or in patients who were having dysphagia at the time of secondary mandibular reconstruction, a laryngeal suspension was performed by placing permanent sutures through the thyroid cartilage and through drill holes in the symphysis. Maximum elevation was achieved by flexion of the head while placing two 0 polypropylene sutures through these structures. Coronoidectomies were performed in patients undergoing secondary reconstruction or primary reconstruction following irradiation, in whom there was a considerable amount of trismus. Forty-nine patients underwent nerve grafts to restore sensation to the lower lip by bridging the gap between the inferior alveolar nerve and the mental nerve following hemimandibulectomy. Bilateral nerve grafts were placed in 24 of these patients who underwent anterior mandibulectomy and in whom both sides of the lower lip were denervated.

mouth following partial glossectomy to maintain the mobility of the residual tongue and to maximize oral function.

Although anatomic limitations related to the extent of the surgical resection may not allow an optimal restoration to be achieved in all patients, the methods are currently available to achieve these goals in most.

In the early phase of the current use of microvascular bone transfer for oromandibular reconstruction, new donor sites were often introduced for this purpose, and their use was heralded as the panacea in oromandibular reconstruction. These donor sites included the ilium, fibula, scapula, radius, humerus, ulna, tibia, rib, and metatarsus. Many surgeons proposed a specific VBFF as the reconstructive option to fit all patients and all defects. What has emerged from this discussion of the optimal donor site is a thoughtful appreciation of the merits of the soft and hard tissue components of each donor site and the value of approaching each patient and each defect through a critical evaluation to select the best donor site. The ilium, scapula, and fibula are the most commonly used sites in contemporary oromandibular reconstruction. Although some surgeons still use the radial forearm composite flap, the potential for fracture of the radius and the paucity of bone that can be reliably transferred have limited its use and the enthusiasm for applying it to oromandibular reconstruction in all but a handful of centers.[5]

The following report is a retrospective review of the experience of 1 microvascular surgeon (M.L.U.) in oromandibular reconstruction involving 210 cases from March 1987 to June 1997. In addition to reviewing the complications in this series, we will chronicle the trends in flap use. We will also discuss in detail our current rationale for selecting single and multiple donor sites.

RESULTS

Of the 210 mandibular reconstructions that were performed, 202 were successful in reestablishing mandibular continuity using vascularized bone. The overall success rate was 96%. A total of 16 patients sustained ischemic complications of their VBFF. Of this group, 8 patients were returned to the operating room and their flaps successfully salvaged; these patients went on to uneventful

Table 1. Profile of 201 Patients Undergoing Oromandibular Reconstruction (209 Vascularized Bone Flaps Transferred)

Description	No. of Patients
Sex	
Male	137
Female	64
Age groups, y	
0-19	5
20-39	22
40-59	86
60-69	63
70-90	25
Primary reconstructions done at tumor resection	
Initial tumor treatment	100
Treatment of recurrent tumor after prior therapy	70
Primary reconstructions done at time of sequestrectomy for osteoradionecrosis	10

Table 2. Pathologic Diagnosis of Diseases Leading to Segmental Mandibulectomy

Pathologic Diagnosis	No. of Cases
Squamous cell cancer	142
Osteoradionecrosis	10
Osteogenic sarcoma	8
Rhabdomyosarcoma	4
Salivary gland	
Major	2
Minor	4
Metastatic tumor	3
Ameloblastoma	3
Congenital deformity	2
Angiosarcoma	1
Fibromatosis	1
Keratocyst	1
Hemangioma	1
Trauma	1

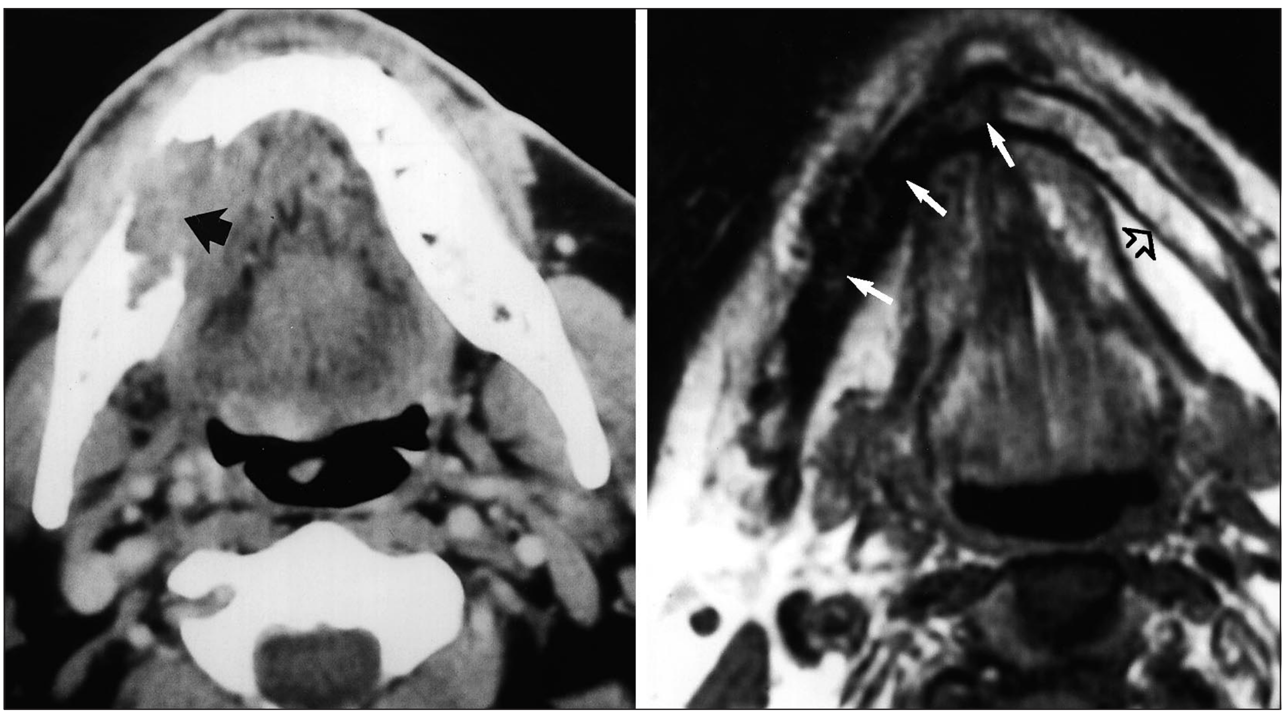

Figure 1. *Left, A computed tomographic scan of a patient with extensive mandibular erosion that appeared to be limited to the body of the mandible (arrow). Right, A magnetic resonance image (MRI, T_1-weighted) of the mandible demonstrates extensive changes throughout the hemimandible to the level of the symphysis (arrows). The difference in the appearance of the fat in the marrow space on the uninvolved side (open arrow) is apparent. The extent of the involvement of the medullary portion of the mandible as shown by this MRI led to an extensive segmental mandibulectomy that encompassed the entire symphyseal region. The MRI findings were corroborated by pathologic examination of the specimen.*

healing. The overall flap ischemia rate was 8%, and the successful salvage rate was 50%.

In the subset of 30 patients (60 free flaps) who underwent double free flaps, the success rate was 95%. Of the 3 flap failures in this group of patients, 2 occurred in the first patient in this series. In this patient, the iliac bone flap was anastomosed to the distal end of the radial forearm flap. Both flaps failed because of kinking of the intermediate pedicle with retrograde thrombosis in the proximal pedicle. The third flap loss occurred in a young woman who was seen for secondary oromandibular reconstruction following the failure of a cadaveric mandible with corticocancellous bone chips and a fibular free flap. The fibular component of the combined fibula-radial forearm flap reconstruction could not be salvaged when a wound infection developed in the early postoperative period. Despite an initial successful revascularization of both flaps and a strategy of planned daily reexploration to irrigate the wound with antibiotic solution, the muscle cuff of the fibular composite flap became infected, which led to irreversible ischemic necrosis of that flap. The radial forearm flap was ultimately successful.

The overall success rate for the endosteal dental implants was 92%. Success was defined as a clinically stable fixture without evidence of peri-implant infection or radiographic evidence of a lack of integration. Of the 81 fixtures that were irradiated postoperatively, 11 failed, and of the 14 fixtures placed in previously irradiated bone, 5 failed, leading to a success rate of 86% and 64%, respectively. In 2 of the patients in the previously irradiated group, osteoradionecrosis developed in the area of the failed implants, necessitating further surgical procedures for the removal of the affected bony segment.

Most (70%) of our patients received implant-assisted prostheses. This decision was based not only on financial concerns of patients but also because this was the only alternative in patients in whom there was a substantial disparity, due to donor site selection, between the height of the native mandible and the neomandibular segment.

Patients in this series were observed for 4 months to 11 years. A detailed discussion of the complications that were encountered in this series is best structured by dividing them between the donor and recipient sites and into those complications that occurred early and late in the postoperative period. In addition, 9 postoperative complications were of a systemic nature and led to considerable morbidity or mortality. Three patients suffered myocardial infarctions that resulted in 1 patient's death and flap failure in the other 2. In these patients, the cardiac event was associated with hemodynamic instability that eventually led to flap ischemia. Because of the patients' instability, they could not be returned to the operating room in a timely manner for salvage surgery. Another patient died on postoperative day 14 due to the development of an esophagopericardial fistula that resulted in cardiac tamponade. A 79-year-old woman who underwent a scapular free flap died on postoperative day 6 of unknown causes following an otherwise uncomplicated postoperative course. The overall postoperative mortality in this series was 1.5%. Delirium tremens developed in 4 patients in the postoperative period, which led to prolonged hospital stays.

In addition to the major early complications at recipient sites associated with flap ischemia and failure described above, partial necrosis of the soft tissue component of the VBFF occurred in 10 patients, of whom 4 required an additional regional flap for wound closure.

Table 3. Location and Incidence of Mandibular Bone Defects*

Bone Defects†	No. of Cases
BSB	53
RB	54
RBS	28
RBS_H	19
CRB	20
BS	13
RBSB	5
CRBS	4
B	4
BS_H	3
RBSBR	2
$CRBS_H$	3
CR	2

*From Urken et al.[2]
†B indicates body; S, symphysis; R, ramus; S_H, hemisymphysis; and C, condyle.

Table 4. Types of Vascularized Bone Free Flaps (VBFF)

Year	Iliac Osteocutaneous Flap, No.	Iliac/Internal Oblique Flap, No.	Scapular System, No.	Fibula, No.	Double Free Flaps, No.
1987	3	14	1	0	1
1988	1	9	1	0	0
1989	8	14	3	0	0
1990	7	15	1	0	6
1991	9	2	5	3	3
1992	10	5	1	5	1
1993	4	2	3	2	3
1994	8	2	5	7	7
1995	7	3	1	12	3
1996	7	2	3	13	3
1997	3	2	3	4	3
Totals	**67**	**70**	**27**	**46**	**30***

*The VBFF component of these double free flaps is tabulated independently under each donor site.

Conservative wound management resulted in secondary healing in the other 6 patients. Facial paralysis occurred in 2 patients as a result of secondary reconstruction of the ramus and condyle in a previously irradiated area. In 1 patient, reexploration revealed an intact nerve that was presumably damaged during traction; in the other, a complete nerve transection occurred, which was repaired.

Of the 46 fibular flap transfers performed in this series, 44 were planned as an osteocutaneous composite flap transfer. Two patients required bone-only reconstructions, and a skin paddle was not harvested. In 2 patients, however, the major vascular supply to the skin arose from a dominant cutaneous perforator that appeared to originate from the proximal posterior tibial artery, with no suitable septal or muscular perforators occurring more distally in the leg. In these 2 patients, the blood supply to the skin was successfully reestablished by a separate anastomosis of the cutaneous pedicle. This vascular anomaly has been described previously.[8] In 2 other patients, there were no significant septal or muscular perforators, and the skin flap was abandoned and replaced with either a radial forearm flap or a regional flap.

Necrosis of the native cervical skin developed in 8 patients, which required a regional flap for closure. All of the patients who had this complication had undergone prior surgery, irradiation, or both. Serious neck infections occurred in 11 patients, which resulted in prolonged hospital stays in 9. Of these infections, 9 were due to pharyngocutaneous salivary fistulae, 1 to seeding of the neck from an unrecognized communication of the tracheostomy site with the neck, and 1 to a chyle fistula.

Late complications of recipient sites were most commonly related to the fixation hardware. In 7 patients plate exposure developed through the external skin, which required its removal. The external skin defect was restored by skin advancement or local or regional flaps following the removal of the hardware. As a result of this complication, we have adopted the policy of removing all fixation plates 12 to 18 months following surgery. Other fixation-related complications resulted that led to an additional surgical procedure in 2 patients who underwent mandibular replacement and reconstruction for osteoradionecrosis. In 1 patient, progression of the osteoradionecrosis developed in the proximal mandibular segment that led to loosening of the fixation plate. This patient underwent removal of the hardware and sequestrectomy without further reconstruction. The second patient had a recurrence of his cancer a year following reconstruction and 2½ years following primary interstitial radiotherapy. This patient underwent a second composite resection and reconstruction with the use of a VBFF. Finally, there was 1 patient in whom osteoradionecrosis of the native mandible developed adjacent to a VBFF that was placed in the primary setting following the ablative surgery.[9]

Early donor-site complications included the development of a femoral nerve palsy following the closure of an iliac donor site. Reexploration of the wound led to the removal of an errant suture, and the neurologic deficits resolved. An additional iliac flap was abandoned because of an inadequate deep circumflex iliac vein, and a scapular flap was used instead. In the series of patients who underwent fibular flap transfer, 8 had wound healing problems of the donor site that were successfully managed with conservative therapy. A serious wound infection developed, however, in a young girl following a fibular transfer, which resulted in muscle and skin necrosis and the necessity for a latissimus dorsi muscle flap for repair.

In this series, late donor-site wound complications were related to the harvest of the iliac flap. One patient underwent additional surgery to repair an abdominal wall hernia; in a second patient an asymptomatic abdominal bulge developed, and the patient did not elect to undergo corrective surgery. The first patient underwent an iliac osteocutaneous flap, and the second underwent a composite iliac-internal oblique muscle flap.

Although an early gait disturbance occurred in virtually all patients who underwent iliac crest and fibular flap transfers, 2 patients in this series had persistent problems that required assisted ambulation with a cane for more than a year after surgery.

COMMENT

Safe and predictable reconstruction of the mandible at the time of performing ablative surgery has substantially affected the management of patients with oral carcinoma and advanced stages of osteoradionecrosis. The 2 major decisions that head and neck surgeons must address when planning the surgical treatment of an advanced case of oral carcinoma are related to the management of the tongue and the mandible. The first decision is to determine how much of these structures must be resected, and the second is to determine the best method to restore the function and aesthetics of this region. Although the reconstruction of the bony mandible is the focus of this series, the successful management of the tongue represents the most important functional factor in a patient's postoperative quality of life; this has been reviewed previously in detail.[10]

With regard to the mandible, the decision must be made of how much to resect to achieve clearance around the tumor and what type of reconstruction to perform. The ability to reconstruct segmental mandibular defects has removed much of the guesswork regarding the adequacy of the bone margins associated with the decision to perform a partial thickness mandibulectomy. A marginal mandibulectomy is a suitable procedure in many patients, maintaining the continuity of the mandible and providing a denture-bearing surface. The functional and vascular status of the residual mandible following marginal mandibulectomy is usually determined by the size of the mandible and the technique used to do the resection.[11] In some patients, in particular those with atrophic edentulous mandibles, a marginal mandibulectomy would leave a small rim of cortical bone that could not withstand the forces of mastication and would not be suitable for dental rehabilitation (**Figure 2**). Thus, while a marginal resection may be oncologically sound and technically feasible to perform, the patients are left with a nonfunctional residual mandible. In addition, marginal resections carry a degree of uncertainty with re-

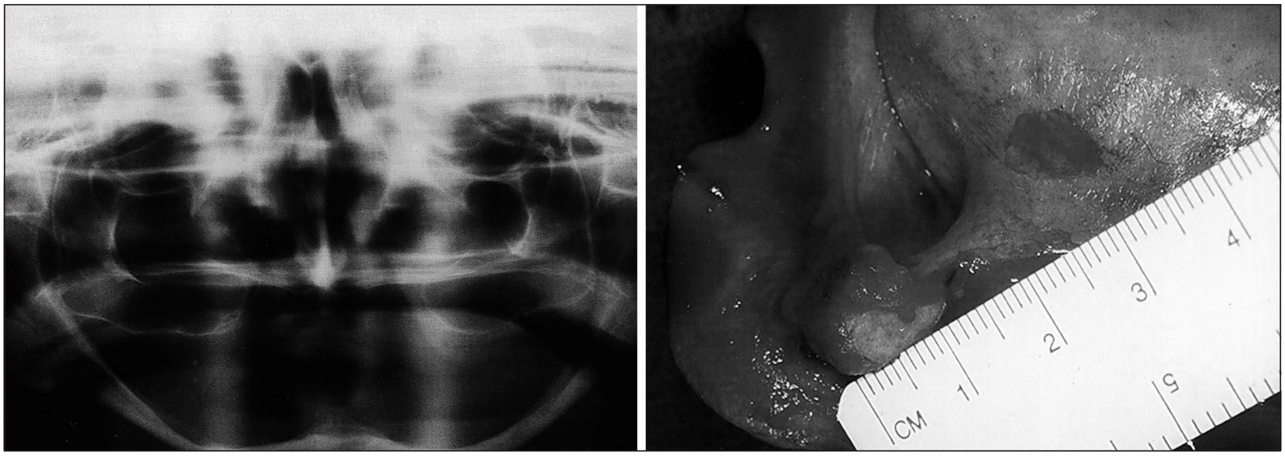

Figure 2. *Left, Panoramic radiograph of a 79-year-old patient with an extensive buccal carcinoma that was fixed to the alveolar ridge. Computed tomographic scan did not reveal evidence of bone destruction. From an oncologic perspective, this patient was a candidate for a marginal resection of the mandible. The caliber of the mandible, however, was not adequate for performing this procedure and preserving a sufficient volume of bone that would withstand the forces that were placed on it in the postoperative period. Right, Intraoperative photograph of the cross-section of this mandible shows the small caliber and the difficulty that would be encountered if a marginal resection of the mandible were attempted.*

Table 5. Oromandibular Defect Analysis

Volume and neurologic status of residual tongue
Extent of remaining mucosal defects
Extent of oropharyngeal defect contributing to velopharyngeal incompetence
Extent and location of external cutaneous defect
Extent and location of upper and lower lip defect(s)
Extent of anticipated sensory deficits in the oral cavity and lips
Mandibular bone defect variables
Length and location of segmental defect
Height of remaining native mandible
Volume of bone in the remaining mandible for placement of dental implants
Status of dentition in remaining mandible and maxilla
Radiation status of native mandible

Table 6. Patient Factors Influencing Donor Site Selection

Primary vs secondary reconstruction
Patient motivation
Comorbidities, prior surgery, prior trauma
Radiation status
Proximity of recipient vessels
Evaluation of the lower extremities
Preexisting gait disturbance
Results of preoperative studies of the collateral circulation to the foot
Signs and symptoms suggesting arterial or venous insufficiency
Body habitus

gard to the depth of invasion of the adjacent neoplasm. In patients in whom a marginal mandibulectomy is of questionable safety, the decision to perform a segmental resection is more easily made when the surgeon can confidently offer the patient a primary bony reconstruction, thereby eliminating the morbidity of the segmental defect and obviating the need for additional reconstructive surgery. Cancer recurrence following marginal mandibulectomy is a frequent cause for referral to head and neck cancer centers.

In addition to erasing the dilemma of marginal vs segmental resection, performing a primary mandibular reconstruction allows the head and neck surgeon to take wide bone margins around the primary tumor. Although frozen sections on marrow scrapings from the ends of the resection provide some evidence regarding the adequacy of the resection, the final pathologic report on the decalcified bone is not available for several weeks.[12] The ability to restore large segments of the mandible has provided head and neck surgeons the luxury of taking larger margins on either end of a specimen without fearing that the patient will suffer added morbidity from a larger bone defect. As an indication of the value of this aggressive approach to performing segmental mandibulectomies, there were only 3 cases in this series of positive findings in the bone margins on permanent section, which represents 1.8% of the 170 cases in which the mandibulectomy was performed for neoplasm. The oncologic value of this strategy has been previously reported.[13] This practice is particularly important when dealing with such pathologic disorders as osteogenic sarcoma and osteoradionecrosis where the disease process often extends beyond the radiographic or clinical assessment.

Many factors enter into the selection of an appropriate donor site for a given patient. The process of choosing the optimal flap begins with a critical assessment of the important components of the defect (**Table 5**). This analysis begins in the preoperative period, but may require modifications intraoperatively pending the results of the ablative surgery and the frozen section evaluation of the margins. In patients undergoing a near-total or total glossectomy, the surgeons must be cognizant of the vascular status of the remaining tongue. Should there be significant ischemic changes in the native tongue, then a decision must be made at the time of surgery as to whether that portion of the tongue can be saved or should be débrided, which may greatly alter the method of reconstruction. Other factors that are specific to a patient (**Table 6**) should also be entered into this decision-making process. One such factor that is common in older patients, who are most susceptible to oral cancer, is the presence of a gait disturbance. In such patients, we are reluctant to harvest a VBFF from the hip or lower extremity.

Although the trends in VBFF use have changed during the 11 years of this retrospective review, even in the later years of this analysis, each of the 3 major donor sites was still selected with considerable frequency (Table 4).

The iliac crest offers the best stock of bone of any donor site currently used in oromandibular reconstruction.[14] The height of the neomandible that can be achieved with this donor site is superior to that of any other donor site and matches up favorably with the dentate native mandible. The restoration of mandibular height may be of importance not only in achieving long-term implant stability but also in avoiding a substantial mismatch with the native mandible that makes prosthetic restoration more difficult because of the unfavorable crown-to-root ratio. In patients who are not deemed to be candidates for prosthetic restoration, because of either cost, motivation, or near-total or total glossectomy, restoring the height of the anterior mandible provides support for the lower lip against retrodisplacement and helps to achieve oral competence. Iliac crest internal oblique flaps are particularly useful in patients who undergo lateral mandibulectomy in combination with an infrastructure maxillectomy. In such patients, the internal oblique muscle can be sutured directly to the margins of the maxillectomy defect to help avoid the need for a complex palatal obturator. In patients who require subtotal or total glossectomy in conjunction with a segmental mandibulectomy involving the symphyseal region, reconstruction is done using the iliac osteocutaneous flap, in the manner described by Salibian et al,[7] where the bone is placed horizontally and the skin paddle is transposed over the bone to reline the oral cavity. We have been pleased with the quality of the function, both speech and swallowing, in patients who have undergone restoration with the use of this technique. Unlike the initial description by Salibian et al in which this flap was based on the superficial and deep circumflex iliac artery and vein, the reconstructions performed in this series were all based on the deep circumflex pedicle alone. We encountered problems with the transposed skin paddle only once. Venous congestion developed in the skin, but the bone remained well perfused. The soft tissue reconstruction was successfully salvaged with a separate rectus abdominis free flap.

The fibular osteocutaneous flap is perhaps the easiest of the VBFFs to harvest.[15] The length of bone that can be transferred makes it particularly useful in the management of such diseases as osteoradionecrosis and osteogenic sarcoma. In patients with those diseases, we perform wide surgical resections to ensure clearance around the disease, which is often difficult to define accurately through preoperative imaging studies (**Table 7**). The height of the neomandible that can be achieved with this donor site matches up favorably with that of an edentulous, atrophic native mandible. The fibula is our flap of choice in patients undergoing mandibular reconstruction in whom the ramus and condyle must be restored. In secondary reconstruction of this region, the creation of a tunnel through which the neomandible can be passed is often hazardous because of scarring and the uncertain position of the facial nerve. In these patients, the smaller caliber of the fibula is actually beneficial in allowing a more limited dissection to take place to provide access to the glenoid fossa. The skin paddle of the fibula is more tenuous than either of the other 2 VBFFs, but this is of no importance when a bone-only reconstruction is required. Despite that we designed our skin paddles over the distal third of the fibula, the consistency of identifying septocutaneous perforators was not as great as that reported by other investigators.[16] We routinely advise all patients who are to undergo free fibular transfers that a second soft tissue flap may be required. The 9% incidence of absent septocutaneous perforators in our series is consistent with the findings of other studies.[17] We and others have not relied on the musculocutaneous perforators exiting through the soleus muscle to supply the skin paddle because of their uncertain origin from the peroneal system.[18]

Table 7. Indications for the Fibular Osteocutaneous Flap

Total or subtotal mandibular reconstruction
Reconstruction of bone-only defects
Reconstruction of an atrophic mandible
Secondary reconstruction of the subcondylar-condylar complex
Pediatric mandibular reconstruction

Table 8. Indications for the Scapular System of Flaps

Massive soft tissue defect
Facial paralysis resulting from resection of the muscles of facial reanimation
Existing gait disturbance

The subscapular system of flaps is perhaps the most versatile of the VBFFs because of the range of soft tissue flaps that can be incorporated and the mobility of these flaps relative to the bone.[19] These attributes help to define the specific characteristics of the oromandibular defects that serve as indications for using this donor site (**Table 8**). The major drawback to the use of this donor site is the quality of the bone, which may be unsuitable for dental implants except in larger male patients.[15] One of the intriguing applications of the subscapular system of flaps is for the reconstruction of composite cheek defects in which the facial muscles have been lost in the ablative procedure. The ability to incorporate the latissimus dorsi muscle with its long neurovascular pedicle provides an opportunity to restore mimetic facial motion. We have applied this technique to several patients in our series with some success in achieving dynamic facial reanimation. In all of the patients who achieved functional results in this manner, the thoracodorsal nerve was anastomosed to the main trunk of the ipsilateral facial nerve. The results would be far better in those patients who do not require external cheek reconstruction wherein a large skin paddle is placed on the surface of the cheek. This inhibits the ability to detect the contractile activity of the latissimus dorsi muscle, which is oriented in an

Table 9. Indications for Double Free Flap Reconstruction of Composite Oromandibular Defects

Reconstruction of a massive soft tissue defect with intricate 3-dimensional requirements
Reconstruction of the total lower lip and symphysis
Reconstruction of the mandible in conjuction with a half to three quarters of the tongue
Nonviability of a critical portion of the soft tissue component of a composite free flap

oblique direction from the temporal fossa to the lateral oral commissure.

Finally, the more advanced approach to contemporary oromandibular reconstruction has permitted us to further customize the type of tissue that is transferred to the oral cavity through the use of 2 separate free flaps. In this technique, 1 VBFF is used to provide the optimal bone reconstruction, and a separate sensate soft tissue flap is used to reline the oral cavity and oropharynx. The limited indications for performing this type of reconstruction are delineated in **Table 9**. Our experience with this technique has been favorable with respect to the quality of the reconstruction that can be achieved and the safety and reliability with which it can be performed. As noted above, in all but the first of the 30 patients who underwent this surgery, the microvascular anastomoses for the 2 flaps were performed to separate recipient vessels.[20,21] The identification of the sensory nerve supply to the skin paddles of the iliac, scapular, and fibular composite flaps will certainly limit the need to transfer a separate cutaneous free flap for the sole purpose of providing sensory potential to the lining of the oral cavity and oropharynx.[22] No VBFFs, however, provide the thin, pliable, sensate, and independently mobile skin of a radial forearm flap.[23]

Despite the many advances in VBFF transfers for oromandibular reconstruction, numerous misperceptions of this technique have been propagated in the literature. Carlson and Marx[24] have contended that because all VBFFs are "nonmandibles," they lack the shape of the mandibular arch. Although the first part of this statement is true, a thorough knowledge of the osseous vascular supply affords surgeons the ability to contour the VBFF to match the shape of the missing segment of the mandible.[25,26] Carlson and Marx also contend that VBFFs lack "the alveolar height and buccal-lingual width critical to denture rehabilitation and normal jaw function."[24] The introduction of dental implants for the rehabilitation of oral cancer patients has greatly altered the rehabilitative potential for these patients.[27,28] The use of an implant-borne or implant-assisted dental prosthesis eliminates many of the stringent requirements that are imposed for successful tissue-borne dentures. A critical element that must be kept in perspective in considering the replacement of oral structures is that the soft tissue elements in this region, and particularly the tongue, are more highly specialized and far more difficult to duplicate than the bone of the mandible. Viable bone from any site in the body can be made to simulate the shape and function of the native mandible. The specialized features that are intrinsic to the native lower jaw include the dentition, which can be restored using endosteal implants that function as tooth-root analogues; the inferior alveolar nerve, which can be replaced using interposition nerve grafts; and the attachments of the various muscle groups, which can be secured to the neomandible using permanent sutures.

The selection criteria that we used to determine which patients should undergo primary endosteal dental implant placement include the following: patient motivation, the bone stock and radiation status of the mandible in the critical locations for appropriate implant topography, adequate tongue function for manipulating the food bolus between the upper and lower incisal surfaces, and financial resources to complete the fabrication of the dental prosthesis. All of these variables must be considered when deciding whether to restore a patient's mandible with an implant-borne or implant-assisted dental prosthesis. Our practice of placing implants in the primary setting is designed to achieve a rapid dental rehabilitation with the fewest surgical procedures. There is also a strategic advantage to this approach in patients who are scheduled to undergo postoperative radiotherapy. The detrimental effects of irradiation on the bone do not begin until 6 weeks after the start of radiotherapy.[29] If radiotherapy begins 6 weeks after surgery, there is a 12-week lag time for integration to occur before the onset of the damaging radiation effects. The effect of this strategy is evident in the 86% success rate of implants placed using this scenario compared with the 64% success rate when implants are placed into previously irradiated bone.

Finally, the issue of advanced age is often a focus of debate when it comes to deciding to perform microvascular free flap surgery in patients undergoing ablative head and neck procedures.[30] In this series, 28% of the patients were older than 60 years, and 12% of the patients were in their eighth or ninth decade of life. Our policy has been to treat patients based on their medical condition and not to withhold treatment solely because of their advanced age. This is especially the case when the quality of the reconstruction will give them a functional advantage and the potential for an enhanced quality of life.[31]

CONCLUSIONS

The practice of performing primary oromandibular reconstruction remains controversial in some centers. Reserving definitive bony restorations until a patient has survived, free of disease, for a defined period of 18 to 24 months not only deprives the patient of the benefit of a fully restored mandible for the duration of their life following ablative surgery but it also commits a substantial percentage of patients to a second major operative procedure that is often more hazardous because of the effects of adjuvant radiotherapy. Our experience has been that secondary oromandibular reconstructions are less likely to produce the same aesthetic and functional results that can be achieved in the primary setting, and, therefore, patients are subjected to a suboptimal result in addition to a delayed restoration. These factors, when coupled with the anticipated success of using VBFFs to achieve a safe and reliable oromandibular reconstruction in the primary setting, have made this approach the standard of care in contemporary head and neck surgery.

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