Reconstruction

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Cancellous Cellular Marrow Grafts and Corticocancellous Block Grafting

Terms:

- Osteoconduction – graft material acts as a scaffold for vascular tissue and mesenchymal cells.
- Osteoinduction – stimulation of osteoprogenitor cells to differentiate into new bone forming cells (osteoblasts).
- Osteogenesis – transfer of vital osteoblasts to contribute to the growth of new bone.
- Allograft – derived from the same species. Can provide osteoconduction and osteoinduction.
- Autograft – graft obtained from the same individual. Provides osteoconduction, osteoinduction, and osteogenesis (See Table 9.1).
- Xenograft – graft from a species that is non-human. Provides osteoconduction.
- Alloplastic graft – graft from synthetic materials.
- Creeping substitution – process by which osteoclastic activity creates new vascular channels, with osteoblastic bone formation,

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Table 9.1 Autogenous bone graft sites

Harvest site	Bone available
Calvarium	No cancellous bone. Use as cortical onlay or bone mill for particulate graft.
Anterior ilium	Up to 50 mL, corticocancellous block also available.
Posterior ilium	Up to 120 mL, corticocancellous block also available.
Tibia	Up to 25 mL cancellous bone available. 1 × 2 cm cortical block.
Symphysis	Corticocancellous block up to 2 × 6 cm, 5 mL if milled for a particulate graft.
Maxillary tuberosity	Very small amount of cancellous bone for socket grafting or peri-implant or periodontal defects.
Ramus	Corticocancellous block of 2 × 5 cm.
Rib	Non-cancellous. Use as a costochondral graft or strut.

resulting in new haversian systems and osteogenesis from the graft.

Tibial Bone Graft

- Ease of access makes this a suitable procedure to be done in the outpatient surgery center or office.
- Contraindications to harvesting bone from the proximal tibia include patients with history of surgery in the area or implanted hardware, acute infection of the soft tissues over the surgical site.
- Relative contraindications would include patients with a history of metabolic bone disease.
- Up to approximately 25 mL of cancellous bone (Table 9.1) can predictably be harvested from the proximal tibia, which makes this donor site good for many maxillofacial indications including alveolar cleft grafting, sinus elevation, and socket grafting.

Anatomy and Surgical Technique

There are two approaches that have been described for harvesting bone from the proximal tibia.

1. Medial approach.
2. Lateral approach that centers over the lateral tibial plateau, also known as Gerdy's tubercle; most common approach. In this review, we will discuss the lateral approach.
   - To minimize difficulty with dissection and postoperative pain, it is important to avoid the tibialis anterior muscle, which attaches inferiorly to the harvest site when the incision is placed over Gerdy's tubercle.
   - The attachments to this tubercle include the fascia lata above and the anterior tibialis muscle below. Together, these form the iliotibial tract that stabilizes the knee and hip during gait. Therefore, minimal stripping of these structures during dissection will minimize pain during ambulation post-operatively.
   - There are no major blood vessels or nerves located between the skin surface and periosteum of the bone over Gerdy's tubercle; although, the lateral genicular artery does travel transversely above the tubercle and the anterior tibial artery travels along the anterior tibial surface below this tubercle.
   - The common peroneal nerve courses inferior to the tubercle and should not be found within the surgical site in a proper dissection.

Surgical Technique (Lateral Approach)

- The patient is positioned with the knee partially flexed and medially rotated and prepared in a sterile fashion.
- The skin and subcutaneous tissue should be infiltrated with epinephrine containing local anesthetic for bleeding and pain control.
- 2 cm incision is marked directly over the palpable ridge of Gerdy's tubercle. This incision is parallel to the tibial plateau (articulating surface) and oblique to the long axis of the tibia. An incision is made through the skin and subcutaneous tissue down to the periosteum.
- Once the periosteum is incised, a small portion of the anterior tibialis muscle inferiorly

and the fascia lata above will be stripped to allow access to the cortex.
- A fissure bur, under copious irrigation, is used to make a 1.5–2.0 cm circular corticotomy. This can be removed with an osteotome and mallet or a periosteal elevator.
- Curette is inserted, and in a rotational manner, the cancellous bone is harvested. The curette should be inserted transversely across the tibia in a downward direction. The risk of perforating the subchondral bone at the superior edge of the tibia and violating the knee joint is small; but proper care during curetting to avoid the area will minimize the chance of that complication.
- Once the graft harvest is complete, the graft is placed into a 10 mL syringe and compacted. Tibial cancellous bone has a higher composition of fat compared to iliac cancellous grafts. It is important to extrude the extra fat cells and concentrate the progenitor cells.
- This is stored on ice until ready for graft inset and the leg is closed. Bovine microfibrillar collagen (Avitene®) or absorbable gelatin sponge (Gelfoam®) can be placed into the harvest site for hemostasis.
- The wound is then closed in layers and a dry sterile dressing is applied.

Complications and Management

- Tibial bone graft complications include infection, gait disturbance, osteomyelitis, hematoma, seroma, fracture, and violation of the joint space.
- *Ecchymosis and Swelling of the Lower Leg and Ankle* – more of a pseudo complication, can be decreased by keeping the limb elevated. Although normal weight bearing is permitted postoperatively, strenuous activities should be avoided, as this will increase pain and swelling. Resolves spontaneously.
- *Violation of the Joint Space or Fractures of the Tibia* – treated with non-weight bearing therapy, splinting, and orthopedic surgery consultation.
- *Osteomyelitis* – MRI to evaluate for depth of invasion and true osteomyelitis. Consult orthopedic surgery. Infectious disease and wound therapy consult for possible hyperbaric oxygen and appropriate long-term antibiotic therapy.

Calvarial Bone Graft

- Shown to have rapid revascularization and limited resorption that allows for resistance to remodeling and soft tissue displacement.
- Limited morbidity and donor site deformity as well as donor site proximity to the recipient site makes calvarial bone useful in both craniofacial and dentoalveolar reconstruction.
- The graft is mostly cortical, which makes it a durable graft for not only ridge augmentation but also orbital and craniofacial reconstruction.

Anatomic Considerations

- Although there are several regions of the skull available for harvest, the most common is the parietal area. The skull is thickest in this area (average 6.3 mm) [1] and does not overlay dural sinuses or arteries.
- There are no major nerves in the area. In most patients, the parietal scalp is fully hair bearing, which makes for acceptable scar camouflage.
- Superior sagittal sinus runs 5 mm parasagittal to the midline. To avoid injury to the superior sagittal sinus, harvest should be 2 cm away from midline and 2 cm away from thin squamous portion of temporal bone inferiorly.

Surgical Technique

- The parietal bone can be accessed by either a coronal incision with wide elevation of the scalp (which is convenient when upper facial skeletal exposure is needed in the case of trauma) or through a linear incision directly over the donor site.
- After instilling the area with local anesthetic (with epinephrine), a scalpel is used to make an incision through the SCALP (skin, subcu-

taneous tissue, aponeurosis, loose areolar connective tissue, pericranium). The periosteum can be incised separately, although this is not necessary.

- The loose connective tissue plane easily dissects (either blunt finger dissection or sharp dissection with the back of a scalpel blade) from the pericranium. This allows for separate incision through the pericranium. Separate elevation of the pericranium may lead to less blood loss, as this is less disruptive to cranial perforating vessels.
- Raney clips (or a running suture) should be applied to the scalp edge instead of extensive electrocautery for hemostasis. Extensive electrocautery can damage the skin and hair follicles and increase the risk of alopecia over the incision.
- Once the incision is made, a periosteal elevator can be used to elevate the scalp in a subpericranial plane until adequate bone is exposed for harvest.
- A fissure bur under copious irrigation is used to outline the desired graft through the outer table. The bur can be used to bevel the outer margin of the corticotomy to facilitate placement of a curved osteotome to complete the outer table harvest.
- With a curved osteotome, gentle malleting is done radially around the graft to separate the graft from the donor bed.
- Once the graft harvest is complete, the graft is set aside in saline, and bleeding at the donor site is controlled. This is most commonly accomplished with bone wax. The resulting skull defect may be filled with hydroxyapatite cement or a titanium mesh to avoid a post-harvest deformity, although this is not always required.
- The wound is then closed in layers. Care should be taken to approximate the galea (aponeurosis) as this will decrease scar width.

Complications

Complications associated with harvesting calvarial bone include the possibility of infection, alopecia, intracranial passage of instrumentation, dural tear, epidural hematoma, subgaleal hematoma, contour deformity, and scarring.

Perforation of Inner Cortex/Dural Tear Craniotomy is frequently required to extend the visual field to identify underlying dural or parenchymal injury. If injury to cortex is identified neurosurgical consultation is required. Most tears can be treated with direct repair with a non-resorbable suture such as Nurolon™ (Ethicon). Larger defects may require grafting. Post-operative non-contrast head computed tomogram (CT) should be sought to rule out intraparenchymal hemorrhage.

Anterior Iliac Crest

- Max of 50 cc of uncompressed cancellous bone (up to 5 cm defect) – remember 1 cm defect requires about 10 cc of bone graft.
- Harvest site is located between Anterior Superior Iliac Spine (ASIS) and tubercle of ilium (which is 6 cm posterior to ASIS).
- ASIS – attachment for external oblique muscles (medially), tensor fascia lata (TFL) laterally. Dissection laterally should be minimized as to prevent postoperative gait disturbance and pain. Inferior to anterior iliac crest are the gluteus medius and minimus muscles, which attach to the lateral cortex.
- Iliacus muscle attaches to the medial surface of iliac crest (reflected during medial dissection)
- Sensory cutaneous nerves (there are no motor nerves overlying the anterior ilium):
  - The most commonly encountered nerve is the lateral cutaneous branch of the iliohypogastric nerve (L1, L2) – this nerve courses over tubercle of the ilium. Damage to this nerve causes sensory disturbance over the lateral anterior third of the ilium.
  - Lateral cutaneous branch of subcostal nerve (T12, L1) courses over ASIS passing just inferior to iliohypogastric nerve.
  - Lateral femoral cutaneous nerve (L2–3) – most inferior of all three nerves of interest,

courses medially between psoas major and iliacus, deep to the inguinal ligament, and perforates TFL to innervate lateral skin of thigh. In 2.5% of people, this nerve courses within 1 cm of ASIS placing it at risk during inferior dissection. Damage to this nerve can result in meralgia paresthetica (dysesthesia and anesthesia of lateral thigh) [2].

- Perforators from deep circumflex iliac artery and vein originating from the external iliac system – located on the medial aspect of the ilium are the predominant vascular supply. The most common source of bleeding is from the superior gluteal artery (internal iliac system).
- Left hip is most often chosen for donor site to prevent interference with driving.

Surgical Technique

- Patient is placed in a supine position and a soft roll such as a saline bag or sandbag wrapped in a towel is placed to elevate the hip.
- Retract skin medially with the surgeon's nondominant hand, so that the resulting scar will end up lateral to the iliac crest and less likely to be irritated by clothing. The resulting scar is also more cosmetic.
- Mark the incision site (4–6 cm in length and placed 1–2 cm anterior to tubercle of the ilium and 1 cm posterior to ASIS). Infiltrate the planned area of dissection with local anesthetic with epinephrine.
- The incision is oblique along the anterior iliac crest – this will avoid the iliohypogastric and subcostal nerves which are superior and the lateral femoral cutaneous nerve which is inferior-medial.
- Layers of the incision – skin, subcutaneous tissue, Scarpa's fascia, and muscular aponeurosis.
- Plane of dissection – between TFL (laterally) and external oblique and transverse abdominus muscles (medially) which is in an avascular plane. The dissection in this plane will lead straight to the iliac crest periosteum (sharply transected). The iliacus muscle is sharply dissected from the medial surface.
  - *NOTE: This approach constitutes the medial approach.*

    Disadvantages of medial approach: higher incidence of meralgia paresthetica (lateral femoral cutaneous nerve) and postop ileus.
  - *The lateral approach requires dissecting away the tissues lateral to the crest, which are the TFL and gluteus medius muscles. There is less intra-abdominal injury since the dissection is lateral, but higher postop pain and gait disturbance (TFL).*
- Depth of harvest: 5 cm – depth at which cortical plates fuse
- Techniques for graft harvesting:
  - Clamshell: mid-crestal osteotomy, fold medial and lateral cortices over to expose underlying bone marrow (good technique for cancellous-only harvest) – if you need a larger quantity of bone, full-thickness corticocancellous block can be harvested (maximum 4–6 cm) – limited anteriorly by ASIS and posteriorly by tubercle of the ilium – if you want to decrease risk of fracture of ASIS, leave 3 cm of intact bone posterior to it.
  - Trapdoor: either medial or lateral cortex with attached musculature is pedicled like a hinge to gain access to marrow.
  - Tschopp: oblique osteotomy of iliac crest, pedicled onto external oblique muscle
  - Tessier: medial and lateral oblique osteotomies, both aspects pedicled to gain access
  - Trephine technique: incision only 2 cm in length, no medial or lateral stripping, trephine used to perforate crest, angulated 30° to vertical
- Bone wax and/or microfibrillar bovine collagen can be used to aid in hemostasis. A low suction drain may also be placed to prevent postoperative hematoma.
- Closure – need to reapproximate periosteum over crest followed by a layered closure.

Complications

- *Hematoma* – if non-expanding, pressure packing may be applied. If expanding, require surgical exploration.
- *Massive Hemorrhage* – superior gluteal artery is the usual culprit. This is caused by harvesting proximal to and/or retracting too aggressively near the greater sciatic notch. Treatment includes exploration, ligation, embolization by IR; do not try to blindly clip it or place hemostat, it has the risk of damage to the sciatic nerve or superior gluteal nerve.
- *Seroma* – needle aspiration (if large) vs. pressure dressing (if small).
- *Nerve Injury* – can be from direct injury to nerve, fibrosis, entrapment during closure, hematoma, or seroma causing external nerve compression.
  - Lateral femoral cutaneous (meralgia paresthetica).
  - Iliohypogastric (loss of sensation to lateral gluteal and suprapubic regions).
  - Subcostal nerve (loss of sensation to the lateral hip).
- *Infection of Donor Site* – removal of sutures to allow drainage. Take culture, local wound care, and antibiotics to treat infection.
- *Gait Disturbance* – stripping of TFL, gluteus medius (abductors). Normally self-limiting. Physical therapy to aid in reestablishing gait and possible walking aid in the interim.
- *Bony Fracture (ASIS, Tubercle of Ilium)* – caused by harvest too close to ASIS, due to action of Sartorius and TFL muscles (stay at least 2 cm away from ASIS to avoid this complication). Management is usually nonsurgical, including pain management and bedrest (if greenstick fracture). Large fractures or significant displacement may require fixation, and an orthopedic consult is warranted.
- *Intra-abdominal Injury* – this is a surgical emergency and requires an exploratory laparotomy.
- *Adynamic Ileus* – cessation of mechanical peristalsis of the bowel. This is managed by bowel rest, electrolyte correction, nasogastric suction (for decompression), and minimal use of narcotics. Should this therapy fail, promotility agents such as metoclopramide (Reglan) may restore bowel function. Most commonly this is a time-limited issue. If not self-resolving, further physical examination and imaging to rule out bowel injury is critical.
- *Sacroiliac Instability* – pain in lower back or pubis (posterior destabilization of SI joint). Fusion of SI joint may be needed in future if persistent pain.
- *Abdominal Wall Hernia* – risk factors: >4 cm block harvest, female gender, or obesity. Will require general surgery consultation.

Posterior Iliac Crest

- Up to 100 cc of uncompressed bone available (up to 10 cm defect).
- Superior cluneal nerve (L1–3) – pierces lumbodorsal fascia, travels superior to posterior iliac crest, and provides sensation to posteriormedial buttocks.
- Middle cluneal nerve (S1–3) – traverses through the sacral foramina and innervates the medial buttocks.
- Sciatic nerve (L4–5, S1–3) is 6–8 cm below the level of posterior iliac crest – should not be encountered.
- Blood supply – perforators from the subgluteal artery.
- Additional surgical time to reposition patient.
- Concern for endotracheal tube displacement risk during patient maneuvering.
- Unable to perform simultaneous procedures.

Surgical Technique

- Patient in prone position – 210-degree reverse hip flexion.
- 6–10 cm curvilinear incision is drawn following the course of posterior iliac crest. The superior and inferior boundaries of the field

are defined by superior and middle cluneal nerves. The incision should end inferiorly approximately 3 cm lateral to gluteal crease centered over the insertion of gluteus maximus muscle (bony protuberance in triangular fossa). The area of dissection is infiltrated with local anesthetic with epinephrine.
- The incision layers – skin, subcutaneous tissue, lumbodorsal fascia (separates abdominal and gluteal musculature), and periosteum over the posterior iliac crest.
- The gluteus maximus muscle is stripped from the tubercle using a blade or electrocautery against the cortical bone. Additional exposure may be gained by reflection of the gluteus medius with a Keyes periosteal elevator.
- 5 cm × 5 cm posterior iliac crest osteotomy of lateral cortical plate to access cancellous bone. Limit harvest at least 4 cm from PSIS to avoid violation of the sacroiliac joint.
- Bone wax and/or microfibrillar bovine collagen can be used to aid in hemostasis.
- Closure in layers; reapproximate periosteum and lumbodorsal fascia.
- A drain should be placed to prevent postoperative hematoma.

Complications

- *Arterial Injury* – superior gluteal artery, postop gluteal compartment syndrome (treated with ligation; if continued bleeding, may need exploratory laparotomy via retroperitoneal approach, or embolization by IR).
- *Ureteral Injury* – postop hematuria, abdominal distention, ileus – from excessive electrocautery usage near the greater sciatic notch (usually while you are trying to control bleeding from superior gluteal vessels). Urology consult is indicated. Treatment may include placement of a ureteral stent or surgical repair.
- *Nerve Injury* – cluneal nerves, posterior pelvic pain radiating to buttocks.
- *Gait Disturbance* – weak abductors (mainly gluteus medius) – from excessive stripping.

Microvascular Free Tissue Transfer

- The term free flap (also known as autologous tissue transfer and microvascular free tissue transfer) is used to describe the transplantation of tissue with its own blood supply from one site of the body to another. The circulation in the transferred tissue is reestablished by anastomosis of the transferred arteries and/or veins to recipient vessels in the host bed (Table 9.2).
- Free flaps may be comprised of skin, muscle, nerve, bone (or any combination of these).

Anterolateral Thigh Flap (ALT)

- The ALT is a fasciocutaneous perforator flap based on the descending branch of the lateral circumflex femoral artery. It runs in the intermuscular septum between the rectus femoris (RFM) and vastus lateralis muscle.
- Long vascular pedicle length from 8–16 cm if measured the entire length of the flap.
- Flap is fairly thick due to the presence of copious subcutaneous tissue. Some authors have described "defatting" the flap at the time of harvest to thin the flap; however, this carries the risk of compromising venous circulation within the flap.
- The flap can be raised with only fascia and thin subcutaneous fat without the skin. This will result in a much thinner fascial flap.
- Popular due to the versatility of the flap in design.
- Donor site can often be closed primarily leading to minimal donor site morbidity.

Surgical Technique

- A line is drawn from the anterior-superior iliac crest to the lateral aspect of the patella. This line roughly corresponds to the intermuscular septum between the rectus femoris and vastus lateralis muscles. At the midpoint of this line, a 5 cm circle is scribed (centered on the line). Within this circle (the lateral two

Table 9.2 Free Flap Indications and Vascularity

Free flap	Components	Pedicle length/caliber	Indications
Radial Forearm Free Flap (RFFF)	Skin and fascia. Tendon (palmaris longus) if suspension is needed, bone (radius) if small bone is required.	Long pedicle if taken at take-off from brachial artery. Large caliber 2–4 cm with two venae comitantes or cephalic vein for drainage.	Thin flap is great for intraoral soft tissue defects or tongue reconstruction or lip reconstruction if tendon is included.
Anterolateral Thigh (ALT)	Skin, muscle (vastus lateralis), fascia, large flap up to 10 × 25 cm can be harvested	5–7 cm length, 1.5–3 mm diameter vessel, descending branch of the lateral femoral circumflex artery.	Large facial or intraoral defects, scalp defects, orbitocraniofacial resections, gunshot wounds. May be too thick in obese patients.
Deep Circumflex Iliac Artery (DCIA)	Vascularized iliac crest bone, iliacus muscle, with or without skin.	4–8 cm length, 1.5–3 mm diameter vessels, deep circumflex iliac artery and venae comitantes.	Maxillary or mandibular reconstruction, may require vein grafts if inadequate pedicle length.
Scapula	Skin and bone (lateral border of scapula).	Up to 7 cm length, 2–4 mm vessel diameter, subscapular artery	Mandibular ramus reconstruction, maxillary reconstruction.
Free Fibula Flap (FFF)	Bone, muscle (flexor hallucis longus cuff or adjacent soleus muscle), and skin.	Pedicle length depends on the length of bone needed but can be 5+ cm, 2–4 mm diameter vessel, peroneal artery, and venae comitantes.	Maxillary or mandibular reconstruction, can use closing osteotomies to establish arch form.

quadrants most commonly) is where perforating vessels can be most readily identified. Once this is accomplished, the flap is designed centered over the perforator.

- Flap elevation begins by making a skin incision along the medial margin of the flap. This is carried through the skin, subcutaneous tissue, and fascia over the rectus femoris muscle.
- Once in the subfascial plane, gentle blunt dissection can be carried laterally until the perforating vessels are identified. (Most commonly the perforating vessels are muscular and pierce the vastus lateralis muscle. About 9% of the time, the perforators are septal. The presence of septal perforators does simplify flap harvest but when muscular perforators are encountered, a small cuff of vastus lateralis can be safely taken to protect the perforator.)
- Once the perforator is identified, the intermuscular septum between the vastus lateralis and rectus femoris muscles is dissected and the flap pedicle can be identified. (Motor nerve branches to the vastus lateralis muscle are commonly seen running with the artery and can be separated and preserved.)
- The pedicle is traced back to the takeoff from the lateral circumflex femoral artery. The flap is then incised around the lateral aspect.
- The fasciocutaneous portion of the flap is completely dissected. (Perforators are dissected from the muscle if needed.)
- Once the tumor is ablated and the size of the defect is defined, back cuts are made on flap to the desired size and modified as required.
- Vessels are clamped proximally and ligated, and the flap is delivered from donor site.
- Donor sites up to 8–10 cm wide can usually be closed primarily; if the flap is larger than this, skin graft closure can also be used but is less cosmetically pleasing.

Complications

Specific to the ALT flap paresthesia or anesthesia over the lateral thigh, seroma formation, wound infection. Paresthesia over the lateral thigh is not usually very bothersome. Seromas may require drainage and infections should be treated with antibiotics to cover for skin flora.

Herniation of Muscle There are reports of vastus lateral and rectus femoris muscle herniation. Requires exploration and repair. Repairs include direct closure or coverage with a split thickness skin graft. Larger hernias may be treated with a polypropylene mesh [3, 4].

Rectus Femoris Muscle Necrosis [4] Uncommon complication from ligation of the lateral circumflex artery proximal to take-off of the descending branch during harvest. Authors recommend when a larger pedicle is needed to place a vessel loop at the site of planned vessel harvest prior to definitive ligation to evaluate blood flow to the rectus femoris muscle.

Compartment Syndrome [4] Increase in pressure within a closed fascial space resulting in a decrease in capillary flow. If the deep fascia was used for closure, treatment describes release of the deep fascia. If deep fascia closure was not performed and compartment syndrome was discovered, debridement with VAC therapy has been described.

Radial Forearm Free Flap

- The radial forearm free flap is a fasciocutaneous flap based off the radial artery.
- Venous outflow is provided by either the venae comitantes or the cephalic vein.
- Used mostly for floor of mouth, tongue, lip, and buccal mucosa reconstruction. Defects that require more bulky tissue such as subtotal glossectomy and large skull base tumors are better suited with a bulkier flap such an ALT [5, 6].
- This flap is also being described to include a portion of the radial bone, the palmaris longus tendon, or brachioradialis muscle.
- Because the skin of the volar forearm is quite thin and pliable, this flap has become a workhorse flap in oral cavity, laryngeal and pharyngeal reconstruction. It is also useful for resurfacing defects where a thinner flap is desirable.
- Long vascular pedicle with large caliber vessels allows for easy anastomosis.
- There are usually no long-term sequelae of the donor site with hand and wrist mobility and finger strength being preserved in usual flap harvests.
- Major complaint is unaesthetic donor site due to scarring or poor color match when skin grafts are used for closure.

Preoperative Considerations

- Note any recent intra-arterial or intravenous lines placed as they may compromise flap vascularity. “No stick” order should be placed for patients presenting for reconstruction.
- Best to harvest from non-dominant hand in the event that there is a donor site complication that would compromise the hand or reduce hand strength or mobility.
- A preoperative Allen test is useful for determining whether the patient has acceptable ulnar collateralization. Many patients undergoing oral cavity reconstruction have poor peripheral circulation and an Allen test can be difficult to interpret. Therefore, the use of a pulse oximeter on the thumb when doing the test can improve sensitivity of the exam. Adequate compression of the ulnar and radial arteries should result in complete cessation of the arterial waveform on the pulse oximeter. Release of the ulnar artery should result in return of pulsatile flow but with an attenuated waveform. Then, release of the radial artery should result in restoration of the complete amplitude of the waveform. (In the traditional description, reperfusion of the fingers or nail beds should be seen in 15–20 seconds). In this scenario, adequate ulnar collateral flow is evident, and the patient should tolerate radial artery harvest without a risk for devascularization.
- Further vascular imaging studies are generally not necessary. In the event that the patient has a concerning Allen test, the patient can still undergo radial forearm free flap harvest; how-

ever, the radial artery should be reconstructed immediately with vein grafting. While the cephalic vein is commonly used for venous outflow of the flap, it can be used for reconstruction of the radial artery while the venae comitantes are used for the venous circulation of the flap.

Radial Forearm Harvest Technique

- The radial artery is palpated and marked as is the cephalic vein. The appropriately sized flap is then drawn over the radial and volar surface of the forearm centered over the radial artery. The distal aspect of the flap margin is marked approximately 1 cm from the distal wrist crease.
- A tourniquet is utilized and inflated to 250 mmHg for exsanguination.
- Flap elevation begins at the distal aspect of the segment. A#15 blade is used to incise the skin, subcutaneous tissue, and fascia along the distal margin of the flap. Curved hemostats are then used to dissect the cephalic vein as well as the radial artery and radial artery venae comitantes. They are then ligated and transected.
- Next, starting on the medial and distal corner, the flap is elevated in a subfascial plane. Care must be taken during this portion of the flap elevation to avoid dissecting the fascia from the radial artery. When elevating the flap over the flexor carpi ulnaris, palmaris longus, and flexor carpi radialis tendons, the paratenon over those tendons should be preserved to aid in skin graft take.
- Flap elevation is continued to the radial distal edge and, while lifting the flap, the two superficial dorsal branches of the radial nerve can be identified and left in place during flap elevation. This minimizes paresthesia over the dorsum of the hand along the thumb and index finger. Once the flap is elevated to the proximal margin, the proximal aspect of the flap is incised with care not to transect the cephalic vein.
- Releasing incision is then opened to the antecubital fossa. Vessel loops are placed around the cephalic vein distally and this vein is followed proximally and dissected out of the subcutaneous tissues with care being taken to ligate and divide any branches.
- The brachioradialis muscle is retracted laterally and the flap is elevated to place gentle tension on the radial artery. Vessel loops were placed around the radial artery and it is traced proximally as branches are ligated and divided.
- The cephalic vein and radial artery are traced to the antecubital fossa both in order to provide adequate pedicle length and also to improve vessel caliber.
- The tourniquet is deflated, and the flap is reperfused for 20 minutes.
- The flap can then be harvested by ligating and dividing the radial artery and two venae comitantes as well as the cephalic vein.
- The flap is passed into the oral cavity for inset and anastomosis.
- Closure of the radial forearm donor site is most commonly accomplished by primary closure of the releasing incision and then skin graft application over the flap donor defect. Some surgeons prefer a full-thickness skin graft harvested from the medial surface of the upper arm as this area is already prepped into the surgical field and a full-thickness skin graft gives thicker coverage for the flexor tendons. Others will utilize a split thickness skin graft harvested from a distant site such as the thigh.
- If a skin graft is used, it should be perforated to allow seepage of fluid. A bolster is kept in place for 5–7 days and the splint is kept in place for 4 weeks.

Complications

Delayed Wound Healing Failure of the skin graft resulting in tendon exposure, infection, and decreased mobility of the wrist or fingers due to scarring. Treatment options depend on the extent of necrotic tissue. The tissue may be debrided and a second skin graft attempted. The defect may be allowed to heal by secondary intention, by covering with moist gauze until healed [7, 8].

Hand Ischemia Can normally be avoided if Allen test is properly conducted, or can use color flow doppler if Allen test is not conclusive [8–11]. Can occur if the radial artery is the major blood supply to the hand, damage to the ulnar artery, or insufficient collateral blood flow between arterial systems. Treatment is an interpositional vein graft to the divided stump from either the saphenous or cephalic vein.

Decreased Pincer Grasp and Hand Strength Can result from harvesting a portion of the radial bone.

Infection Antibiotics with activity against skin flora are indicated if signs of infection are present. Serial debridement of necrotic material and irrigation of the wound is recommended. Cultures should be taken and considered for infectious disease consultation.

Nerve Injury Complaint of dysesthesia in the distribution of radial nerve, but this becomes less noticeable overtime [8, 10].

Fibula Free Flap

- Excellent option for reconstruction of any mandible defects (most commonly from neoplasm, osteonecrosis, and trauma).
- Ideal for composite osseous defects that require reconstruction of adjacent oral lining or external skin.
- The fibula is a long, thin bone that articulates with the lateral condyle of the tibia proximally and with the connective tissue of the ankle mortise distally. It is a non-weight bearing bone with a relatively thick cortex circumferentially.
- Bone height varies from 9 to 15 mm with a total length of approximately 35 cm, typically up to 25 cm can be harvested.
- The peroneal artery (PA) and its venous comitantes provide vascular supply to the fibular free flap. The external diameter of the peroneal artery is 1.5–2.5 mm and the pedicle length is between 2 and 6 cm [12].

Fascial Compartments

- The lower leg is separated into compartments dictated by the tibia and fibula bones as well as fascial planes (Fig. 9.1).
- The tibia and fibula with their interosseous septum separate the anterior and posterior compartments. The anterior lower leg is further subdivided into anterior and lateral compartments by the anterior intermuscular septum.

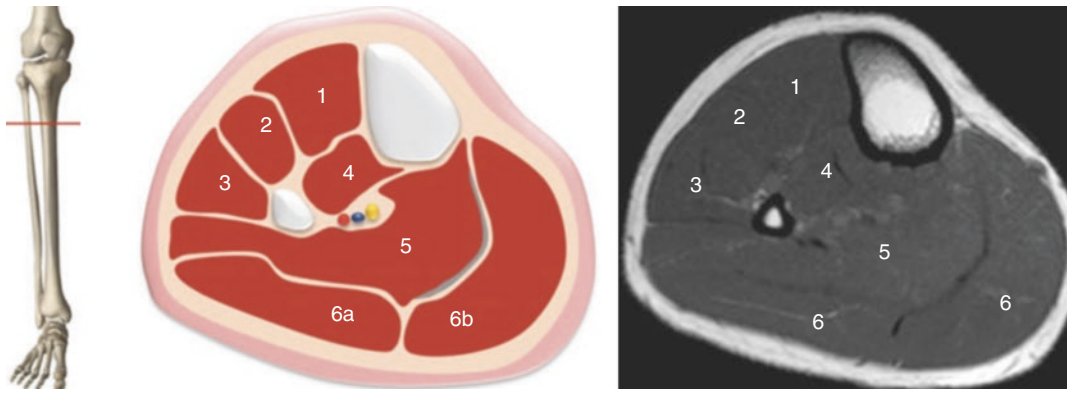

Fig. 9.1 1 Tibialis anterior; 2 extensor digitorum and hallucis; 3 peroneus longus; 4 tibialis posterior; 5 soleus; 6 gastrocnemius lateralis (6a) and medialis (6b). (Reprinted with permission from Silvestri et al. [13])

- The posterior lower leg is subdivided into deep and superficial compartments by the transverse intermuscular septum.
- The lateral and posterior compartments are separated by the posterior intermuscular septum which importantly carries the skin perforator vessels essential to skin paddle harvest.
- Knowledge of these fascial compartments and their contents is essential when harvesting a fibular flap.

Preoperative Workup

The integrity of the lower limb and foot vasculature is essential before planning for a fibular free flap. Work up should be focused on identifying abnormal vascular patterns to the foot as well as identifying compromised vessel quality. Imaging is recommended to confirm three vessel run-off.

History

- Inquire about cardiovascular disease risk factors (coronary artery disease, peripheral vascular disease, smoking, etc.).
- Specifically check for history of claudication, dependent edema, venous thrombosis, varicose veins, prior lower limb surgery, and prior lower limb trauma.

Physical Exam

- Inspect for signs of peripheral vascular disease including edema, induration, varicosities, shiny/hairless skin, and cold feet.
- Palpate dorsalis pedis and posterior tibial pulses.
  - "Modified" Allen test: Apply pressure to dorsalis pedis artery while palpating for posterior tibial pulse and vice versa to eliminate retrograde flow.
- ABI (Ankle-Brachial Index): Objective measure to detect arterial insufficiency although its use is primarily historical in this setting due to improved imaging modalities.

Imaging

1. Magnetic Resonance Angiography.
2. Computed Tomographic Angiography (Fig. 9.2).
3. Conventional Angiogram.
4. Color-Flow Doppler Imaging (may also play a role in localizing perforators).

Guidance Point PVD doesn't necessarily preclude use of FFF; however, there is a higher risk of thrombotic events and flap complications. Other osteocutaneous flaps should be considered in these patients, such as the scapula, since the vascular supply is more proximal and less affected by PVD.

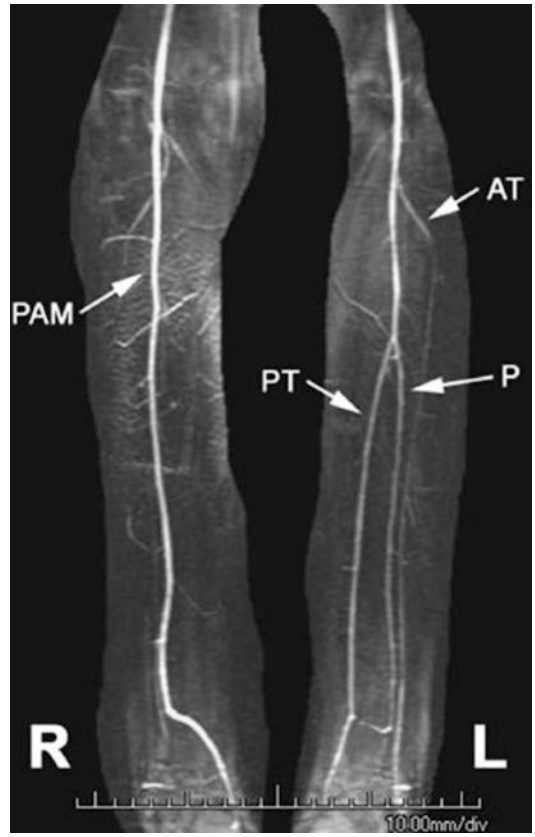

Fig. 9.2 Peronia Arteria Magna of right lower leg on angiography. Lower left leg demonstrating all three vessel branches of the popliteal artery (1) anterior tibial (AT) (2) posterior tibial (PT) and (3) peroneal artery. (Reprinted with permission from Betz and Betz [14])

Variation in Arterial Supply

- Surgically significant anomalies occur in 10% of population, 5.2% of any given limb.
- Variations are clinically asymptomatic but impact surgical candidacy.
- Infra-popliteal Arterial Branching Classification (Kim-Lippert's Classification System) [15]:
  - I: Normal level of branching
  - II: High-Division of PA (at or right above the knee)
  - III: (10.37% Overall) Hypoplastic/aplastic branching with altered distal supply (Table 9.3).
  - IV: PA vessel caliber variation
    - IV-A: Hypoplastic (not recommended, but may not fully preclude FFF harvest given anastomoses of vessels as small as 1 mm possible)
    - IV-B: Aplastic (absolute contraindication)

Fibula Free Flap Technique

- Exsanguinate leg with compressive bandage. Apply thigh tourniquet inflated to 250–350 mmHg.
- Plan a long anterior curvilinear incision to transverse intermuscular septum, along anticipated skin paddle. Making a lengthy anterior incision along the fibula allows for ease of access as well as preparation for variations in skin perforator anatomy.

Table 9.3 Type III subtypes of lower leg branching patterns

Type III (10%)			
Subgroup	IIIA	IIIB	IIIC
Notes	2-vessel runoff Deficient vessel: PT (63%)	2-vessel runoff Deficient vessel: AT (29%)	Single-vessel runoff (Peronia Arteria Magna). See Fig. 9.2. Deficient vessel: Both tibial arteries (8%)
Implication	Possible but unwise	Possible but unwise	Absolute contraindication

- Incise skin and soft tissue to the fascia overlying the peroneus muscles.
- Identify intermuscular septum and locate perforators to the skin.
  - Dominant perforators are typically located in the middle and distal thirds of the fibula.
- Dissect along the length of the anterior aspect of fibula via elevation of the peroneus longus, peroneus brevis (which are retracted anteriorly), and extensor hallucis longus.
- Continuing dissection along the bone to the medial aspect reveals the interosseous membrane.
- Proximal and distal fibula bone cuts are made (at least 6–8 cm preserved on both ends to maintain ankle and knee stability and provide access for adequate vascular pedicle length).
- Making posterior skin cuts down to the subfascial plane at this point helps in fully mobilizing the fibula.
  - Visual identification and protection of skin perforator(s) are crucial to avoid compromise of the skin paddle.
- The fibula is retracted laterally exposing the interosseous membrane. Transection of interosseous membrane to separate the fibula from tibia exposes the peroneal pedicle below the membrane.
- Distal peroneal artery and veins are identified after the distraction of fibula. Ligate and transect distal pedicle.
- Dissect the pedicle from distal to proximal while separating the chevron shaped tibialis posterior muscle.
  - It is prudent to preserve a cuff of muscle along the fibula (as well along with the periosteum) as to not injure the multiple musculoperiosteal nutrient branches to the fibula bone.
- It is important to be aware that the peroneal vessels will begin to course medially in an oblique fashion as they near the junction of the posterior tibial artery.
- Transect the flexor hallucis longus muscle (leaving a cuff attached to flap) and ligate the pedicle proximally.

Table 9.4 Traditional flap inset and orientation (other options are feasible depending on the soft tissue constraints)

	Right fibula		Left fibula	
	Anterior exiting vessels	Posterior exiting vessels	Anterior exiting vessels	Posterior exiting vessels
Right mandible defect	Skin paddle positioned over neomandible for mucosal defect	Skin paddle inferior to neomandible for external defect or transposed for mucosal defect	Skin paddle inferior to neomandible for external defect or transposed for mucosal defect	Skin paddle positioned over neomandible for mucosal defect
Left mandible defect	Skin paddle inferior to neomandible for external defect or transposed for mucosal defect	Skin paddle positioned over neomandible for mucosal defect	Skin paddle positioned over neomandible for mucosal defect	Skin paddle inferior to neomandible for external defect or transposed for mucosal defect

  - It is typically most useful to ligate the peroneal pedicle near its take off to maximize pedicle length as well as vessel diameter; however, a small stump of the pedicle should be left in situ to avoid damage to the remaining tibioperoneal trunk.
- The flap is now harvested in preparation for contouring, insertion, and anastomosis (Table 9.4).
- Fibula donor site is closed by first reapproximating the lateral compartment muscles to the soleus. The remainder of the wound is closed in a layered fashion in a tension free manner. Skin grafting may be required.

Use of Microsurgery in Head and Neck Reconstruction

Recipient Vessels

- Commonly, the vascular system proximal to the site of reconstruction or within the reach of the vascular pedicle of the chosen flap is utilized.
- Occasionally due to prior operation, radiation therapy, or poor vessel quality, more distant vessels must be utilized.
- Commonly, the superficial temporal artery and vein are used for upper face and scalp reconstruction.
- The facial artery and vein or external jugular vein are convenient vessels for oral cavity and lower facial reconstruction.
- The anterior jugular veins should be used with caution when the patient has undergone tracheotomy placement as these vessels may be compromised inferiorly.
- The internal jugular vein and its branches routinely provide improved caliber veins with higher vessel pressures.
- Commonly vein branches sized at least 3 mm in diameter can be found along the internal jugular vein.
- The lingual and superior thyroid artery can be used when the facial artery is not acceptable and the transverse cervical artery at the base of the neck can be utilized when no other superior options are available.
- In cases where a neck exploration is required, careful handling of the tissue is imperative to avoid injury to the recipient vessels. The vessels should be gently tied with silk ties or vascular clips and dissected sharply.
- Electrocautery or high-energy cautery including harmonic scalpels should not be used directly on the recipient vessels as this increases the risk for intimal damage and later thrombosis.
- Excessive handling of the vessels during dissection can lead to shearing, tearing of branches and uncontrolled bleeding, spasm, and delamination of the intima of the vessel.
- Patients with atherosclerosis or prior radiation may have friable vessels with sclerosis of the adventitia. These vessels are more prone to dissection and thrombosis. Any defect noted within the lumen of the vessel should be

trimmed back until the vessel demonstrates a smooth, uniform intima.

Anastomosis

- The most common type of anastomosis is the end-to-end anastomosis of the donor and recipient vessel.
- End-to-side anastomoses are also relatively common.
- Most of the flaps used within the head and neck have a vessel caliber similar to those in the neck.
- Techniques to overcome vessel discrepancy include [16]:
  1. Trimming the smaller vessel back (2:1 discrepancy).
  2. Dilating the smaller vessel gently (2:1 discrepancy).
  3. Spatulation – the end of the smaller vessel is incised longitudinally. The apex of the incision is sutured first to the recipient vessel and the anastomosis is completed allowing accommodation for the vessel size (between 2:1 and 3:1 discrepancy).
  4. Beveling the edge of the smaller vessel, no more than 30° (between 2:1 and 3:1 discrepancy).
  5. End to side anastomosis (>3:1 discrepancy).
- Vessels are typically sewn with 9-0 or 10-0 nylon suture on a tapered-point needle.
- While hand sewn venous anastomoses are still common, the use of vein couplers has simplified vein anastomosis. Several coupler diameters are available and chosen based on the best fit to both the donor and recipient veins. The couplers may also be equipped with a Doppler sensor to facilitate flap monitoring post-operatively.
- Couplers are best used for vessels more equal in size, but some surgeons have used it up to a 3:1 discrepancy.
- They have been shown to result in completion of anastomosis 4–5 times faster than hand sewing.

Flap Vitality

- The most common cause of vascular failure of a flap is venous congestion vs. arterial thrombus (4:1).
- Most congestion occurs within 48 hours of surgery.
- After 12 hours of ischemia, free flap salvage is not possible. It is common to have hourly checks for the first 24 hours and 2-hour checks for the next 48 hours.
- The rate of flap necrosis is around 4% [17].
- Hemostasis is imperative since hematomas can result in external compression of the vessels resulting in occlusion.
- It is important to minimize vasoactive medications that can result in vasospasm within the flap.
- Since veins are low-pressure vessels, they are susceptible to torsion and external compression by hematomas.
- Redundant vessels may appear to lay flat when the head is turned and the neck extended during the operation. But, when the neck is in a neutral position or flexed, the vessels may become tangled and occluded.
- Delayed arterial thrombosis is less common. Several pharmacological agents have been described to reduce thrombotic complications, but no regimen has been established as superior:
  - Aspirin blocks thromboxane A2 production that has vasoconstrictor activity and aids in platelet binding. This is usually started immediately after surgery and the length of treatment postoperatively varies widely but commonly lasts between 30 and 90 days.
  - Heparin binds to antithrombin III which causes an increased activity, preventing the activation of factor IIa, XIIa, IXa, and Xa [5]. Heparin is not typically utilized due to the risk for bleeding and hematoma formation which could have a devastating effect at the site of the micro-surgical anastomosis. Heparin irrigation is commonly used as a vessel irrigant given its highly negatively charged state and affinity for the vessel wall and its ensuing antithrombotic effects.

  - Dextran has been described in vascular and microvascular surgery to improve vascular patency. Low molecular weight dextran has both an electrochemical and rheological effect on the vessel wall and red blood cells respectively. There is concern for antigenicity and a test dose is usually given before an infusion is started. Non-cardiogenic pulmonary edema, respiratory distress syndrome, renal damage, and cardiac overload have been associated with dextran infusion [5, 18].

Flap Monitoring

- If there is evidence of impaired venous drainage of a flap or decreased arterial inflow, the most common problem is structural in nature. The pedicle may be compressed or twisted. The perforating vessels may be twisted or stretched too tightly. The vein may be kinked or compressed by a hematoma. In any one of those instances, the patient should be taken back to the operating room for exploration of the flap as soon as compromise is identified.
- The earliest signs of flap vascular congestion may be increased turgor or a faint bruise within the flap. This can progress to diffuse and dark ecchymosis as the problem advances. Often, the Doppler signal will remain normal or near normal until late stages of congestion, and therefore, should not be solely relied upon for flap monitoring.
- Flap color and character of bleeding on pin prick are perhaps the most important tools in the diagnosis of vascular compromise in the postoperative period.
- Methods of flap evaluation include:
  - Clinical Evaluation: Pinprick, surface temperature (difference of 3 °C associated with arterial insufficiency and 1–2 °C with venous insufficiency) [18], capillary refill, turgor of tissue, serial photography (taken time of surgery when well perfused and during flap checks to evaluate changes).
  - Doppler: internal, external, and laser.
  - Pulse Oximetry: Commonly quoted, best to monitor digit.

Pinprick Test

- Medium gauge needle used to pierce flap.
- Arterial occlusion will have minimal to no bleeding. The turgor of the tissue is decreased due to the lack of inflow of blood.
- Venous occlusion will cause a rapid bleed of dark blood. The turgor of the tissue is increased due to inability to clear venous blood.

Tracheostomy

- The term tracheostomy refers to the surgical creation of an artificial opening into the trachea.
- The indications for tracheostomy include the need to bypass the upper airway and in patients who require prolonged intubation, such as those with encephalopathy due to trauma or cerebrovascular disease. A tracheostomy both protects the laryngeal tissues and trachea from prolonged intubation, facilitates pulmonary physiotherapy and suctioning. It also allows for weaning of sedation while maintaining a secured airway. Additionally, it can be used for severe sleep apnea.
- The tube should correspond to the size of the patient's trachea (in general, a size 8 tube will work for most men and a smaller tube such as a size 6 will work for most women).
- In obese patients, extra-long (XLT) tracheostomy tubes with proximal or distal extensions can be used to reduce the risk of tracheostomy tube displacement.
- The cuff on the tube should be inflated to check for leaks and then lubricated with water-soluble lubricant to facilitate passage into the trachea.

Technique for Tracheostomy (Fig. 9.3)

- Extend the patient's neck to facilitate distraction of trachea out of thoracic cavity which also brings the anterior surface of the trachea closer to the skin. This may be contraindicated

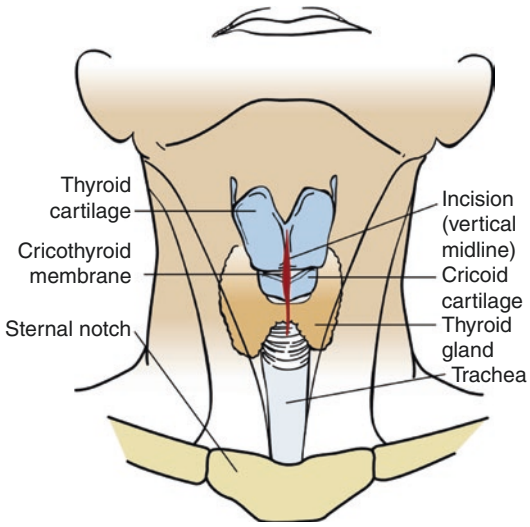

Fig. 9.3 Tracheostomy anatomy. (Reprinted with permission from Roden [54])

in certain cervical spine conditions such as injury or inflammatory spinal disorders or in cases of atlanto-occipital instability.

- Identify the thyroid notch, cricoid cartilage, bilateral sternocleidomastoid muscles (SCM), and sternal notch and mark.
- Approximately half-way between the sternal notch and cricoid cartilage, a transverse incision is marked. This can extend from the anterior edge of SCM to the contralateral anterior edge of SCM.
- The incision is then infiltrated with a local anesthetic containing epinephrine for hemostasis.
- The skin is then incised into the subcutaneous tissues. Careful blunt dissection is carried out in the subcutaneous tissues. The superficial layer of the deep cervical fascia should be divided vertically taking care not to damage the anterior jugular veins and branches. They can be retracted laterally or ligated and divided.
- The strap muscles are next encountered. The median raphe between the infrahyoid strap muscles are divided and retractors are placed to laterally retract the sternohyoid and sternothyroid muscles.
- The thyroid isthmus commonly lies within the superior aspect of this dissection and can either be retracted cephalad or ligated and divided. This can be accomplished by dissecting around the isthmus circumferentially and then applying silk suture ligatures or with electrocautery.
- After this is complete, the trachea is plainly visualized. The pretracheal fascia is divided.
- Next, the anesthesia team is advised to deflate the endotracheal tube cuff to avoid rupture of the cuff and a cricoid hook is placed from inferior to the cricoid cartilage. Gentle traction is then applied cephalad.
- 3-0 silk stay sutures can be placed prior to the incision; these facilitate retraction of the cut margins of the trachea and, therefore, placement of the tracheal tube.
- Using an 11 blade, a transverse incision is made through the membranous portion of the trachea between the second and third tracheal rings (above this the tube may erode through the cricoid cartilage leading to subglottic stenosis, below this there is risk to the mediastinal structures such as the innominate artery) [19]. A heavy tissue scissor is then used to transect one to two rings inferior to the transverse incision.
- Several incisions have been described, but a "T" incision is the simplest. A Bjork flap, which is an inferiorly based anterior tracheal wall flap, can be used when creating a tracheal stoma for long-term tracheotomy.
- The anesthesia team is asked to slowly withdraw the endotracheal tube. Once the tube clears the tracheotomy site, a tracheal dilator can be inserted to gently enlarge the opening.
- A lubricated tracheostomy tube is then inserted into the lumen of the trachea (lubrication reduces the likelihood of damage to the balloon, which can be easily damaged on insertion). This is held in place while the stylet is removed, and the inner cannula is inserted and ventilator circuit is attached.
- The presence of end-tidal CO_2, chest rise with ventilation, and bilateral breath sounds confirm placement.
- The tracheal tube flange can then be secured to the skin and tracheotomy ties passed around the neck for added security.

Complications

- *Bleeding* – usually due to untreated injury to the anterior jugular vein or inadequate control of the highly vascular thyroid. It commonly occurs during incision into the trachea (the critical portion of the procedure when the airway is not protected) and is usually caused by small vessels along the lateral trachea. Extensive electrocautery should be avoided here as the recurrent laryngeal nerve travels in the area of the tracheoesophageal groove. Use of a bipolar cautery can be useful for controlling bleeding in this location. Some surgeons advocate the application of Surgicel® once the tracheal tube is in place. This may help with minor nuisance bleeding post-operatively, but caution should be exercised during tracheal tube change as these friable pieces of Surgicel® can become dislodged into the trachea and cause airway obstruction.
- *Wound Infections* – are possible as these wounds are contaminated with airway flora. Local wound care with dry sterile dressings or wet to dry dressings and antibiotic coverage usually suffice.
- *Pneumothorax and Subcutaneous Emphysema* – can occur due to wide dissection done during tracheostomy, tracheostomy tube displacement, and early ventilation prior to tube security. Must identify source of air (rule out hole in trachea – posterior wall tear commonly reported) or displacement of tracheostomy tube. Repair of the hole in the trachea and bypassing the hole with the tube are possible options. Pneumothorax, if small, can be treated with watchful waiting and serial chest X-rays. If the pneumothorax is large, emergent needle decompression with chest tube placement is indicated. Subcutaneous emphysema, once source controlled, will gradually resolve. Subcutaneous fenestrated catheters can be placed for severe cases. Consider warm heat and antibiotic coverage.
- *Tracheal Tube Displacement* – the most devastating complication. This can occur during initial placement or postoperatively and should be recognized promptly. Intraoperatively, a lack of breath sounds, lack of chest rise, or lack of end tidal CO_2 necessitates prompt re-evaluation of tracheal tube placement. Post operatively respiratory distress, inability to pass a suction cannula, or poor oxygenation requires rapid evaluation of the position of the tracheal tube in a controlled environment. A bronchoscope can be useful for visualization, but the surgeon should not waste time with these maneuvers if the patient is in respiratory distress. In the case of a dislodged tracheal tube, an attempt at re-securing the airway via translaryngeal intubation should be undertaken. If a displaced tracheal tube is attempted to be replaced prior to maturation of tracheostomy tract (rule of thumb prior to 7 days), it may create a false passage into the neck. Once the airway is secured, re-exploration of the tracheotomy in a controlled environment can be accomplished and the tracheal tube replaced.
- *Tracheal Stenosis* – is linked to prolonged endotracheal intubation and wide dissection of the trachea during tracheotomy. Surgical options include tracheoplasty or laser excision of scar tissue.
- *Tracheo-Innominate Fistulas* – can result in life-threatening bleeding. It results from the tracheal tube eroding through the anterior wall of the trachea and the posterior wall of the innominate artery as it crosses the trachea. A "herald" or "sentinel" bleed can precede a massive exsanguinating hemorrhage; but this is not always the case. Over inflation of the tracheotomy cuff may aid in stopping the bleeding. If a patient is bleeding and the innominate artery is the suspected source, the Utley maneuver is indicated (maneuver by which a gloved finger can be inserted into an enlarged tracheotomy incision and used to tamponade the innominate artery against the sternum or proximal clavicle until a thoracotomy can be performed).
- *Tracheocutaneous Fistula* – formation of a fistula from the skin into the trachea. Commonly seen in patients who have been cannulated for about 1 year [20]. Treatment is to remove the scar tissue. The strap muscles are then dissected and repositioned over the trachea.

Closure of skin and subcutaneous tissue performed after.

- *Tracheoesophageal Fistula* – formation of a fistula between the posterior wall of the trachea and the anterior wall of the esophagus. These commonly require an interpositional muscle flap for repair of the esophagus with prolonged bypass of the esophagus with a nasogastric tube.

Muscular Flaps

- Local Flaps – flaps created with tissue adjacent to the defect.
- Regional Flaps – located at a distance from the donor site with its own bloody supply.

Pectoralis Major Myocutaneous Flap

- Can be used to reconstruct soft tissue defects of oral, oropharyngeal, skull base, esophageal, partial tracheal, and pharyngeal defects. Also used to cover exposed major vessels and cutaneous defects of the neck and gain additional soft tissue neck bulk after radical neck dissection.
- Pectoralis major provides adduction and internal rotation of arm. Expected to have some functional postoperative decrease in arm and shoulder function.
- Arc of rotation limits ease of use and normally best for defects anterior to the retromolar region of the jaw and inferior to the ear lobe [21].
- Good alternative for those who are not free flap candidates or for flap salvage.
- Can be harvested with rib to reconstruct segmental defect.
- One stage surgery, with possibility of two teams.
- Distinct color mismatch to the face and hair growth (in male patients) in areas that are normally bare.
- Creates a bulge over the clavicle and neck that will atrophy over time due to denervation.
- Arterial Supply: Pectoral branch of thoracoacromial artery, lateral thoracic artery, superior thoracic artery, and intercostal artery (Fig. 9.4).
- Motor innervation to the muscle from the medial and lateral pectoral nerves (branches of the brachial plexus).
- Venous drainage via venae comitantes of the accompanying arteries that drain into the axillary vein.
- Sensory innervation via the anterior cutaneous branches of the intercostal nerves.
- A 6 × 6 cm flap can be harvested in men without need to skin grafting. This can be doubled in females [21].
- In patients with Poland syndrome, the flap cannot be utilized on the ipsilateral side of the defect. Poland syndrome is a congenital anomaly characterized by unilateral hypoplasia of pectoralis major and minor with associated unilateral brachysyndactyly.
- In patients with breast implants, discussion of removal of implant should be forewarned.

Technique

- First measure the defect of the recipient site.
- A string/suture is placed at the clavicle and swiveled to the margin of the defect point to aid in marking the most inferior portion of the skin paddle.
- The dimensions of the paddle are transferred to the donor site medial and inferior to the nipple. In females, the inframammary crease corresponds to the inferior edge of the skin paddle. (A medial or lateral incision is now decided. A lateral incision is more cosmetic and allows for a wider arc of rotation but closure in females may be more difficult due to need for retraction of breast tissue.)
- Incision is carried through the skin and subcutaneous tissue on the lateral aspect of the incision.
- Dissection is carried down to the pectoralis fascia.

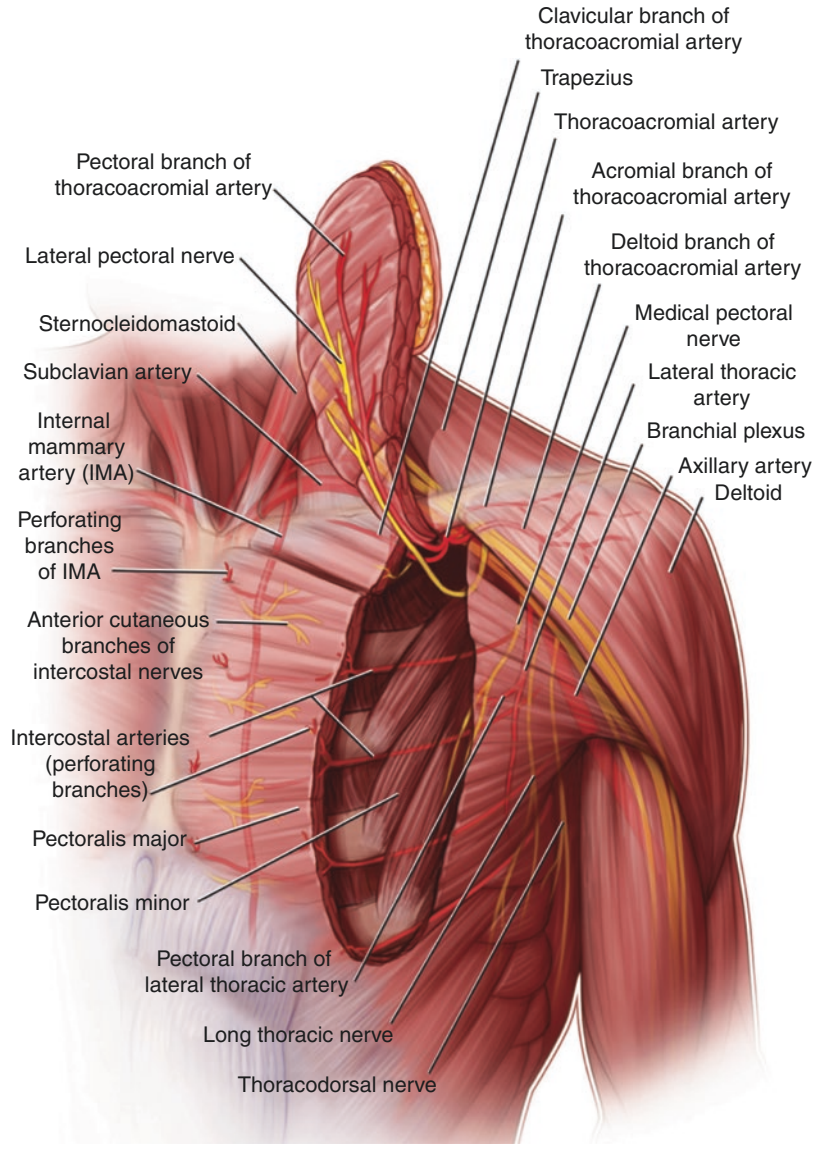

Fig. 9.4 Pectoralis flap anatomy. (Reprinted with permission from Wei and Wai [22])

- The curvilinear extension of the flap is now dissected laterally toward the free margin of the pectoralis major muscle and the insertion of the muscle superiorly and medially toward the sternal and clavicular origins of the muscle.
- The remainder of the skin paddle incision is now completed, and the skin paddle is sutured down to the fascia.
- The flap is now elevated between the pectoralis major and minor muscles. The inferior attachment of the pectoralis muscle to the ribs must be released.
- Once the flap is released, the pectoral nerves are released to aid in arc of rotation and to induce atrophy of the muscle to improve esthetics by reducing bulk.
- Lateral attachment to the humeral insertion is released via blunt dissection.
- A tunnel is now created into the head and neck. A subplatysmal plane of dissection is carried over the clavicle. Most circumstances neck exposure is part of operative field. If sternocleidomastoid still present, the plane is superficial to this muscle. Tunnel should be of

adequate size and typically should accommodate the width of four fingers.
- The flap is now inset.
- Chest is closed in layers.
- A skin graft may be required depending on defect size.

Complications
- More common complications include infection, hematoma/seroma, and wound dehiscence.
- *Flap Necrosis* – must ensure no twisting of flap. Adequate tunnel width to the neck is necessary to avoid pressure on the flap. Avoid tight bandages. Treatment with hyperbaric oxygen has not shown to provide much improvement. For partial flap necrosis conservative treatment with debridement of necrotic tissue with wet to dry dressings. Consider hyperbaric oxygen for partial necrosis. For complete necrosis, flap should be brought down and a new flap should be performed for reconstruction.
- *Osteochondritis* – more commonly seen in patients that have donor site repaired with skin graft [23]. The cause is thought to be due to rib exposure leading to infection and loss of blood supply to the periosteum (due to disruption of thoracoacromial artery). Treatment involves IV antibiotics and debridement/resection of osteocartilaginous segment.
- *Hematoma/Seroma* – large undermining for flap development can lead to large dead space [23]. Drain placement and achieving hemostasis is paramount. Compression bandaging leads to concern for flap compromise. If seroma forms, serial aspirations may be preferred. If minor hematoma, aspiration with mild pressure bandaging is indicated. Major hematomas require identification and control of vessel.
- *Pneumothorax* – if air leak is noted on Valsalva maneuver, a suction catheter should be placed into breach. A purse string suture is then placed, and under suction the catheter is removed, and the purse string is tightened. Small tears will normally resolve on their own. Serial chest X-rays are taken to observe progression. A large pneumothorax or instability of patient will require a chest tube.
- *Shoulder Dysfunction* – shoulder weakness with difficulty in adduction and rotation of arm is commonly seen. Preservation of clavicular portion may reduce functional disturbance. Physical therapy may aid in regaining partial function. If neck dissection done concomitantly, this may be a complication of this procedure.

Temporoparietal Fascia Flap

- Supplied by superficial temporal artery and vein. Vein runs on the surface of fascia and anterior to the artery. Vein runs superficial to the fascia while arteries covered by fascial fibers. Superficial temporal artery bifurcates 2–4 cm above the zygomatic arch.
- Innervation is from the auriculotemporal nerve.
- Temporal branch of the facial nerve runs deep to the temporal fascia. It can be mapped by a line drawn starting from the tragus to a line 3 cm above and 2 cm lateral to the supraorbital rim surgically. The frontal branch is noted to be 1.5 cm lateral and superior to the eye brow [24].
- Very thin flap, 2–4 mm [25], difficulty in dissecting the superficial portion.
- Up to 12 × 14 cm size, making it difficult to use for large defects [25, 26].
- Thin pliable tissue with good extension.
- Great for orbital, auricular, and maxillary reconstruction.
- Flap can be harvested with cutaneous tissue (skin/forehead) or cranial bone.

Technique
- The superficial temporal artery can be identified and mapped using doppler if desired.
- The incision is marked through a preauricular crease in front of the tragus and extends superficially into a hemi-coronal incision (the incision should be parallel to the direction of the hair follicles).
- Superficial dissection through the subcutaneous fat adhered to the fasciae. Anterior exten-

sion is done to a safe length to the expected course of the frontal branch of the facial nerve. Superiorly the extension is carried to the vertex of the scalp.
- Check the arc of rotation with a suture or lap sponge from the preauricular area.
- Release the fascia with the desired pedicle from the underlying temporalis muscle. The galea is separated from the temporoparietal fascia along the margins unto the subgaleal supraperiosteal layer.
- The release is completed in the subgaleal areolar tissue (Merkel's space) down to the zygomatic arch [25].
- A subcutaneous tunnel should be formed to allow extension of flap to defect without putting pressure on the flap.

Complications
- *Transient or Permanent Alopecia* – avoided by deepening the dissection and not dissecting hair follicles.
- *Frontal Branch of Facial Nerve Damage* – Nerve innervates the frontalis muscle and runs deep and transversely along the temporoparietal fascia. Avoid taking flap anterior to the temporal hairline.
- *Temporal Hollowing* – may volumize bone with hydroxyapatite, fat grafting, or custom implants.
- *Flap Failure* – uncommon, risk if pedicle compromised during harvest or kinking of vessel on rotation. Normally, does not leave a defect due to thinness of flap. May treat area of involvement conservatively with debridement if easily accessible. Alternative flap may be required to treat defect.

Other Regional Flaps

Paramedian Flap/Median Forehead Flap

- Color of forehead makes a great match for face and nose.
- Can incorporate supratrochlear artery as part of flap. Artery is approximately 2 cm from the mid glabella [27].
- Supratrochlear artery emerges from supratrochlear foramen, travels superficial to the corrugator muscles and deep to the orbicularis oculi. It ascends 2 cm before piercing the frontalis muscle [28].
- Median forehead flap designed to capture both supratrochlear arteries while the paramedian flap is aligned vertically over the supratrochlear notch to capture a single side of the artery [28].
- The flap raised in supraperiosteal plane. The flap will contain skin, subcutaneous tissue, and frontalis muscle. If nasal reconstruction is planned, the area of nose should be thinned of most of the subcutaneous tissue.
- The pedicle width should be 1.5 cm [28].
- The forehead is closed primarily after careful undermining. Any areas that are not primarily closed on the forehead will heal by secondary intention.
- The division of the pedicle is most reliably done at 3 weeks [27]. Flap viability can be tested by tying a rubber band to the flap and evaluating color/perfusion.
- Must rule out prior history of cutaneous malignancies within the expected skin paddle. Also ensure no scars are within the potential region of the pedicle.

Melolabial Flap/Nasolabial Flap

- A cutaneous flap harvested from the skin lateral to the melolabial crease. Can be harvested with a superior or inferior base, depending on the defect site.
- Superior flaps commonly used to reconstruct nasal, palatal, or oral sulcular defects.
- Inferior flaps are mostly used to address lip, floor of the mouth, and buccal mucosa defects [29, 30].
- It is supplied by the branches of the facial artery and is drained via the facial angular vein [30, 31]. The facial artery runs deep to the mimetic muscles [30, 32].
- Advantage: good color match especially of the skin of the lips and caudal lateral nose [31]. The scar can be positioned parallel or in the melolabial fold that can provide cosmesis.

- The incision is placed 1–2 mm lateral to the melolabial fold to prevent a flattened appearance.
- Most commonly used for cutaneous reconstruction. The flap is rotated into place (a tunnel flap for single stage has also been described) and 3 weeks later the pedicle is divided.
- Intraoral defects require transbuccal tunneling. It is imperative to deepithelialize the tunneled portion of the flap.
- Possible ectropion and scleral show are dependent on the extent of the flap. Scarring may cause facial asymmetry. There is limitation in the arc of rotation.

Facial Artery Musculomucosal Flap (FAMM Flap)

- Based on the facial and angular arteries.
- Can be based inferiorly (anterograde flow) – best for floor of mouth, tongue, gingival, alveolar, and lower lip reconstruction.
- Can be based superiorly (retrograde flow) – best for palate, skull base, conjunctiva, intranasal lining of nose, nasal septum, and upper alveolar defects [30, 33].
- The flap can be up to 2 cm wide but must take into consideration the position of Stensen's duct.
- The mucosal surface can be utilized for moderate tongue defects with the advantage of no visible scars.
- There is limitation in the arc of rotation, a second stage surgery required for division after 3 weeks and may limit mouth opening [33, 34].

Tongue Flap

- Can be a random or axial flap.
- The axial flap is based off the dorsal-lingual branch of the lingual artery.
- Random flaps are most commonly used and include the dorsal tongue and lateral tongue flap.
- Dorsal tongue flap can be based anteriorly or posteriorly, fed by dorsal lingual artery [35]. Posterior based flap is best soft palate, posterior buccal mucosa, and retromolar region. Anterior based flap is best for anterior floor of mouth, lips, and hard palate.
- The random tongue flap can be as thin as 3 mm [36]. Flaps can be as thick as 10 mm and up to 2/3rd of the dorsum of the tongue can be raised up to circumvallate papillae [35, 36].
- Design should be 20% bigger than defect.
- The pedicle can be divided in 2–3 weeks and debulking (if required) is done at no earlier than 3 months [36].
- A double-door tongue flap has been described for large buccal mucosa defects. An incision is used to split the lateral tongue horizontally. The superior and inferior flaps are undermined and raised to cover the mucosal defects. Three weeks later the flaps are divided [37].
- The sliding posterior tongue flap is an axial flap based on the dorsolingual branch of the lingual artery. It is used to treat lateral tongue defects up to 6 cm by advancing the posterior tongue after releasing from the hyoid bone and the vertical septum [36].
- Patients with psychiatric disorders or cognitive delay may not be good candidates due to the need for tongue immobility.

Submental Artery Island Flap

- Based off the submental artery, a branch of the facial artery, and the submental vein.
- Useful for reconstructing facial skin, oropharynx, esophageal, nasopharyngeal, floor of mouth, retromolar, soft palate, and tongue defects and maxilla [38, 39].
- Advantages: Good color and texture match for cutaneous defects, rich vascularity allowing a flap as large as 15 × 6 cm [40]. The flap is thin and pliable with low morbidity and good cosmesis.
- Disadvantages: Risk of transfer metastatic lymph nodes at level I [41] and in males the beard hair may be a nuisance in non-hair bearing areas.

Buccal Fat Pad Flap

- Buccal fat pad is composed of three lobes (anterior, intermediate, and posterior). The posterior lobe has four extensions from the posterior portion: buccal, pterygoid, pterygopalatine, and temporal. The main body lies on the anterior border of the masseter [42].
- Fat contains some stem cells.
- Grafts normally epithelialize in 4 weeks with squamous epithelium.
- Utilized for small and proximal defects.
- Most commonly used for oral antral fistulae but uses include repair of oncological defects, cleft palate, drug induced osteonecrosis, and osteoradionecrosis.
- Blood supply from the buccal and deep temporal branch of the maxillary artery and the superficial temporal artery from the facial transverse branch [43].

Lip Reconstruction

- Lower lip is supplied by the branches of the facial artery: inferior labial artery, horizontal labial artery, and vertical labial artery. Sensation is from the mental branch of the inferior alveolar nerve. Motor innervation provided by marginal mandibular branch of the facial nerve [44].
- Upper lip is supplied by the superior labial artery of the facial artery. Sensation is from the infraorbital branch of the maxillary division of the trigeminal nerve. Motor innervation from the zygomatic branch of the facial nerve.
- Reconstruction of lip is commonly described as a simple algorithm based on the size of the defect.
- Lip excisions are commonly combined with vermilionectomies (also known as a lip shave).
- Lip shave procedures are indicated for cases of actinic cheilitis, leukoplakia, or carcinoma in situ [45].
- Irregularity of the vermilion, as little as 1 mm, may be noticed by an observer speaking at a distance [45].
- Lip-switch flaps result in a smaller oral opening.
- Loss of 50% of one lip only results in a 25% decrease in the total oral circumference.
- Almost complete regain in the sensation of lip with return of pain, touch, and temperature (cold then hot) over first year [46].

Upper Lip

Defects 1/4 of the Upper Lip

- V, W, shield, and pentagonal incisions are commonly used for primary closure of defects [45, 47].
- A wedge excision will cause some asymmetry of the upper lip. Cosmesis of upper lip may be compromised due to three esthetic subunits of upper lip (philtrum and two lateral segments) [45]. Consider Abbe flap or lip switch for cosmesis.
- T- Excision (Fig. 9.5): Bilateral advancement flap for upper lip. Most commonly used for centrally located lesions. A rectangular excision is made surrounding the lesion. The horizontal portion of the flap is created in the nasal sulcus with Burow's triangles relieved in the

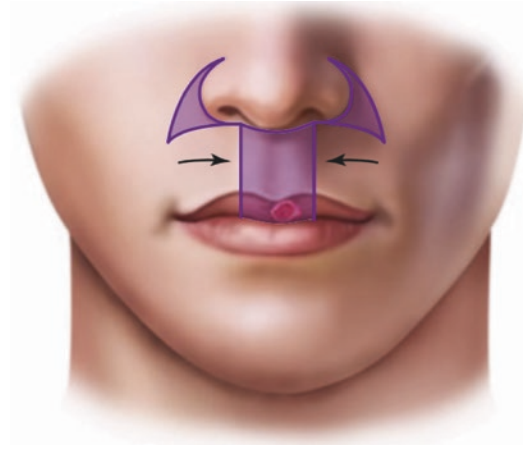

Fig. 9.5 T-excision. The lesion is excised in a full-thickness fashion leaving a defect in the central upper lip. Partial-thickness perialar excisions of skin and subcutaneous tissue can be used to gain further advancement of the wound edges. (Reprinted with permission from Urbanek and Bailey [45])

crease of the nasal alar folds. The edges are advanced medially. The philtrum and cupid's bow are lost in this procedure.

Lower Lip

Defects 1/3 of Lower Lip

- V, W, and shield excision more commonly used. Wedge resection is more acceptable in the lower lip.
- Lateral (rectangular) advancement flap (Fig. 9.6): Used more commonly for centrally located lesions. A rectangular incision is made, and a full thickness incision is made along the labiomental crease. Burow's triangles are excised to facilitate closure. The edges are advanced medially for closure [45, 46].

Defects 1/3 to 2/3 of Upper Lip

- Abbe Flap (Fig. 9.7): Cross lip transfer of full thickness lip tissue based on the inferior labial artery. Triangular wedge from lower lip is designed to reconstruct a wedge excision of the upper lip region. The flap is raised, transposed 180°, and inset. The donor site is closed directly. Division occurs 21 days later. The width of the wedge is about ½ designed slightly smaller, but height should match [46–48].
- Primary closure if less than 50% of lip, but unaesthetic.
- Karapandzic Flap (Fig. 9.8): A rotation neurovascular advancement flap, good for 2/3 or subtotal reconstruction of the upper or lower lip. The lesion is resected in a rectangular full thickness fashion. Semicircular partial thickness incisions in skin and mucosa are performed from the edge of the skin defect toward the nasolabial and labiomental folds bilaterally. The vasculature and the nerves are identified and released to allow stretch without damage. The facial nerve branches, sensory branches of CN V2 and V3, and superior and inferior labial arteries are preserved as incisions are not of full thickness in the area of the flaps [41, 45–49]. This does lead to microsomia as no additional tissue is recruited.
- McGregor Flap: Modification of Gilles (see below). Flap is rotated around the commissure and transfers tissue from the melolabial region, which prevents microstomia. Does not restore natural looking vermillion [49].

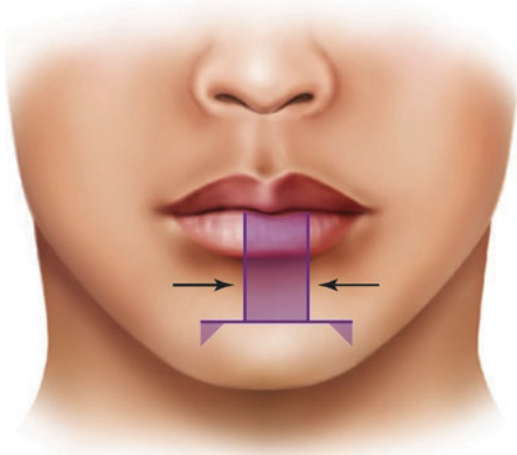

Fig. 9.6 Lateral advancement flap. The lesion is excised in a full-thickness fashion and the wound edges are advanced medially. Burow's triangles may be incorporated into the resection to prevent bunching of the tissue during wound advancement and closure. (Reprinted with permission from Urbanek and Bailey [45])

Defects 1/3 to 2/3 of Lower Lip

- Stein Flap (Fig. 9.9): Double Abbe flap with preservation of the philtrum but harvesting on either side of the philtrum [45]. Leads to greater denervation of the reconstructed lip and not particularly esthetic, less favored.
- Reverse Abbe Flap: Abbe flap based on the superior labial artery.
- Johanson Stair-Step Flap (Fig. 9.10): Good for defects up to 2/3 of lower lip. Can be raised unilateral or bilateral. Full thickness rectangular resection. A partial thickness stair step incision is made inferiorly and laterally with 8 mm × 10 mm blocks respectively. Burow's triangle is excised in the bottom of the staircase. The skin flaps laterally are undermined and brought medially.

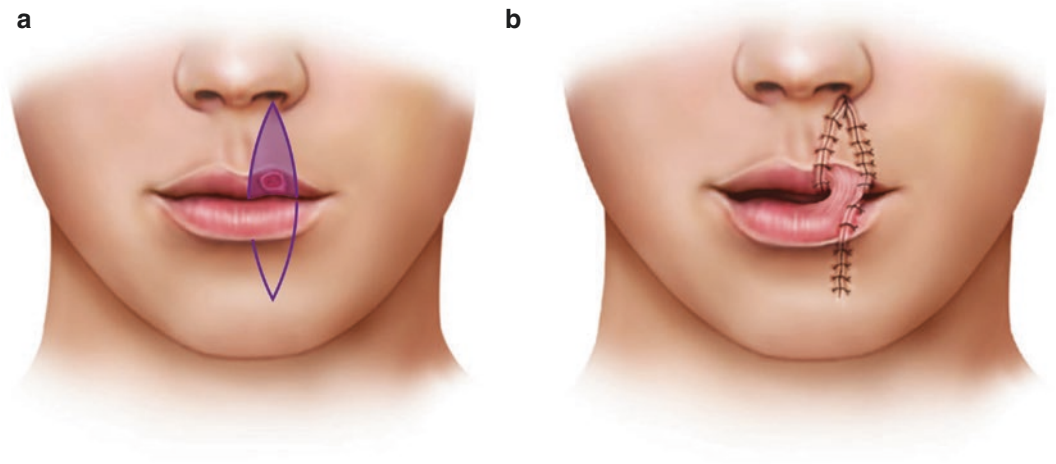

Fig. 9.7 Abbe flap. (**a**) Triangular excision of the upper and lower lip incision is made in a full-thickness fashion with extension up to the vermillion to preserve the vascular pedicle. Which is typically based medially. (**b**) The lower lip flap is then rotated superiorly and inset into the upper lip defect. The lower lip defect is closed primarily. After 21 days of healing, the vermillion tissue pedicle is divided and inset. (Reprinted with permission from Urbanek and Bailey [45])

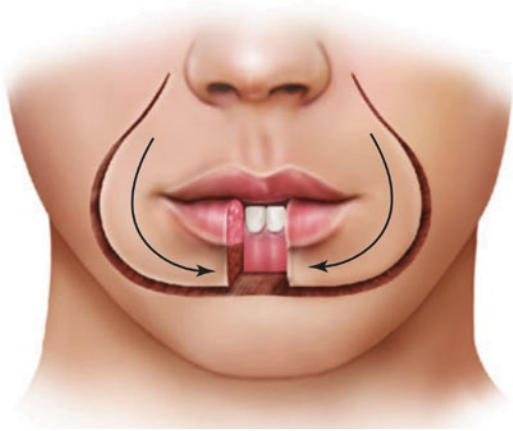

Fig. 9.8 Karapandzic flap. Incisions are carried along the labiomental crease and into the nasolabial creases. The incisions are made through the skin and subcutaneous tissue. Dividing muscle and mucosa as needed to gain mobility. The flaps are advanced medially and the defect is closed in a layered fashion. (Reprinted with permission from Urbanek and Bailey [45])

- Karapandzic Flap: See above.
- Gillies Fan Flap (rotation-advancement nasolabial flap) (Fig. 9.11): Transfers of tissue around the commissure toward defect. Based on the superior labial artery. Moves cheek and lip tissue. A rectangular resection of the defect. A curvilinear full thickness incision is extended laterally and superiorly running into the labiomental crease and the nasolabial fold. A full thickness flap is then rotated medially recruiting lip and cheek tissue. Will result in blunting of the commissure.
- Modified Webster-Bernard Flap (Fig. 9.12): Good for near total or total defects of the lower lip. Utilizes bilateral cheek advancement flaps. Places Burow's triangles in relaxed skin tension lines in the mesiolabial fold. Scar leads to "jump man" stick figure.

Defects of the Commissure

- Estlander Flap: Lip-switch flap for reconstruction of pericommissural defects of upper or lower lip. Single stage flap with no need for sectioning of the pedicel. Apex of the flap is made into the nasolabial or labiomental crease. The flap is transposed 180° from the upper lip to the lower lip or vice versa. This procedure results in a smaller oral stoma and indistinct commissure, which may require further revision.

Fig. 9.9 Stein flap. Triangular flaps from the central upper lip is used to reconstruct a defect of the central lower lip. Like the Abbe flap, once sufficient collateral circulation has formed, the vermillion pedicles are divided and inset. (Reprinted with permission from Urbanek and Bailey [45])

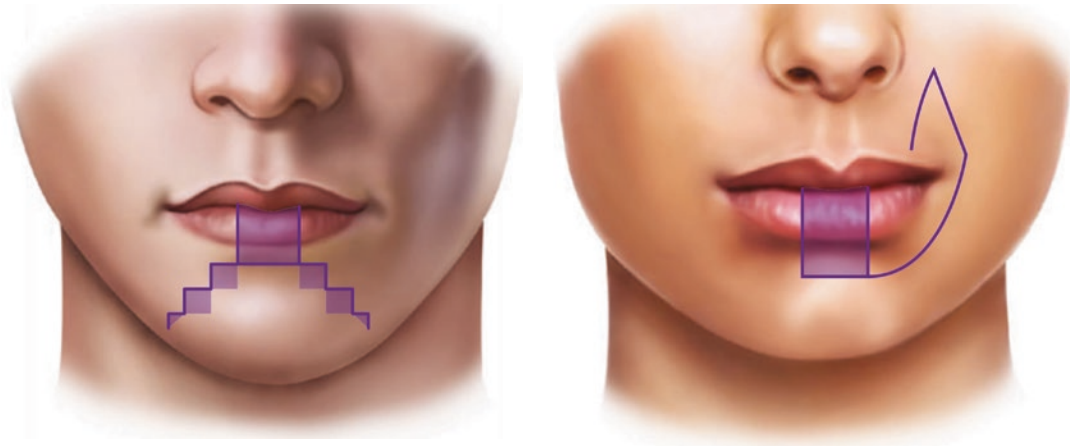

Fig. 9.10 Johanson flap. Full thickness rectangular incision of the lip defect. Partial thickness staircase incision design with undermining laterally. Burow's triangles are made at the bottom of the staircase to aid in medial movement of the flap. (Reprinted with permission from Urbanek and Bailey [45])

Fig. 9.11 Gillies fan flap. The flap is designed to transfer tissue from around the commissure. A full-thickness flap is then raised and rotated medially to bring lip and cheek tissue to the defect. (Reprinted with permission from Urbanek and Bailey [45])

Complete Lip Reconstruction, Upper and Lower

- Radial Forearm Free Flap: Thin, hair free, pliable skin flap with ease of harvest. Color match is acceptable. Thin tissue and lack of lip definition are esthetic drawbacks. Loss of vermillion but this can be recreated with medical tattooing [47, 50].
- Anterior Lateral Thigh Flap: Thicker flap with ability to debulk as needed. Can retain sensation with lateral femoral cutaneous nerve harvested. Does contain hair bearing skin and increased variability in dissection, making it less desirable to use [50].

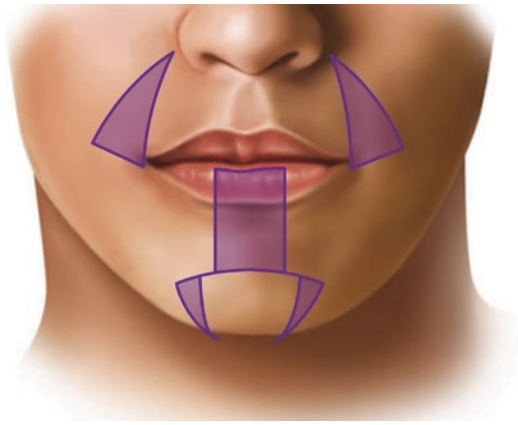

Fig. 9.12 Modified Bernard Webster Flap. Involves a full thickness excision of the pathological up to the labiomental crease. Four Burow's triangles of partial thickness are made at the melolabial crease and the labiomental creases to allow medial advancement of the tissue. (Reprinted with permission from Urbanek and Bailey [45])

Maxillary Reconstruction

- Reconstruction of the maxilla poses a unique challenge to maxillofacial surgeons as there are a wide variety of defects resulting from tumor ablation, trauma, or congenital deformities. Loss of midfacial structures are psychosocially and functionally impairing to patients, particularly when teeth, orbital contents, and facial pillars are involved.
- Several classification systems exist for describing maxillary defects and reconstruction, but perhaps the most widely used system by OMS is the Brown Classification, first described in 2000 then updated in 2010 [51, 52]. This is particularly helpful as it combines both horizontal and vertical defects of the midface with integration of dentoalveolar and functional deficiencies.

Brown Classification (Fig. 9.13)

- Vertical defect classification
  - Class I: Infrastructure defect of the midface, or maxillary alveolus.
  - Class II: Class I plus suprastructure and result in oral/antral communications.
  - Class III: Class II plus defect of the inferior orbital rim and floor
  - Class IV: Class III plus exenteration of orbital contents.
  - Class V: Orbitomaxillary defects.
  - Class VI: Nasomaxillary defects.
- Horizontal defect classification
  - Class A: central palatal defect
  - Class B: is ½ or less of the unilateral palate and alveolus
  - Class C: anterior maxillary defect
  - Class D: greater than ½ palatal and alveolar defect.
- It is important to recognize that achieving successful maxillary reconstruction requires separate goals across two distinct platforms. Oftentimes, achieving facial harmony is not congruent with establishing ideal occlusal arrangements and vice versa.

Goals of Maxillary Reconstruction

Facial form

- Restoring vertical and horizontal buttresses.
- Restoring soft tissue contours.
- Restoring smile.

Function

- Establishing a partition between the neck and aerodigestive tract.
- Establishing a partition between the sinonasal cavities and the oral cavity to allow for speech.
- Maintain oral competence.
  - Lip form for seal.
  - Labial vestibule for saliva.
  - Speech and swallowing.
  - Mastication.
- Using prosthetics as an adjunct for establishing the vertical appropriate positioning of the jaws is also appropriate.

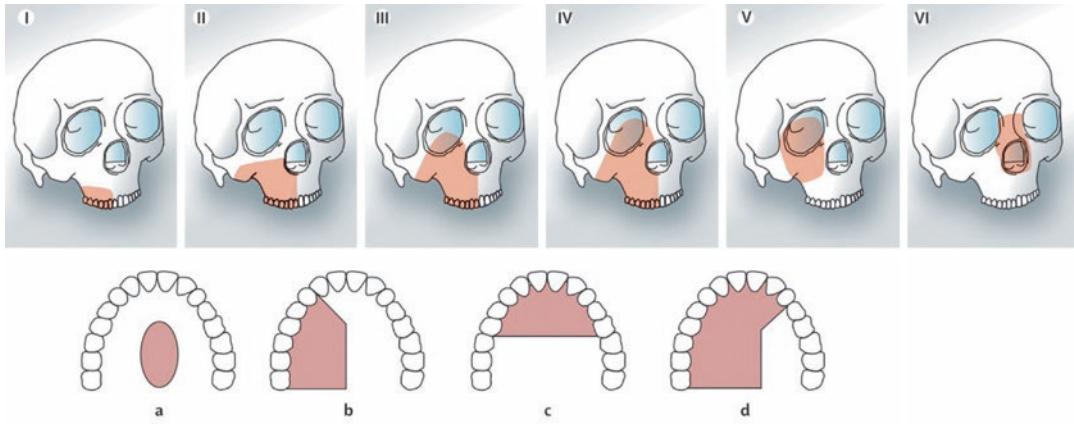

Fig. 9.13 Brown classification of maxillary defects. (Reprinted with permission from Brown and Shaw [52])

Defect Specific Reconstructive Algorithm

Brown Class I (Loss of Alveolus)

Goals: Optimize Alveolar Support

- Options:
  - Tooth supported prosthetics
  - Implant supported prosthetics
  - Local flaps (buccal sliding, palatal rotation)
  - Regional flaps (tongue flap, temporalis flap)
  - Free flaps (radial forearm flap, anterolateral thigh flap)
- This is generally an uncommon defect as it is a pure dentoalveolar or infrastructure defect. By definition, only soft tissue and alveolus below the level of the sinus are missing and several options exist for functional reconstruction. The soft tissue can be reconstructed with local/regional flaps, skin or mucosal grafts, or a small soft tissue free flap. The majority or all of the bony and dentate defects can be replaced prosthetically as the facial pillars are spared.

Defects

- IA defects – the primary goal is to seal the central oronasal communication and this can be done with vascularized soft tissue:
  - Palatal rotation flap
  - Tongue flap
  - Temporalis flap
- IB or IC defects
  - Fixed partial denture (FPD) on existing teeth or implants.
  - Removable partial denture (RPD)
- ID defects
  - FPD/hybrid prosthesis/overdenture (OD) supported with implants after sinus floor augmentation.
  - FPD/hybrid/OD using "All-on-4" configuration.
  - FPD/hybrid/OD using anterior implants and zygomatic implants.
  - Choosing between FPD/hybrid/OD

    Transition line vs. smile line – if smile line shows transition of teeth to gingiva, consider hybrid with pink porcelain.

Brown Class II (Loss of Alveolus and Malar Support)

- Goals: alveolar support, malar projection, nasal support, and seal oral cavity from the nasal and sinus cavities.
- Options:
  - Soft tissue Free flap
  - Osteocutaneous Free flap
  - Regional flap (Temporalis)
  - Zygomatic implant supported prosthesis
  - Obturator prosthesis

- Class II defects create an issue of both the available alveolar bone and also now sinus closure and the vertical and horizontal 3-dimensional buttressing that is critical for malar projection and facial support.
- There are also now diverging pathways for dealing with these issues. The first decision tree is whether the patient needs/wants teeth. If it is a smaller posterior defect, a soft tissue coverage plan may be sufficient. If teeth are needed or desired, then we must decide upon a prosthetic or reconstructed route.

Soft Tissue Reconstruction of Brown Class II Defects

- A soft tissue free flap provides immediate reconstruction and is straightforward. A single operation can close the antral/nasal communication and restore speech and swallowing. Additionally, it does not limit future prosthetic options as zygomatic implants can still be utilized for prosthetic support. The soft tissue option, however, is only useful in class IIB defects as there is no bony lip support for the anterior maxilla. Class IIC/D defects reconstructed this way will have a significant upper lip deformity resulting in poor esthetics and lip incompetence.

Osteocutaneous Free Flap Reconstruction of Brown Class II Defects

- In most cases where osteocutaneous free flaps are chosen for maxillary reconstruction, the fibula proves to be the most useful. The bony segments can be osteotomized to re-create the alveolus/dental arches and can accept dental implants at the time of surgery. The flap has a long pedicle length to tunnel into the neck for anastomosis and can be harvested with a skin paddle to reconstruct the mucosal defects.
- When designing the flap, it is tempting to place the bony segments at the vertical level of the adjacent alveolus; however, it is almost impossible to close the soft tissue over this as the fibula skin paddle is thicker than the adjacent mucosa. It is critical to under correct the alveolus height by a few millimeters to allow for passive soft tissue closure to prevent dehiscence or fistula formation from the nose/sinus.
- Positioning of the bone flap in relation to yaw, pitch, and roll can be difficult. Particularly with multiple segment reconstruction, as the flap typically fills the surgical field during inset and obscures the surgeon's frame of reference. The problem can be mitigated via wide exposure (Weber-Fergusson) and intraoperative CT scan or intraoperative navigation. This is especially important if implants will be placed in the fibula to ensure they are restorable.

Obturator Reconstruction

- Least surgically complex options such as bone, teeth, and soft tissue are replaced with one prosthetic. This may or may not be supported with dental implants.
- Functionally, it can seal the sinus, provide soft tissue facial support, is easy to hygienically maintain, and restore speech and mastication.
- The disadvantage, however, is that it requires a highly specialized prosthodontist or maxillofacial prosthodontist and can be expensive. In some cases, it cannot provide a complete seal and requires special care on the part of the patient to maintain cleanliness.
- One major benefit is that the obturator can be removed, so direct visualization of the tumor bed can be accomplished for tumor surveillance.

Brown Class III (Loss of Maxillary Alveolus, Malar Support, and Orbital Support)

- Goals: Alveolar support, malar projection, orbital projection, nasal support, seal oral cavity from the nasal and sinus cavities.
- Options:
  - Osteocutaneous free flap (fibula, scapula, DCIA).

  - Zygomatic implant supported prosthetic.
- The primary challenge in Brown Class III defects lies in reconstructing malar projection of infraorbital rim/anterior maxillary wall and alveolus. Though this can be accomplished with prosthetic and zygomatic implants, the author (A.P) favors osteocutaneous free flaps for several reasons: immediate hard and soft tissue reconstruction, possibility for implant supported dental reconstruction, and the ability to withstand radiotherapy (most Brown Class III defects are oncologic defects from tumors invading the bone).
- The double barrel configuration highlighted in the previous section can be utilized here, with one segment reconstructing the orbital rim and another for the alveolus. If needed, orbital floor mesh can be placed and fixated to the fibular segment at the rim.
- For cases where there is a through and through or complex soft tissue defect as well, the subscapular system is utilized for free flap reconstruction. The versatility and chimeric nature of the scapula osteocutaneous flap make it indispensable for complex composite maxillofacial reconstruction as multiple segments of bone and multiple soft tissue paddles can be harvested and oriented three-dimensionally.

Brown Class IV (Loss of Maxillary Alveolus, Malar Support, Orbital Support, and Orbital Contents)

- *Goals*: Alveolar support, malar projection, orbital projection, nasal support, seal oral cavity from the nasal and sinus cavities, seal intracranial cavity from nasal and sinus cavities, and obturate dead space.
- *Options*:
  - Osteocutaneous free flap (fibula, scapula, DCIA).
  - Double free flap (osteocutaneous fibula + soft tissue flap).
- Structurally, the class IV defect is similar to the class III defect, with the addition of an orbital exenteration defect. Oftentimes, these are resultant from ablative surgery of maxillary tumors invading the orbit and skull base.
- Most principles of reconstruction of class III defects apply here; however, one must take into consideration the possibility of an intracranial communication, either via the orbital apex or formal anterior skull base resection. If this is the case, as it often is, vascularized soft tissue is all that is needed to seal the dura/brain from the paranasal sinuses. The scapula "mega-flap," incorporating the scapular and parascapular skin paddles, scapula bone, and latissimus dorsi muscle, is of greatest utility in these cases.
- Alternatively, a double free flap may be used, such as a fibula osteocutaneous flap to restore facial and alveolar bone as well as the oral mucosal defect, and an anterolateral thigh flap to obturate the orbit and seal of the nasal cavity and sinus from the intracranial contents.

Flap Design and Considerations

1. Fibula
   - For maxillary reconstruction, using the contralateral fibula will orient the skin paddle toward the oral cavity and pedicle coming off the posterior of the flap. This allows for the most direct tunneling of the vessels into the neck while placing skin on the oral side.
   - In many cases (Brown II and above), there will be a resultant lateral nasal mucosal defect. The skin paddle can be partially folded to also reconstruct this wall with a small bridge of deepithelialized skin in between the mouth and nose.
2. Scapula
   - This is less critical as the orientation of the bone, skin, and vessels is much more flexible. Ease of harvest takes priority as the flap is usually raised with the patient in lateral decubitus.
   - If the scapula tip is being used based on the thoracodorsal vessels, be sure to flip the bone 180° so the vessels can come off posteriorly into the neck.
3. DCIA
   - Some surgeons prefer the ipsilateral iliac crest for maxillary reconstruction with vessels oriented posteriorly. This allows for the

thick crest to be positioned toward the oral cavity while the thinner cut surface can be contoured to the orbital rim and piriform aperture. In most cases, the internal oblique muscle only is harvested to reconstruct the soft tissues as the skin paddle is thick and fixed to the bone. The muscle is thin and flexible and is wrapped over the crest into the oral cavity to close the surgical fistula.

Case Example #1

Reconstruction Case

56-year-old male with history of tonsil squamous cell carcinoma treated with chemoradiation 5 years prior presents with nonhealing left oromandibular wound and exposed bone. Associated symptoms included trismus, foul smelling odor, and severe pain. Computed tomographic imaging showed a left mandible fracture with surrounding osteosclerosis. The diagnosis of osteoradionecrosis was made. The decision was made to take patient for composite mandible resection with immediate fibular reconstruction (See Fig. 9.14).

- *PMH: Tonsil cancer, GERD*
- *Medications: Omeprazole*
- *Allergies: NKDA*
- *PSH: None*
- *Social: Social alcohol. History of 1 PPD smoker. Works as a mechanic.*

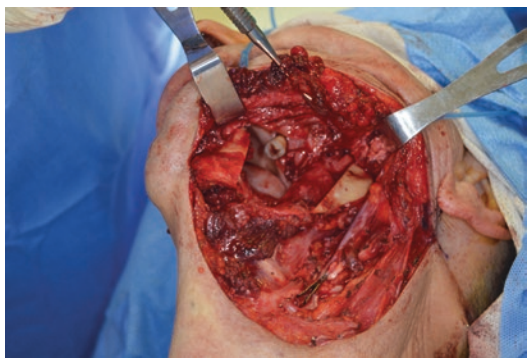

Fig. 9.14 Left mandible oromandibular defect after surgical resection. (Courtesy of Dr. Brett Miles)

- *Why is a fibula free flap a viable option for reconstructing the defect (Please comment on the defect pictured below)?*

  The composite mandibulectomy site displays a combined osseous defect with an adjacent mucosal and cutaneous defect. The fibular free flap would be ideal as the defect requires reconstruction of adjacent oral mucosa, skin of the face, and bone. The fibula can also be easily contoured with osteotomies for reconstruction of the neomandible. The bone stock that is available allows dental implant reconstruction. The fibula is a good osteocutaneous reconstructive choice for this patient due to his young age and lack of risk factors for peripheral vascular disease. Additionally, the lengthy pedicle is useful in radiated fields with low recipient vessel quality. A non-vascularized graft would not be appropriate due to the lack of vascularity in the tissue bed and exposure to the oral cavity and the neck greatly reducing its success.

- *How much bone can be harvested from the fibula?*

  Bone height varies from 9 to 15 mm with a total length of approximately 35 cm, typically up to 25 cm can be harvested.

- *Why would plate-only reconstruction not be a poor option for this patient?*

  Due to the fact that the region has poor vascularity, plate-only osseous reconstruction would have an unacceptably high wound complication rate.

- *What preoperative imaging would you request prior to fibular reconstruction?*

  A CT-angiogram of the lower extremities is indicated for preoperative confirmation of three-vessel flow for potential surgical candidates.

- *What other studies could you request?*

  Magnetic resonance angiography, ankle-brachial index screening, and doppler studies are alternatives.

- *What is a normal three vessel runoff?*

  A normal three vessel run of would show the popliteal artery branches into the anterior tibial artery, posterior tibial artery, and the peroneal artery. Commonly the peroneal artery branches from the posterior tibial artery (called the tibioperoneal take-off)

- *This patient underwent CT-angiogram of the lower extremities that demonstrated a normal 3-vessel runoff pattern. What modalities are available for postoperative flap monitoring?*
  - Temperature, color, turgor assessed on exam.
  - External Doppler, implantable Doppler, laser Doppler monitoring devices available.

- *What are the advantages and disadvantages of using a fibular free flap?*

  Advantages
  - Thick cortical bone that allows the fibula to tolerate mastication forces.
  - Large length of potential harvest allows for large segments of mandible to be reconstructed.
  - Large length of vascular pedicle allows the use of distant neck vessels.
  - Two teams may work simultaneously.
  - Skin can simultaneously be harvested with bone graft.
  - Higher success rate of vs. non-vascularized grafts
  - Does not rely on adjacent vascular bed.

  Disadvantages
  - Increased operative time
  - Increased cost
  - ICU admission
  - Height of fibula leads to difficulty in implant reconstruction.

- *What is a double barrel fibular flap?*

  It involves the removal of a 1 cm segment of the fibular bony segment and the bone flap is folded upon itself to increase the height of reconstruction.

- *The reconstruction was completed, and the donor site was closed* via *primary closure. The patient returned 3 weeks later showing evidence of wound dehiscence and muscle necrosis. What are the possible mechanisms for this presentation? How do you proceed?*
  - Compartment syndrome: Compartment syndrome is difficult to detect in early stages. Necrosis of underlying muscles may develop despite initial healing at the incision site and intact dorsalis pedis/posterior tibial pulses. Harvest inherently causes tissue damage and muscle ischemia. The resultant edema may cause intracompartmental pressure to exceed perfusion pressure of anterior and posterior tibial artery.
  - Iatrogenic trauma: Damage to the posterior tibial artery can occur during the procedure.
  - Congenital vascular anomaly: this should have been excluded in preoperative examination
  - Excessive wound tension (most common)

- *What should be done in the setting of wounds that may have excessive tension when closing?*

  A skin graft should be used whenever primary closure may produce excess tension. Another option includes the use of a tissue expander to expand the dorsal skin of the calf.

- *Patient presents with an equinovarus deformity as well as loss of sensation on the anterior and lateral calf and dorsum of the foot. What is the mechanism of injury and how could it have been prevented?* (Fig. 9.15)

  Injury to the common peroneal nerve can occur due to iatrogenic dissection or excess traction. The nerve wraps posterolaterally around the neck of the fibula, and beneath peroneus longus muscle, where it then splits into deep and superficial branches. It is most vulnerable when the proximal fibula and head are harvested. The best way to avoid this com-

Fig. 9.15 Equinovarus deformity. (Reprinted with permission from Coughlin et al. [53])

plication includes identifying the nerve early in dissection as well as leaving 6–7 cm segment of bone attached to the knee.

- *A fibula was used to reconstruct a defect after resection of an ameloblastoma. Initial surgical margins appeared clear but final pathology review indicates one of the bony margins is positive. How do you manage this?*

  The pathology needs to be re-resected. After about 6 weeks, the skin paddle should have allowed adequate healing to the oral mucosa to seal the wound. The wound can be opened carefully through the neck incision (being careful not to injure the pedicle) and second non-vascularized bone graft can be applied to the new gap after re-resection of the positive margin or the proximal segment of the mandible can be rotated counterclockwise to establish bony continuity depending on the patient's anatomy, occlusion, and size of the re-resection.

- *What if the pathology being resected was a squamous cell carcinoma and the final path showed a positive bony margin?*

  Current National Comprehensive Cancer Network (NCCN) guidelines recommend re-excision when feasible. However, treatment should not delay adjuvant therapy. In cases where a positive margin is present, adjuvant chemotherapy and radiation therapy are recommended.

Case Example #2

Maxillary Reconstruction Case

48-year-old male with biopsy proven low grade adenocarcinoma of the right maxilla causing expansion of the hard and soft palate and crossing the midline (Fig. 9.16). *Mass had been increasing in size over the past 2 years. Associated symptoms included right maxillary jaw pain that radiates to the right ear causing 8/10 pain. Computed tomographic imaging showed a 6 × 6 × 5 cm mass centered in right maxillary sinus causing destruction of the lateral and medial walls of the right maxillary sinus and hard palate, extending to the right nasal cavity and abutting the right orbital floor* (Fig. 9.17). *The decision was made to take the patient for composite right maxillary resection with immediate fibular reconstruction.*

- *PMH: Gastroesophageal reflux disease.*
- *PSH: Right inguinal hernia repair at 4-years-old.*
- *Medications: None.*
- *Allergies: NKDA.*
- *Social: Denies tobacco and alcohol use.*

- *What are the surgical margins required for this entity?*

  The surgical margins require 1.5 cm.

Fig. 9.16 Maxillary reconstruction case image. (Courtesy of Dr. Fayette Williams)

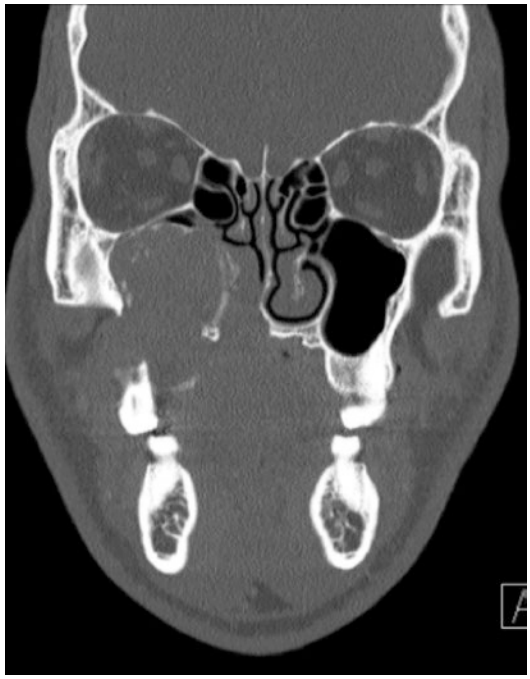

Fig. 9.17 Bone window CT, coronal cut for case #2. (Courtesy of Dr. Fayette Williams)

Fig. 9.18 Defect after resection of lesion of the right maxillae. (Courtesy of Dr. Fayette Williams)

- *Why is a fibula free flap a viable option for reconstructing the defect* (Fig. 9.18)*?*

  The maxillary resection created an osseous and mucosal defect. According to the Brown and Shaw Classification, this is a Class III D defect, which involves the loss of orbital support in addition to loss of cheek and dental arch support. The fibula free flap offers bony support to the orbit and facial skin, as well as use of skin paddle for oral mucosa that was included as a part of resection. Additionally, a fibula free flap offers reliable dental reconstruction with endosseous dental implant placement, immediately or delayed. Careful selection of osteotomy sites allows the fibula to be contoured and used for both orbital support and dental arch support, which extends across the midline. Furthermore, the length of pedicle is adequate to perform microvascular anastomosis without the need for vein grafting, as the pedicle must be tunneled to reach the neck.

- *What is the blood supply for the fibula free flap?*

  Blood Supply: Peroneal artery and venae comitantes.

- *What preoperative imaging would you request prior to fibular reconstruction?*

  A CT angiogram of the lower extremities to confirm three-vessel flow. The three vessels are anterior tibial, posterior tibial, and peroneal arteries. May use conventional angiography, MRA, or a doppler study.

- *What are the contraindications for fibula free tissue transfer?*

  Peronea arteria magna (where one dominant peroneal artery perfuses the whole foot), two vessel runoff, and open wound of the leg.

- *What are additional options available for maxillary reconstruction?*

Obturator

- Advantages: Offers immediate reconstruction, including dental reconstruction, of defect and provides tissue support to the face. Allows for easy surgical site surveillance.
- Disadvantages: Requires additional procedures to modify obturator as tissue heals and contracts. Not a viable option for a long-term orbital support. Poor fitting obturators are difficult to care for. Poor dexterity or trismus may render the obturator useless.

Lateral Scapula Free Flap

- Advantages: Osteocutaneous potential for both hard and soft tissue defects. Harvest site morbidity is low, scar is hidden. May use for maxillary or mandibular reconstruction, including orbital support. Potential for chimeric flap design to include the latissimus dorsi, cutaneous branch, and skin paddle.
- Disadvantages: Bone stock not as good as fibula, making dental implants more difficult. Possible shoulder dysfunction. Single team approach and thus longer surgery.
- Blood supply: Circumflex scapular artery which divides into periosteal, transverse, and descending cutaneous arteries and their respective venae comitantes, most frequently from the subscapular system.

Deep Circumflex Iliac Artery Free Flap

- Advantages: Provides bony structure that closely resembles mandible and may also be used for maxillary defects. Provides good bulk of bone facilitating dental implant placement. Can be used for both hard and soft tissue reconstruction with skin paddle and/or muscular component (for oral mucosal reconstruction).
- Disadvantages: Vascular pedicle is short and most likely requires vein graft for maxillary reconstruction. Skin paddle can be very bulky making reconstruction of skin defects difficult. Donor site morbidity and the likely need for mesh support and concerns for hernia formation.
- Blood Supply: Deep circumflex iliac artery and venae comitantes.

Radial Forearm Free Flap

- Advantages: Reliable flap that can be used for soft tissue reconstruction. Not as bulky as an ALT flap and is ideal for tongue and floor of mouth reconstruction. May also be used for palatal defects including the hard and soft palate. Long pedicle length (10–12 cm). Low morbidity. Also offers osteocutaneous reconstruction utilizing the radial bone allowing for reconstruction of small bone defects of the maxilla or mandible or to provide orbital support. Two team approach.
- Disadvantages: Some patients do not have adequate palmar arch from the ulnar artery, thus blood supply to hand is compromised if the radial artery is harvested (Allen's test required). Not enough tissue available for large bulky defects. If radial bone is also harvested, the bone stock is not ideal for dental implants. Postoperative sensory changes at the dorsal aspect of thumb and index finger. Large scar on forearm.
- Blood Supply: Radial artery, cephalic vein, and venae comitantes.

Anterolateral Thigh Free Flap

- Advantages: Provides more tissue bulk for large oral defects. Ideal for large skin defects and offers pliable tissue, which can be contoured to existing anatomy. Low morbidity and allows primary closure without skin grafting. Two team approach.
- Disadvantages: Variable perforator blood supply. Can be too bulky for some reconstructions. Relatively short pedicle length.
- Blood Supply: Descending branch of the lateral circumflex femoral artery and its venae comitantes.

Temporalis/Temporoparietal Fascia Flaps

- Advantages: Versatile flap that can be used for maxillary/mandibular soft tissue reconstruction. Can provide coverage of defects and watertight seal. Reliable vascularity. May be used for facial reanimation.
- Disadvantages: Temporal hollowing, and some may require osteotomy of the arch to gain enough length.
- Blood Supply: Anterior deep temporal artery, posterior deep temporal artery, middle temporal artery.

- *What should be done in the setting of persistent oronasal fistula?*

  Depending on the size of the defect and reliability of the palatine arteries after resection, palatoplasty is an option. With larger defects, or previous failure of palatoplasty, a radial forearm free flap or other soft tissue flap may be used.

- *What is an option for dental reconstruction if using a soft tissue only free tissue transfer?*

  Zygomatic implants.

- *What is the difference between hypoglobus and orbital dystopia?*

  Hypoglobus is the inferior displacement of the globe commonly due to lack of bony orbital support as seen in cases of trauma of midface reconstruction. Orbital dystopia is the displacement of the entire orbit as commonly seen among the pediatric craniofacial patient population. May be evident as hypertelorism (horizontal) or vertical discrepancy when comparing the symmetry of the orbits.

- *Describe the difference between hyper- and hyponasality.*

  Hypernasality: Airflow escapes into the nasal cavity. Often a result of velopharyngeal dysfunction resulting from palatal clefting but may be acquired as such from Le Fort advancement, or maxillectomy. Numerous genetic syndromes are associated with hypernasality including DiGeorge syndrome, Treacher Collins syndrome, Prader-Willi, etc.

  Hyponasality: Air passage into the nasal cavity is restricted as seen with enlarged tonsils, inflammation and swelling from any number of etiologies (i.e., common cold), deviated septum, tumors, etc.

- *What are some ways to monitor a free tissue transfer?*

  Pen Doppler, internal Doppler, external color Doppler, pin prick to visualize bleeding, temperature, turgor assessment.

- *What is the most common reason for flap failure?*

  Vascular thrombosis is the primary cause of free flap failure. Venous thrombosis is more common than arterial thrombosis. When venous thrombosis occurs, the flap can appear boggy and have a bluish/purple hue with brisk capillary refill. The majority of flap failures take place within the first 48 hours of the postoperative period.

- *What is Ohngren's line and how does it relate to overall prognosis in regard to maxillary/midface tumors?*

  A plane extending from medial canthus to the angle of the mandible in the sagittal plane delineating suprastructure and infrastructure of the midface/maxilla. Tumors that are above this line, superior and posterior within the suprastructure, tend to have a worse prognosis when compared to infrastructure tumors (anterior maxilla).

- *What are some of the different approaches to the maxilla?*

  Weber Ferguson incision, split mandibulotomy, and midface degloving.

- *What are ways to decrease bleeding when performing maxillary surgeries?*

  Meticulous surgical technique, reverse Trendelenburg positioning, use of electrocautery, permissive hypotension, use of injectable vasoconstrictors, and vasoconstrictor or thrombin impregnated packing gauze.

- *What happens if performing an osteotomy and massive bleeding is encountered?*

  Pack the site, complete the osteotomy, then try to localize and control the source of bleeding. If unable to control the bleed, the site should be aggressively packed with an urgent consultation to interventional radiology for arterial embolization.

- *What is the most common source of bleeding when performing maxillary surgery?*

  The descending palatine artery which branches from the internal maxillary artery. The ascending palatine branch from the facial artery and the ascending pharyngeal artery supply blood flow to the down-fractured maxilla.

- *What are examples of regional flaps that may be utilized in the case of head/neck free flap failure?*

  Pectoralis major myofascial or myocutaneous flap, supraclavicular artery island flap, temporalis flap.

- *If there are signs of flap failure (i.e., loss of Doppler signal, negative pin prick, dusky and congested skin paddle, wound margin dehiscence) what should be the appropriate management?*

Emergent exploration in the operating room under general anesthesia. Assess for potential hematoma or seroma formation causing compression which results in compromised flap perfusion. Open up previous neck incision and assess the geometry of the pedicle and identify any kinking of the vessels. If geometry appears appropriate, the next step is to identify venous and arterial thrombosis. Venous thrombosis is more common due to lower blood flow and lower pressures when compared to arterial flow. If thrombus is identified, a thrombectomy should be performed. The use of antithrombotic agents such as heparinized saline or Fogarty catheter are used locally during and after thrombectomy. Thrombolytic therapy (streptokinase, tissue-plasminogen activator) may also be used to treat thrombosis or used in addition to surgical exploration/thrombectomy. Thrombolytic therapies are infused directly into the resected end of anastomosis or into a side branch to prevent systemic side effects.

References

1. Moreira-Gonzalez A, Papay FE, Zins JE. Calvarial thickness and its relation to cranial bone harvest. Plast Reconstr Surg. 2006;117(6):1964–71.
2. Marx RE, Stevens MR. Atlas of oral and extraoral bone harvesting, vol. 1. Hanover Park: Quintessence Publishing Company; 2010.
3. Odili J, Wilson E, Chana JS. Muscle herniation: a complication at the anterolateral thigh perforator flap donor site. Br J Plast Surg. Elsevier. 2009;62(11):1530–3.
4. Agostini T, Lazzeri D, Spinelli G. Anterolateral thigh flap: systematic literature review of specific donor-site complications and their management. J Craniomaxillofac Surg. Elsevier. 2013;41(1):15–21.
5. Woo BM, Kim DD. Chapter 69 – Radial forearm free flap. In: Current therapy in oral and maxillofacial surgery. St-Louis: Elsevier; 2012. p. 8.
6. Kademani D, Tiwana P. Atlas of oral and maxillofacial surgery. Amsterdam: Elsevier Health Sciences; 2015.
7. Yamashiro M, Hasegawa K, Uzawa N, Michi Y, Ishii J, Yoshitake H, et al. Complications and outcome of free flap transfers for oral and maxillofacial reconstruction: analysis of 213 cases. Oral Sci Int. 2009;6(1):46–54.
8. Fernandes R. Reconstruction of maxillary defects with the radial forearm free flap. Atlas Oral Maxillofac Surg Clin North Am. 2007;15(1):7–12.
9. Jones BM, O'Brien CJ. Acute ischaemia of the hand resulting from elevation of a radial forearm flap. Br J Plast Surg. 1985;38(3):396–7.
10. Kaban LB, Pogrel MA, Perrott DH. Complications in oral and maxillofacial surgery. Philadelphia: W.B. Saunders; 1997.
11. Miloro M, Kolokythas A. Management of complications in oral and maxillofacial surgery. Chichester: Wiley; 2012.
12. Salgado CJ, Chim H, Moran SL, Wei F-C, Mardini S. Chapter 52 – Fibula flap. In: Flaps and reconstructive surgery. 2nd ed. Edinburgh/New York: Elsevier; 2017. p. 5527.
13. Silvestri E, Muda A, Orlandi D. Ultrasound anatomy of lower limb muscles. Cham: Springer; 2014.
14. Betz LH, Betz BW. Peronea arteria magna. Pediatr Radiol. Springer-Verlag. 2009;39(9):1016.
15. Kim D, Orron DE, Skillman JJ. Surgical significance of popliteal arterial variants. A unified angiographic classification. Ann Surg. Lippincott, Williams, and Wilkins. 1989;210(6):776–81.
16. Sabapathy SR. Chapter 25 – Vessels. In: Flaps and reconstructive surgery. 2nd ed. Edinburgh/New York: Elsevier; 2017. p. 2912.
17. Nakatsuka T, Harii K, Asato H, Takushima A, Ebihara S, Kimata Y, et al. Analytic review of 2372 free flap transfers for head and neck reconstruction following cancer resection. J Reconstr Microsurg. 2004;19(06):363–8.
18. Rimler J, Nguyen A, Evans GRD. 29 – Postoperative care. In: Flaps and reconstructive surgery. 2nd ed. Edinburgh/New York: Elsevier; 2017.
19. Casey J, Bellian K. Chapter 77 – Intubation and tracheotomy. In: ENT secrets. 4th ed. Philadelphia: Elsevier; 2015.
20. Albergotti WG, Myers EN. 23 – Management of a tracheocutaneous fistula and depressed scar. In: Operative otolaryngology. 3rd ed. Philadelphia: Elsevier; 2017. p. 1527.
21. Carlson ER. Pectoralis major myocutaneous flap. Oral Maxillofac Surg Clin North Am. 2003;15(4):1–11.
22. Wei WI, Wai CY. 34 – Pectoralis major flap. In: Flaps and reconstructive surgery. 2nd ed. Edinburgh/New York: Elsevier; 2017.
23. Kim B, Kaleem A, Zaid W. Case reports of two unusual donor site complications of the pectoralis major myocutaneous flap and literature review. J Am Oral Maxillofac Surg. 2016;74(7):1504.e1–1504.e12.
24. Fernandes R. Chapter 11: The temporoparietal fascia flap. In: Local and regional flaps in head neck reconstruction: a practical approach. Chichester: Wiley-Blackwell; 2014. p. 75–91.

25. Cesteleyn L. The temporoparietal galea flap. Oral Maxillofac Surg Clin North Am. 2003;15(4):537–50.
26. Moran SL, Santamaria E. 32 – Temporoparietal fascia flap. In: Flaps and reconstructive surgery. 2nd ed. Edinburgh/New York: Elsevier; 2017.
27. Fernandes R. Paramedian forehead flap. In: Local and regional flaps in head & neck reconstruction. Hoboken: Wiley; 2014. p. 13.
28. Oo K, Park S. The midline forehead flap in nasal reconstruction. Facial Plast Surg Clin North Am. Elsevier. 2011;19(1):141–55.
29. Fernandes R. Nasolabial flap. In: Local and regional flaps in head & neck reconstruction. Hoboken: Wiley; 2014. p. 9.
30. Braasch D, Lam D, Oh E. Maxillofacial reconstruction with nasolabial and facial artery musculomucosal flaps. Oral Maxillofac Surg Clin North Am. Elsevier. 2014;26(3):327–33.
31. Baker SR. Chapter 12 – Melolabial flaps. In: Local flaps in facial reconstruction. 3rd ed. Philadelphia: Elsevier; 2014. p. 37.
32. Carucci JA. Melolabial flap repair in nasal reconstruction. Dermatol Clin. 2005;23(1):65–71, vi.
33. Ferrari S, Ferri A, Bianchi B, Contadini E, Leporati M, Sesenna E. Head and neck reconstruction using the superiorly based reversed-flow facial artery myomucosal flap. J Oral Maxillofac Surg. 2015;73(5):1008–15.
34. Pirgousis P, Fernandes R. Chapter 62 – Contemporary methods in tongue reconstruction. In: Current therapy in oral and maxillofacial surgery. St-Louis: Elsevier; 2012. p. 8.
35. Strauss R, Kain N. Tongue flaps. Oral Maxillofac Surg Clin North Am. Elsevier. 2014;26(3):313–25.
36. Buchbinder D, St-Hilaire H. Tongue flaps in maxillofacial surgery. Oral Maxillofac Surg Clin North Am. Elsevier. 2003;15(4):475–86.
37. von Domarus H. The double-door tongue flap for total cheek mucosa defects. Plast Reconstr Surg. 1988;82(2):351–6.
38. Fernandes R. Chapter 14 – Submental island flap. In: Local and regional flaps in head & neck reconstruction: a practical approach. Hoboken: Wiley; 2014. 11 p.
39. Rahpeyma A, Khajehahmadi S. Submental artery island flap in intraoral reconstruction: a review. J Craniomaxillofac Surg. Elsevier. 2014;42(6):983–9.
40. Curran AJ, Neligan P, Gullane PJ. Submental artery island flap. Laryngoscope. John Wiley & Sons, Ltd. 1997;107(11):1545–9.
41. Salama A, Lam D. Chapter 8 – Maxillofacial reconstruction; 2015. p. 42.
42. Toshihiro Y, Nariai Y, Takamura Y, Yoshimura H, Tobita T, Yoshino A, et al. Applicability of buccal fat pad grafting for oral reconstruction. Int J Oral Maxillofac Surg. 2013;42(5):604–10.
43. Cordero GB, Ferrer SM, Fernández L. Odontogenic sinusitis, oro-antral fistula and surgical repair by Bichat's fat pad: literature review. Acta Otorrinolaringol Esp. SEGO. 2016;67(2):107–13.
44. Schlieve T, Kolokythas A. Anatomic considerations of the lips. In: Lip cancer. 7th ed. Berlin, Heidelberg: Springer; 2013. p. 5–9.
45. Urbanek DE, Bailey JS. Reconstruction considerations based on size of defect. In: Lip cancer. 2nd ed. Berlin, Heidelberg: Springer; 2013. p. 59–78.
46. Renner GJ. Chapter 19 – Reconstruction of the lips. In: Local flaps in facial reconstruction. 3rd ed. Philadelphia: Elsevier; 2014. p. 49.
47. Fernandes R. Chapter 22 – Lip reconstruction. In: Local and regional flaps in head & neck reconstruction. Hoboken: Wiley; 2014. p. 20.
48. Seki J. Chapter 60 – Lip reconstruction. In: Plastic surgery secrets plus. 2nd ed. Philadelphia: Elsevier; 2010.
49. Kim B, Kim DD. Reconstruction of complex lip defects. In: Lip cancer. 1st ed. Berlin, Heidelberg: Springer; 2013. p. 79–113.
50. Ramirez CA, Fernandes R. Microvascular lip reconstruction. In: Lip cancer. 6th ed. Berlin, Heidelberg: Springer; 2013. p. 115–26.
51. Brown JS, Rogers SN, McNally DN, Boyle M. A modified classification for the maxillectomy defect. Head Neck. John Wiley & Sons, Ltd. 2000;22(1):17–26.
52. Brown JS, Shaw RJ. Personal view reconstruction of the maxilla and midface: introducing a new classification. Lancet Oncol. Elsevier. 2010;11(10):1001–8.
53. Coughlin MJ, Saltzman CL, Medycyna RBA, Mann RA. Mann's surgery of the foot and ankle. Amsterdam: W.B. Saunders; 2014.
54. Roden D. Chapter 223 – Cricothyroid catheter insertion, cricothyroidotomy, and tracheostomy. In: Pfenninger and Fowler's procedures for primary care. Philadelphia: Elsevier; 2019.