Important Aspects of Head and Neck Reconstruction

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Learning Objectives: After studying this article, the participant should be able to: 1. Select appropriate local and pedicled flaps for oral cavity reconstruction based on the location and extent of the defect and donor-site characteristics. 2. Understand the functions of the tongue and select the appropriate reconstructive technique based on the size and location of the glossectomy defect. 3. Understand the advantages and disadvantages of treating various maxillectomy defects with prosthetics, soft-tissue pedicled and free flaps, and osteocutaneous free flaps. 4. Conceptualize a reconstructive algorithm for the hypopharynx based on the extent of circumference resected and need to replace external neck skin. 5. Understand advantages of the fibula over other osteocutaneous flaps for mandible reconstruction.

Summary: Head and neck defects are among the most challenging for the reconstructive surgeon because of the intimate relationship between form and function in this anatomical area. Microsurgical techniques have improved outcomes for these procedures by expanding the available reconstructive methods beyond the limitations of traditional pedicled flaps, although the pectoralis flap remains a useful workhorse option. This article reviews current surgical techniques for reconstruction of the oral cavity, maxilla, hypopharynx, and mandible in the cancer patient. (*Plast. Reconstr. Surg.* 134: 968e, 2014.)

ORAL CAVITY RECONSTRUCTION

The oral cavity is bounded by the lips anteriorly and the base of the tongue and the soft palate posteriorly. Subsites of the oral cavity include the floor of the mouth, oral tongue (anterior two-thirds of the tongue), buccal mucosa, hard palate, mandibular and maxillary alveolar ridges, and retromolar trigones. Squamous cell carcinoma, arising from the mucosa, is by far the most common type of cancer affecting the oral cavity.

FLOOR-OF-MOUTH RECONSTRUCTION

The major indication for floor-of-mouth reconstruction is to close defects that communicate with the neck to prevent vascular rupture caused by salivary contamination. Any reconstructive flap used must not interfere with tongue movement such that it impedes speech and swallowing function. Also, exposed mandibular bone may not spontaneously remucosalize, particularly in the setting of radiation therapy, and is usually another indication for flap reconstruction.

Modest defects of the floor of the mouth can be repaired with a facial artery musculomucosal flap.[1] The facial artery musculomucosal flap is based on the facial artery and includes the buccal mucosa and buccinator muscle. It is useful for small defects (2 to 3 cm) that allow primary closure of the donor site. A neck dissection in which the facial artery is ligated is a contraindication to performing this flap.

The pedicled pectoralis major myocutaneous and pectoralis major muscle flaps are supplied by the thoracoacromial artery and can also be used for extensive floor-of-mouth and many other oral

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cavity reconstructions. The skin paddle of the pectoralis major myocutaneous flap is reliable when designed to include adequate cutaneous perforators.[2] Limitations include restricted reach, neck contracture caused by fibrosis of the proximal muscle and, frequently, an unsightly bulge in the neck. Despite these drawbacks, the pectoralis major myocutaneous and pectoralis muscle flaps are still commonly used in patients who are poor free flap candidates, as an additional flap in conjunction with a free flap to reconstruct massive defects, or as a secondary option in the event of a free flap failure.

An additional flap that has gained popularity in recent years is the supraclavicular artery island flap.[3] This is a cutaneous flap based on the supraclavicular artery, a branch of the thyrocervical trunk. It can reach the floor of the mouth, provided the neck is not extremely long. Similarly, the submental island pedicled flap, based on the submental branch of the facial artery, may be used to reconstruct defects of the floor of the mouth, provided the blood supply has not been disrupted by neck dissection.[4]

Free flaps are preferred for reconstruction of sizable floor-of-mouth defects. Free flaps typically have a more robust blood supply and a better arc of rotation than pedicled flaps. The radial forearm fasciocutaneous free flap is useful for moderate to large floor-of-mouth defects because it is thin and is unlikely to compromise speech or swallowing resulting from excess bulk.

BUCCAL MUCOSA RECONSTRUCTION

The goal of reconstruction for defects involving the buccal mucosa is to prevent cicatricial trismus. For most defects, a fasciocutaneous free flap, such as the radial forearm fasciocutaneous flap, is indicated to prevent scar contracture from limiting mouth opening. Buccal mucosa resections that result in through-and-through cheek defects require reconstruction with flaps that are folded onto themselves, deepithelializing a portion of the flap to allow wound closure at the flap margin, or flaps with multiple cutaneous perforating blood vessels that allow harvest with dual skin paddles for separate reconstruction of the buccal mucosa and external cheek skin, such as the anterolateral thigh and rectus abdominis myocutaneous free flaps.

TONGUE RECONSTRUCTION

The goal of tongue reconstruction following partial or hemiglossectomy is to allow the residual tongue to contact the premaxilla and palate for speech articulation, and to be able to sweep and clear the oral cavity and move food and secretions from anterior to posterior.[5,6] In practical terms, free flaps are usually required for glossectomy defects approaching half the tongue and larger. Although some studies advocate one flap over another, Engel et al. have pointed out that the specific defect should determine flap selection (**Level of Evidence: Therapeutic, IV**).[7] For defects up to two-thirds of the tongue volume, a thin, pliable flap, such as the radial forearm fasciocutaneous flap, is recommended to preserve tongue mobility, although a small amount of bulk is needed to obliterate the oral cavity dead space with the mouth closed and not create a funnel for secretions to drain directly into the larynx (Fig. 1). Adequate flap width is needed to prevent tethering the tip of the tongue to the floor of the mouth and to recreate a sulcus.

The strategy for reconstruction following nearly total and total glossectomy is different. In these cases, a bulkier flap is required to reconstruct the greater volume of resection, and flaps such as the anterolateral thigh or rectus abdominis myocutaneous are commonly used (Fig. 2).[8] Swallowing and speech outcomes are better when the flap can be made convex into the oral cavity (**Level of Evidence: Therapeutic, III**).[9] If at all possible, concave reconstructions should be avoided because they tend to result in problems with aspiration resulting from pooling of oral secretions. In any case, the patient should be counseled preoperatively about the risks of unintelligible speech, inability to swallow, and chronic aspiration.

Free flaps can be made sensate by coapting associated cutaneous sensory nerves to the stump of the lingual nerve. Low-volume flaps, such as the radial forearm fasciocutaneous free flap, have also been shown to recover some sensation spontaneously, even if nerve repair is not performed. It remains unclear, however, whether the amount of sensibility typically recovered secondary to nerve repair actually translates into improved speech or swallowing.[10–12]

MAXILLARY RECONSTRUCTION

The paired maxillary bones are the pivotal structures of the midface, separating the oral, antral, and orbital cavities and providing support to the globes, lower eyelids, cheeks, lips, and nose. In addition, the maxillae play a critical role in speech, swallowing, and mastication. Maxillectomy defects can be treated by prosthetic obturation, autologous tissue reconstruction, or a combination thereof. Each technique has

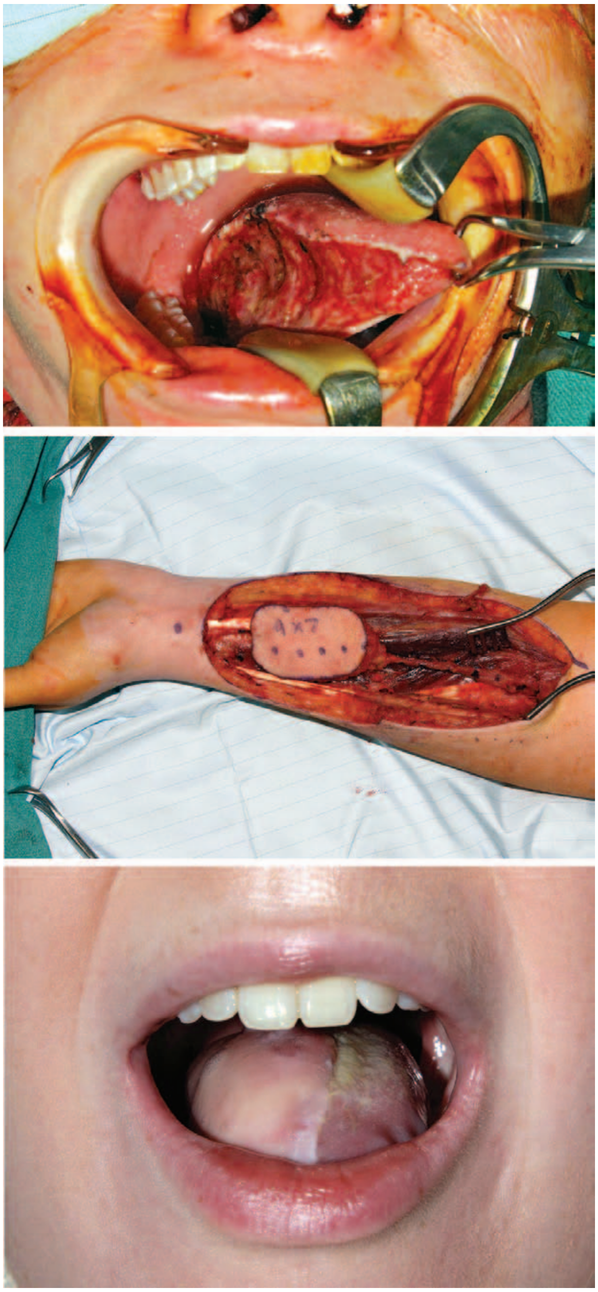


Fig. 1. (*Above*) A right hemiglossectomy defect in a 30-year-old female patient with recurrent squamous cell carcinoma of the tongue. (*Center*) Reconstruction was performed with a radial forearm fasciocutaneous free flap. (*Below*) Postoperative appearance. The patient achieved good speech and swallowing function.

its advantages and disadvantages, and the best approach is a subject of debate.

PROSTHETIC REHABILITATION

Rehabilitation with a palatal obturator has traditionally been the most common approach for treating maxillectomy defects. The advantages of this technique include short operative time and hospital stay, and complete visualization of the maxillectomy cavity, which simplifies surveillance for tumor recurrence. Okay et al.[13] found that successful obturation depends not only on the size of the defect but also on the presence of remaining dentition. Midpalatal resections that spare all of the teeth, and premaxillary resections that include only the incisors and unilateral posterior defects that involve only the teeth posterior to the canine, result in a defect that is amenable to obturation based on the biomechanical stability imparted by fixation of the prosthetic to the remaining teeth.

Successful obturation of maxillectomy defects involving up to 50 percent of the hard palate and alveolus is less predictable because there are fewer teeth for clasping and less hard palate and alveolus available to support the prosthesis. Defects that involve more than 50 percent of the palate can rarely be obturated because of lack of support and the excessive weight of the prosthesis. Poor retention of an obturator may compromise speech and swallowing function by resulting in hypernasal speech and regurgitation of foods and liquids into the nasal cavity. Although results were similar for smaller defects, Moreno et al. found a statistically significant difference in both speech ($p = 0.019$) and swallowing ($p = 0.043$) outcomes for defects that encompassed 50 percent or greater of the palatal surface area in patients receiving prosthetic obturators compared with patients receiving free flap reconstruction following maxillectomy (**Level of Evidence: Therapeutic, III**).[14]

Even though prosthetic rehabilitation provides good functional results in reconstruction of modest palatal defects, there are other limitations inherent in all obturators. These include difficulty with keeping the maxillectomy cavity clean, the inability to eat or communicate effectively without the device, and the need for periodic readjustment of the obturator because the size and shape of the palatal defect can change over time. Several authors have demonstrated that free flap reconstruction improves patient quality of life over prosthetic rehabilitation even in patients with small to medium-size defects.[15–17]

AUTOLOGOUS RECONSTRUCTION

Microvascular free flaps are usually preferred to local and regional flaps, which have limited volume and reach, for maxillary reconstruction. Many authors have described algorithms for reconstruction with various free flaps, depending on the specific defect.[18–20] Among the most useful

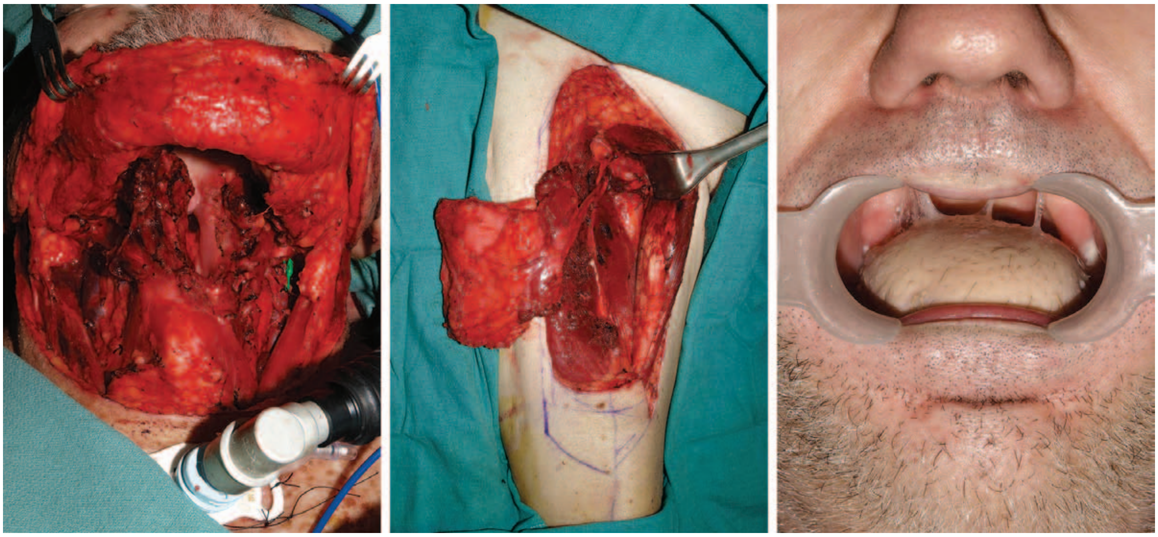


Fig. 2. (*Left*) A nearly total glossectomy defect in a 60-year-old male patient with a large squamous cell carcinoma of the tongue. (*Center*) Reconstruction was performed with an anterolateral thigh myocutaneous free flap. (*Right*) Postoperative appearance. The patient achieved intelligible speech and was independent of tube feeding.

is the algorithm described by Cordeiro and Santamaria (**Level of Evidence: Therapeutic, IV**).[19] This algorithm is based on restoring the various walls of the maxillary bone, which they conceptualize as a hexahedron bounded by the orbit above, the cheek anteriorly and laterally, the nasal cavity medially, the skull base posteriorly, and the oral cavity inferiorly.

In Cordeiro and Santamaria's algorithm, limited anterior and medial wall defects, which they term type I defects, are addressed with a fasciocutaneous free flap with two skin islands, if necessary, to cover grafts and restore the cheek skin and nasal lining (Fig. 3). For defects that involve resection of the lower five walls of the maxilla but not the orbital floor (type II defects), an osteocutaneous free flap is indicated to restore palatal competence and bony support for either a denture or osseointegrated dental implants (Fig. 4). The authors recommend a radial forearm osteocutaneous free flap reconstruction of these defects, although a number of other osteocutaneous flaps have been described (Fig. 5).[21–25] For defects that involve the anterior maxillary arch, soft-tissue

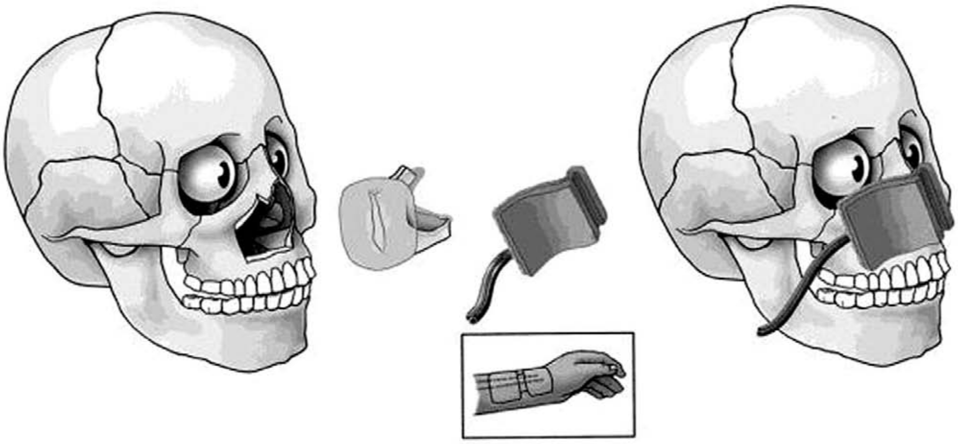


Fig. 3. Type I (limited maxillectomy) defect. Resection of two walls of the maxilla, the anterior and medial walls associated with a skin and soft-tissue resection (*left*). The radial forearm fasciocutaneous flap (donor site depicted in *inset*) can be used to resurface the anterior cheek and medial nasal lining with two skin islands (*right*). (Reprinted from Cordeiro PG, Santamaria E. A classification system and algorithm for reconstruction of maxillectomy and midfacial defects. *Plast Reconstr Surg*. 2000;105:2331–2346.)

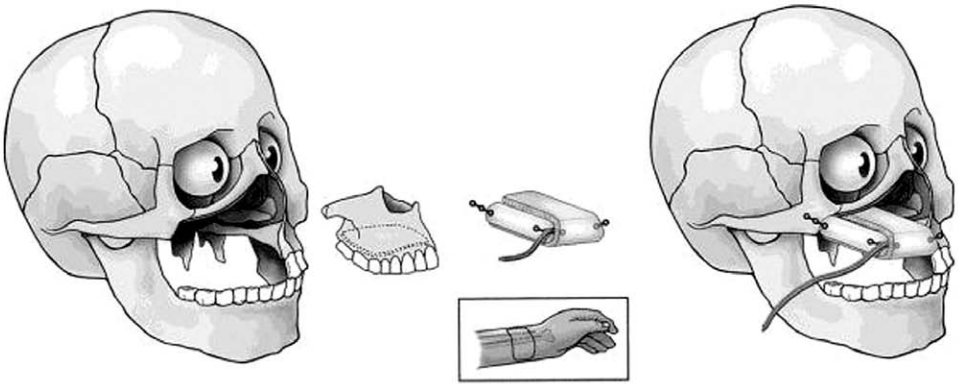


Fig. 4. Type II (subtotal maxillectomy) defect. The lower five walls of the maxilla, including the palate, are resected. The orbital floor is spared (*left*). The radial forearm osteocutaneous flap (donor site depicted in *inset*) provides a strut of vascularized bone for reconstructing the anterior maxillary arch deficit (*right*). (Reprinted from Cordeiro PG, Santamaria E. A classification system and algorithm for reconstruction of maxillectomy and midfacial defects. *Plast Reconstr Surg*. 2000;105:2331–2346.)

reconstruction alone will result in loss of midfacial projection and lack of a stable surface for mastication, and will not provide bone stock for osseointegrated implants.

Bulkier free flaps, such as the rectus abdominis myocutaneous free flap, are recommended for total maxillectomy defects involving removal of all six walls of the maxilla (type IIIa defects), although a temporalis muscle flap can be used in patients who are not free flap candidates (Fig. 6). Multiple skin paddles can be included in the flap design if the orbital contents are sacrificed and the orbit must be covered in addition to the palate (type IIIb defects) (Fig. 7). A rectus abdominis myocutaneous free flap is also suggested for defects that include the upper five walls of the maxilla and the orbit, leaving the dura and brain exposed (type IV defects) (Fig. 8).

When the orbital floor has been removed, it is usually reconstructed separately. Both titanium mesh and autologous bone grafts have been used to restore the orbital floor, although many authors prefer bone when postoperative radiation therapy is anticipated.[19] It is critical to accurately restore the orbital floor position to prevent enophthalmos, exophthalmos, or orbital dystopia, which can result in diplopia.

HYPOPHARYNX (LARYNGOPHARYNX) RECONSTRUCTION

The hypopharynx is the portion of the pharynx immediately posterior to the larynx. Its other name, the laryngopharynx, underscores its close association with the larynx and more appropriately describes the nature of oncologic surgery in this complex region of the neck. Anatomically, the laryngopharynx extends from the hyoid bone to the lower margin of the cricoid cartilage. Through contraction and passive relaxation of pharyngeal musculature, it allows smooth passage of the food bolus and oral secretions from the oral cavity/oropharynx to the cervical esophagus. Because it lies inferior to the epiglottis and extends to the location where this common pathway diverges into respiratory (larynx) and digestive (esophagus) pathways, its finely tuned sensory input plays a critical role in preventing aspiration.[26]

The primary goal of laryngopharynx reconstruction is to improve health-related quality of life by restoring alimentary tract continuity so patients can eat and can handle oral secretions. Reliable restoration of normal breathing and speech following concomitant laryngectomy is not possible with current reconstructive techniques. Reduced to its simplest form, the laryngopharynx can be thought of as a cylindrical conduit connecting the oropharynx and esophagus. Reconstructive algorithms are based on the amount of the laryngopharynx circumference missing and extent of soft-tissue involvement to adjacent regions, including the nasopharynx, oropharynx, and neck skin (**Level of Evidence: Therapeutic, IV**).[27]

Defects involving less than 50 percent of the laryngopharynx circumference are generally reconstructed with fasciocutaneous free flaps such as the radial forearm or anterolateral thigh flap. [**See Figure, Supplemental Digital Content 1**, which displays partial laryngopharynx defect with a nasogastric tube in place (*left*). (*Center*) Radial forearm and anterolateral thigh free flaps are

Fig. 5. (*Above*, *left*) Maxillectomy involving the entire alveolus in a 50-year-old female patient with mucosal melanoma. (*Above*, *center*) Resulting bilateral maxillectomy defect. (*Above*, *right*) Fibula osteocutaneous free flap shaped to restore the maxilla; the skin paddle is used to close the palatal defect. (*Below*, *left*) Postoperative appearance. (*Below*, *center*) Intraoral view. (*Below*, *right*) Osseointegrated implants were placed in the fibula after healing was complete.

commonly used to patch partial laryngopharynx defects. (*Right*) Partial flap inset into defect, ***http://links.lww.com/PRS/B121***.] Such defects occur following a standard laryngectomy and require a patch-like reconstruction that minimizes disruption to remaining normal anatomy. The flap is sutured longitudinally on each side to the remaining hypopharyngeal mucosal strip with vascular anastomosis to external carotid side branches and the internal jugular vein. The recently repopularized supraclavicular flap has a useful role in situations where free tissue transfer is not desirable or feasible.[28] [**See Figure, Supplemental Digital Content 2**, which displays a supraclavicular perforator flap based at the posterior triangle of the neck (*left*). (*Center, left*) The flap is elevated with a skin island for laryngopharynx closure created by deepithelialization of the remainder of the flap. (*Center, right*) Partial inset of the skin island. (*Right*) Donor-site closure, ***http://links.lww.com/PRS/B122***.]

Extensive noncircumferential defects involving multiple anatomical levels require soft-tissue bulk; thus, the vertical rectus abdominis myocutaneous flap and the anterolateral thigh flap with vastus lateralis muscle are the preferred flaps. These defects follow resection of a tumor that has spread to levels beyond the laryngopharynx such as the base of the tongue, mandible, soft palate, and floor of the mouth. In addition to providing an ample reliable skin island to replace lining of the laryngopharynx and other

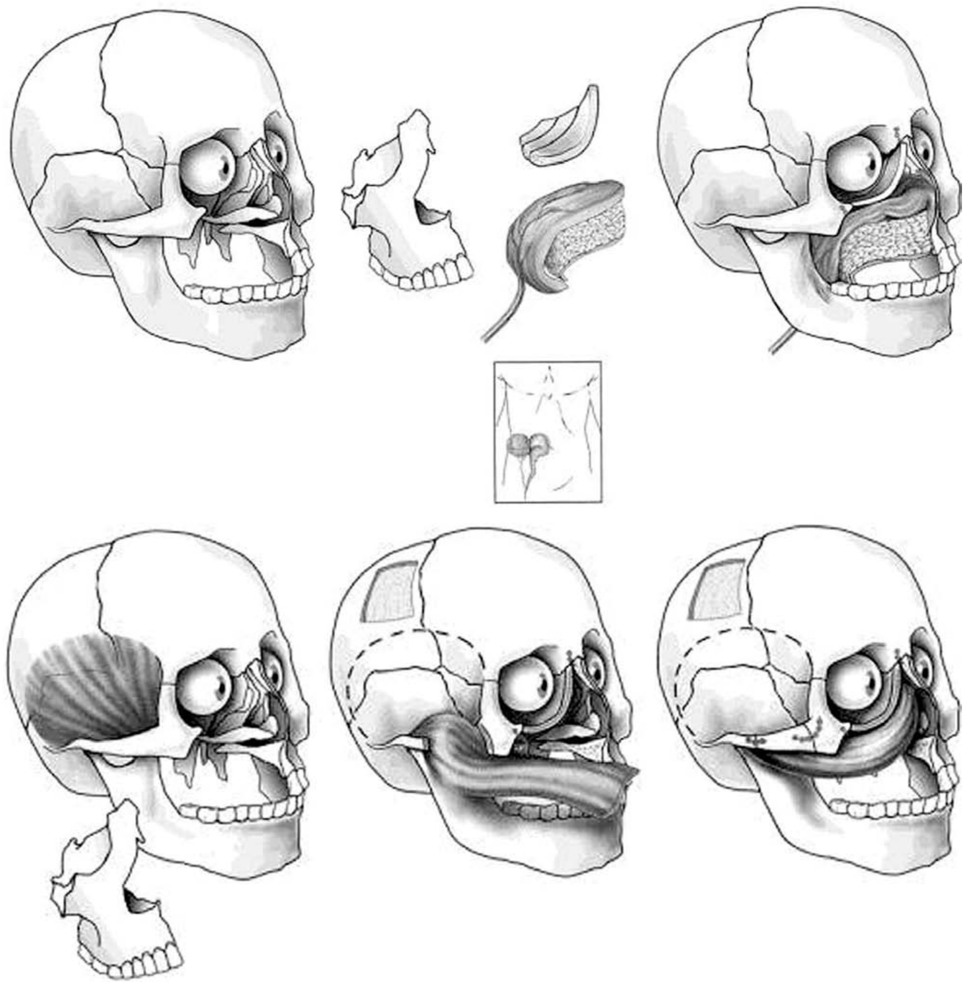


Fig. 6. Type IIIa defect. All six walls of the maxilla, including the floor of the orbit and the hard palate, are resected, preserving the orbital contents (*above*, *left*). The orbital floor is reconstructed with a bone graft and supported by a rectus abdominis myocutaneous flap with single skin paddle that is used to close the palatal defect (*above*, *right*). In patients who are not free flap candidates, reconstruction can be performed with a temporalis muscle pedicled flap, transposed anteriorly by temporarily removing the zygomatic arch, which is later replaced (*below*). (Reprinted from Cordeiro PG, Santamaria E. A classification system and algorithm for reconstruction of maxillectomy and midfacial defects. *Plast Reconstr Surg*. 2000;105:2331–2346.)

mucosal structures, the flap's muscular component can replace missing soft-tissue bulk, thereby eliminating dead space. The muscular portion can be sutured broadly to adjacent neck structures such as the mylohyoid or sternocleidomastoid muscles to theoretically reduce fistula rates and prevent carotid blowout from saliva leakage. Alternatively, the pectoralis major myocutaneous is a dependable pedicled flaps that can be performed expeditiously for these defects.[29] [**See Figure, Supplemental Digital Content 3**, which displays a paramedian skin island design for pectoralis myocutaneous flap (*left*). (*Center, left*) Extensive noncircumferential laryngopharynx defect extending into the oropharynx. (*Center, right*) Skin island already inset with the pectoralis muscle used for coverage of the laryngopharynx and neck vessels. (*Right*) Donor-site closure, ***http://links.lww.com/PRS/B123***.] When raised with a paramedian vertical skin island rich in perforators, the pectoralis major myocutaneous flap easily reaches this location in the neck. Excessive bulk along the subcutaneous tunnel connecting the recipient and donor sites may limit primary closure of the neck, necessitating skin grafting.

Defects involving greater than 50 percent of the circumference or the entire laryngopharynx require reconstruction of the complete laryngopharyngeal cylinder. These defects follow resection of laryngeal cancer that has spread beyond the

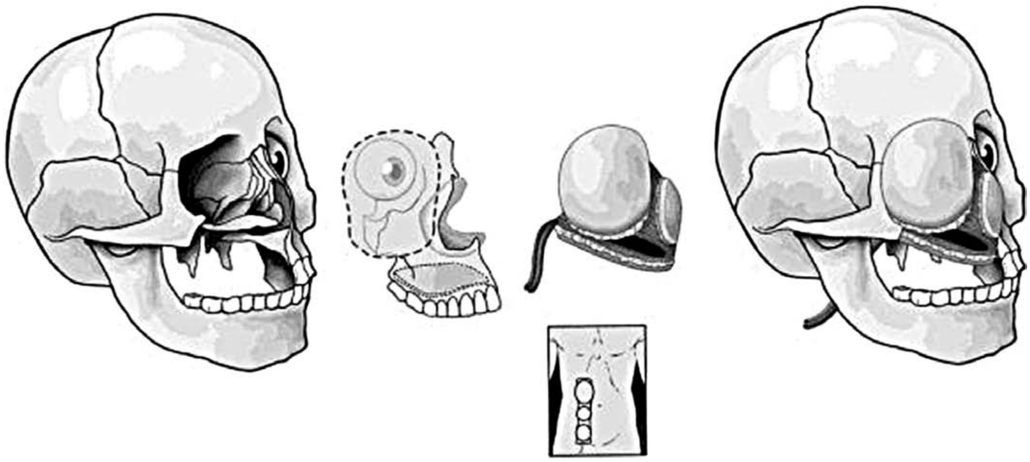


Fig. 7. Type IIIb defect. All six walls of the maxilla and the orbital contents are resected (*left*). A multiple skin paddle rectus abdominis myocutaneous free flap is used to resurface the external skin defect and palatal defect, and, if possible, the lateral nasal defect, although this surface will mucosalize spontaneously over time if a skin paddle is not used to line the nasal cavity (*right*). (Reprinted from Cordeiro PG, Santamaria E. A classification system and algorithm for reconstruction of maxillectomy and midfacial defects. *Plast Reconstr Surg*. 2000;105:2331–2346.)

anatomical boundary of the larynx to involve the pharynx. The two most common flaps used in this scenario are the tubularized anterolateral thigh and the free jejunum. Each technique has inherent technical aspects that are reviewed briefly here.

Reconstruction with an anterolateral thigh flap requires a flap width of 9.4 cm to achieve the 3-cm diameter of the native cervical esophagus (**Level of Evidence: Therapeutic, IV**).[30] Important technicalities include an oblique opening at the proximal end of the flap to match the enlarged opening of the base of the tongue. Insetting a triangular lip of distal anterolateral thigh flap into a slit in the esophagus reduces ring strictures at the distal enteric anastomosis. The longitudinal anterolateral thigh seam is placed posteriorly along the prevertebral area to contain leaks, prevent vascular compression, and position vessels anteriorly for microvascular anastomosis. The flap fascia is wrapped around the tubed flap to reinforce suture lines.

The jejunal flap is generally based on the second or third mesenteric arcade, approximately 40 cm beyond the ligament of Treitz. This area is chosen because the mesenteric arcade (and flap vessels contained within) is the longest at this location, thereby facilitating microvascular repair. The

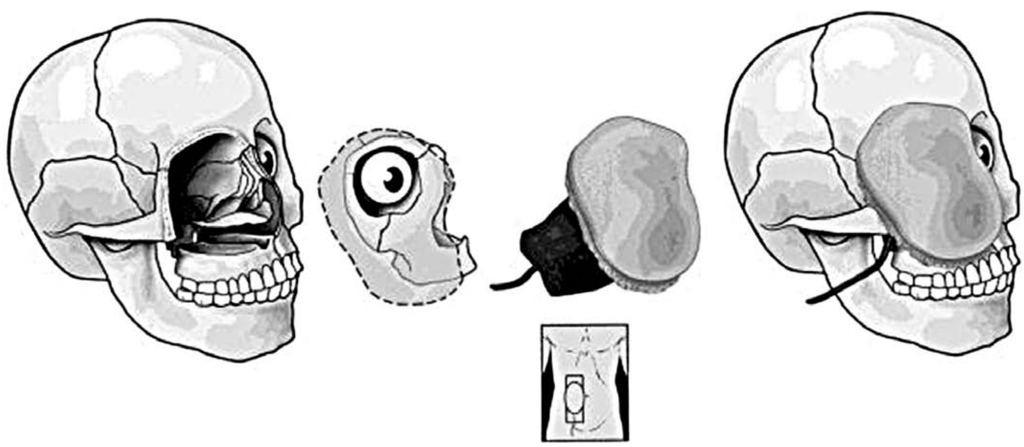


Fig. 8. Type IV (orbitomaxillectomy) defect. The upper five walls of the maxilla, including the orbital contents but sparing the palate, are resected (*left*). A single skin paddle rectus abdominis myocutaneous free flap is used to reconstruct the defect (*right*). (Reprinted from Cordeiro PG, Santamaria E. A classification system and algorithm for reconstruction of maxillectomy and midfacial defects. *Plast Reconstr Surg*. 2000;105:2331–2346.)

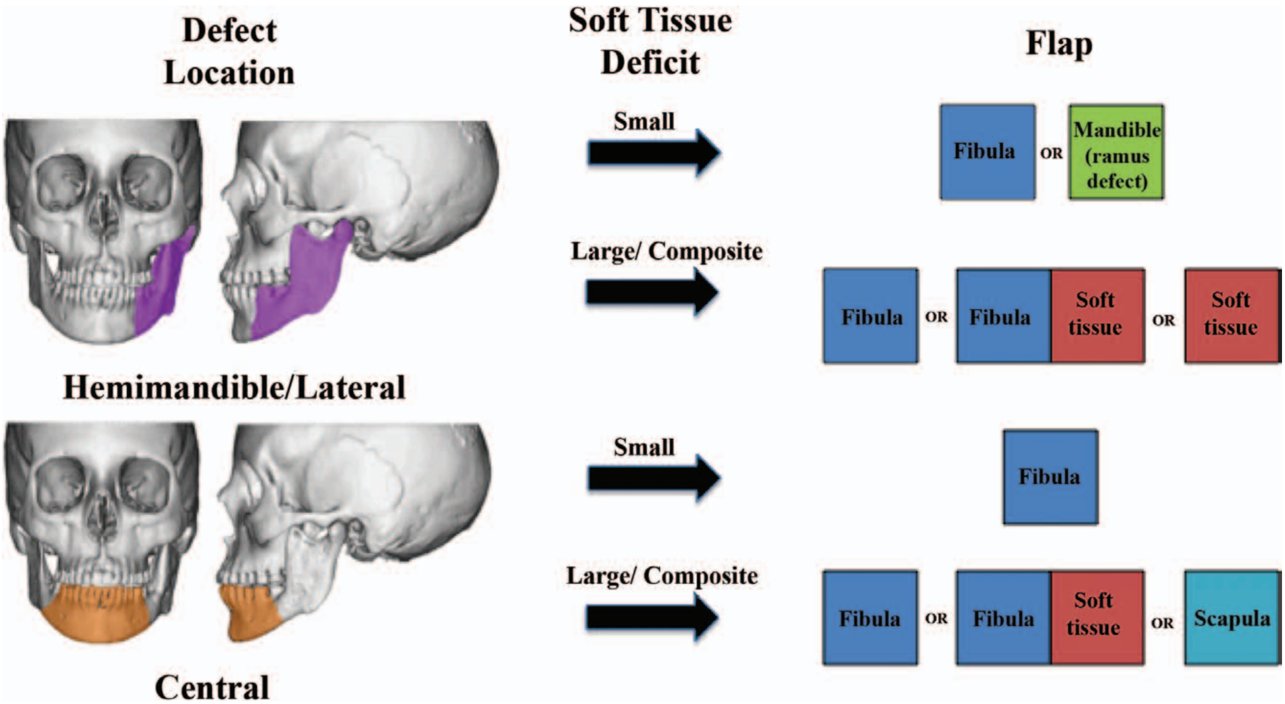


Fig. 9. This image depicts the mandible defect reconstructive algorithm.

flap is oriented with a stitch so that isoperistaltic orientation is maintained after transfer to the neck. Microsurgical anastomosis is performed ideally in less than 2 hours, because the intestine tolerates ischemia most poorly of all flaps. Separation of the mesenteric artery and vein is limited; thus, recipient neck vessels need to lie in close proximity. The distal enteric anastomosis needs to be performed on gentle stretch to prevent bowel redundancy. [**See Figure, Supplemental Digital Content 4**, which displays a circumferential laryngopharynx defect (*left*) and a jejunal flap elevated and attached only by its mesenteric pedicle (*center, left*). (*Center, right*) Jejunal flap inset into base of tongue and cervical esophagus. (*Right*) Externalized segment of jejunum used as a flap monitor, ***http://links.lww.com/PRS/B124***.]

Defects with simultaneous involvement of the laryngopharynx and external neck skin require reconstruction with a double-island flap or second flap. Options for double-island flaps include the radial forearm fasciocutaneous, vertical rectus abdominis myocutaneous, or anterolateral thigh if more than one perforator is present.[31–33] Regional flaps to replace missing or damaged neck skin include supraclavicular, pectoralis, internal mammary artery perforator, and deltopectoral flaps. Insetting needs to be performed carefully to avoid obstruction of the permanent tracheostoma.

Laryngopharyngeal reconstruction has a unique set of considerations for postoperative care and complications. To enhance early identification of flap compromise in buried free flaps, special monitoring techniques must be used.[34] Implantable Doppler probes can be used but have both false-positive and false-negative readings.[35] Alternatively, a flap segment, such as an additional piece of intestine or skin island, can be left outside the neck closure as a direct method of flap evaluation (**see Figure, Supplemental Digital Content 4**, ***http://links.lww.com/PRS/B124***). Salivary leaks and fistulas are significant postoperative complications that occur in 6 to 10 percent of patients; the majority of these resolve with conservative measures.[27,30] Stricturing of the distal anastomosis occurs in 6 percent of patients, particularly those who receive postoperative radiotherapy. Strictures may be managed with endoscopic balloon dilation. Current methods of voice reconstruction lag behind. Patients commonly use an electrolarynx or surgically created fistula between the esophagus and trachea called a tracheoesophageal puncture.

MANDIBLE RECONSTRUCTION

Mandible reconstruction has important functional and aesthetic aspects. The mandible contributes to airway stability, speech, deglutition, and mastication. Specific functional goals include preservation of tandem temporomandibular joint movement with maximal mouth opening and maintenance of occlusion. Aesthetic goals include symmetry, preservation of lower facial height, maintenance of chin projection, and replacement of submandibular soft tissue.

The vast majority of mandible defects result from removal of squamous cell cancer. A minority of defects are caused by osteogenic sarcoma or benign tumors. A proportion of patients receiving head and neck radiotherapy develop complications of osteoradionecrosis, such as fracture or fistula, which require mandibulectomy with reconstruction.

Mandible reconstruction algorithms are based on (1) the location of the bone defect and (2) the extent of soft-tissue involvement. Bone defects are classified as central (lying between the canine teeth), lateral, and hemimandible.[36] [**See Figure, Supplemental Digital Content 5**, which displays a hemimandible, central, lateral classification of bony mandible defects. (*Left*) Lateral defect. (*Center*) Hemimandible defect. (*Right*) Anterior or central defect, ***http://links.lww.com/PRS/B125***.] Hemimandible defects differ from lateral defects by the presence of the condyle. The quantity and location of missing soft tissue are evaluated next. Features influencing flap selection include the absence of mucosal lining, skin, or both.

Although mandible reconstruction can be achieved with a variety of methods, including bone grafts, metal reconstruction plates with or without soft-tissue flaps, and pedicled flaps, free tissue transfer remains the criterion standard because of its low complication rate and ability to most closely restore the mandible to its native state. Nonvascularized bone grafts can be used for short bone gaps (<3 cm) in the setting of benign disease; however, even small grafts fare poorly in the setting of radiation therapy required for head and neck cancer.

Osteocutaneous free flap reconstruction is the most effective method of mandible repair. Although the ilium was the workhorse for the first decade of free flap mandible reconstruction, further evolution has led to development of the radius, scapula, and fibula donor sites (**Level of Evidence: Therapeutic, IV**).[37] These additional options have increased the flexibility and precision of mandible reconstruction as assets and limitations of each donor site have become clearer. A comparison of the attributes of each osseous flap is shown in Figure 9 (**Level of Evidence: Therapeutic, IV**).[38]

Because of its many advantages, the fibula is the most common flap used for mandible reconstruction.[37] [**See Figure, Supplemental Digital Content 6**, which displays the design of a fibula skin island centered over the posterior fibula border (*left*). Perforators entering the skin island are usually found at the junction of the middle and distal thirds of the fibula (*second from left*). Fibula osteotomies and fixation are performed while the flap is still perfused (*center*). The flexor hallucis muscle is used to replace submental soft tissues removed with the extirpation (*second from right*). Titanium miniplate fixation of the flap to native mandible is performed while the patient is in intermaxillary fixation (*right*), ***http://links.lww.com/PRS/B126***.] The bone is available with enough length to reconstruct any mandible defect. The straight quality of the bone with adequate height and thickness constitutes the ideal bone stock for precise shaping and receipt of osseointegrated implants. The dual endosteal and periosteal blood supply allows osteotomies to be placed wherever necessary and as close as 2 cm apart without concern for bone viability. The vascular pedicle has sufficient length and caliber for microsurgical repair. The flexor hallucis longus muscle, which accompanies the flap, is useful to fill soft-tissue defects following neck dissection. The skin island component is reliable in approximately 91 percent of patients.[37] When a large skin paddle is harvested, the donor site requires a skin graft for closure. The location of the fibula away from the head and neck area allows simultaneous flap harvest and tumor ablation. Preoperative imaging is not required except in patients with peripheral vascular disease or an abnormal pedal pulse examination. The fibula is indicated for all central segment defects and most lateral defects.

Two preoperative studies guide intraoperative shaping of the fibula flap.[39] A 1:1 ratio computed tomographic scan taken in the axial plane below the tooth roots and a lateral cephalogram are converted to acrylic plastic and serve as templates for shaping the neomandible in transverse and sagittal planes. [**See Figure, Supplemental Digital Content 7**, which displays a preoperative lateral cephalogram and a 1:1 computed tomographic scan of the mandible in the axial plane are converted to acrylic templates for intraoperative use. The lateral cephalogram is used to determine angulation of the mandibular angle. The axial computed tomographic scan is used to determine angulation of the midbody and parasymphyseal angles. The acrylic templates guide creation of closing wedge osteotomies (*right*), ***http://links.lww.com/PRS/B127***.] Together with the surgical specimen as a reference, the bone is shaped while the vascular pedicle remains intact. Alternatively, some surgeons are now using computer-aided design and manufacturing to fabricate cutting jigs for the native mandible and fibula to guide flap shaping.[40] [**See Figure,**

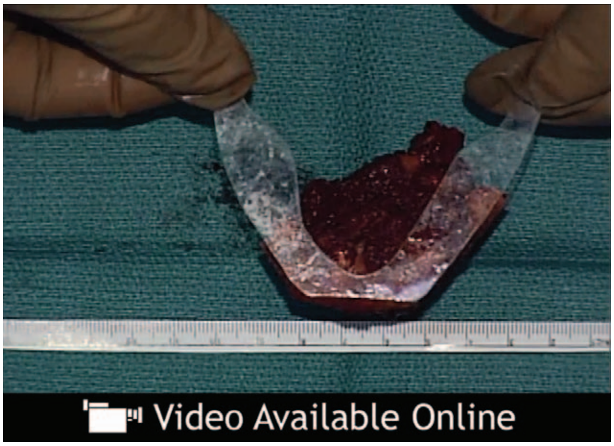
Supplemental Digital Content 8, which displays application of computer-aided design and manufacturing technology to assist flap shaping. (*Above, left*) Proposed segment of mandible to be removed as determined by the surgical oncologist. (*Above, center*) Planned reconstruction with fibula segment. (*Below, left*) Mandible cutting guide. (*Below, center*) Fibula cutting guide. (*Right*) Similarity between a complex multisegment construct and planned model, ***http://links.lww.com/PRS/B128***.] Bony fixation can be accomplished with either miniplates or preformed reconstruction plates.[41] Intermaxillary fixation is used only as an adjunctive form of fixation; its primary role is to maintain occlusion during flap insetting. (**See Figure, Supplemental Digital Content 8**, ***http://links.lww.com/PRS/B128***.)

(**See Video, Supplemental Digital Content 10**, which displays information on fibula flap elevation, contouring, and insetting following anterior mandibulectomy. Part 1 displays flap elevation. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B130***. **See Video, Supplemental Digital Content 11**, which displays information on fibula flap elevation, contouring, and insetting following anterior mandibulectomy. Part II continues the demonstration of flap elevation. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B131***. **See Video, Supplemental Digital Content 12**, which displays information on fibula flap elevation, contouring, and insetting following anterior mandibulectomy. Part III displays flap contouring. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B132***. **See Video, Supplemental Digital Content 13**, which displays information on fibula flap elevation, contouring, and insetting following anterior mandibulectomy. Part IV displays flap insetting. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B133***.)

Soft-tissue flaps serve one of two purposes in mandible reconstruction. First, they can be used in addition to a fibula flap for composite soft-tissue defects where both skin and mucosal lining are missing. Because of its thinness, the forearm flap is placed intraorally to replace delicate structures and the fibula skin island is positioned externally for skin replacement. Second, although anterior mandible defects require the rigidity provided by osseous flaps to prevent sequelae of the Andy Gump deformity such as airway collapse, drooling, and facial distortion, in specific scenarios, lateral and hemimandible defects can be adequately reconstructed with soft tissue alone. For example, defects involving both the lateral/hemimandible and intraoral soft tissues in difficult locations such as the retromolar trigone, palate, and oropharynx are more easily closed with a soft-tissue flap. Composite soft-tissue defects can also be closed with a single folded double-island flap such as an anterolateral thigh or vertical rectus abdominis myocutaneous, rather than with the fibula skin island, which has limited rotational degrees of freedom around the intermuscular septum. [**See Figure, Supplemental Digital Content 9**, which displays a composite posterolateral hemimandible defect involving skin, bone, and lining (*left* and *second from left*).

Video 1. Supplemental Digital Content 10 displays information on fibula flap elevation, contouring, and insetting following anterior mandibulectomy. Part 1 displays flap elevation. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B130***.

Video 2. Supplemental Digital Content 11 displays information on fibula flap elevation, contouring, and insetting following anterior mandibulectomy. Part II continues the demonstration of flap elevation. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B131***.



Video 3. Supplemental Digital Content 12 displays information on fibula flap elevation, contouring, and insetting following anterior mandibulectomy. Part III displays flap contouring. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B132***.

Video 4. Supplemental Digital Content 13 displays information on fibula flap elevation, contouring, and insetting following anterior mandibulectomy. Part IV displays flap insetting. This video is available in the "Related Videos" section of the full-text article on PRSJournal.com or at ***http://links.lww.com/PRS/B133***.

(*Center*) Planned double-island vertical rectus abdominis myocutaneous on the abdomen with one island for lining and the other for cheek skin. (*Second from right*) Intraoral island is already inset with excision of intervening tissue between the paddle for skin replacement. (*Right*) Final flap inset, ***http://links.lww.com/PRS/B129***.] Retrospective series demonstrate equivalent aesthetic and functional outcomes of soft-tissue and osseous flaps, with the exception of an inability to place osseointegrated dental implants (**Reference 42, Level of Evidence: Therapeutic, II**).[42–44] Donor site attributes are presented in Table 1.

Consultation with the dental service is valuable in the management of mandible reconstruction patients. Intermaxillary fixation, intraoperative tooth extraction, custom splint fabrication, and other ancillary procedures are best performed with the help of interested colleagues. Dental service involvement also sets the stage for postoperative dental rehabilitation with either conventional dentures or osseointegrated implants. These implants serve as a permanent foundation on which a dental prosthesis is mounted.[45] Osseointegrated implants are generally unsuitable for placement in irradiated bone flaps.

Free-flap failure is the single most important postoperative complication but, fortunately, occurs in less than 5 percent of cases.[40] Reconstruction plate exposure and intraoral wound dehiscence (which may lead to orocutaneous fistula formation) constitute other serious problems. Donor-site complications such as delayed healing following skin grafting are uncommon and rarely require additional surgery.

Table 1. Osteocutaneous Free Flap Donor Site

	Tissue Characteristics			Donor-Site Characteristics	
Flap	**Bone**	**Skin**	**Vessels**	**Position**	**Morbidity**
Fibula	1	2	2	1	1
Radius	4	1	1	3	4
Scapula	3	2	2	4	2
Ilium	2	4	4	2	3

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PATIENT CONSENT

The patient shown in Figure 5 provided written consent for the use of her images.

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