Chapter 37

REPAIR OF MIDFACE BONY DEFECT

CECELIA E. SCHMALBACH, MD, FACS*

**Lieutenant Colonel, Medical Corps, US Air Force; Associate Professor of Surgery, Otolaryngology Residency Program Director, Head & Neck Microvascular Surgery, Division of Otolaryngology, The University of Alabama at Birmingham, 1720 Second Avenue South, Birmingham, Alabama 35294-0012*

INTRODUCTION

The bony midface, with the maxilla as the cornerstone, plays a vital role in facial aesthetics as well as in the functions of speech, swallowing, and vision. A comprehensive understanding of the bony and soft-tissue anatomy is required for successful reconstruction of this region. The objective of this chapter is to highlight pertinent midface anatomy, associated defect classification systems, and reconstructive goals. A comprehensive algorithm for the reconstruction of bony midface defects is outlined, implementing the reconstructive ladder from prostheses and local and pedicled flaps to free bone grafts and free tissue transfer. Unique combat-related considerations will be highlighted using case studies, along with reconstructive pearls to maximize successful bony midface restoration.

EVIDENCE-BASED REVIEW

Midface Anatomy

The maxilla functions as the cornerstone to the midface and is considered the most important paired bones of this region.[1] The maxilla is a hexahedrium, with six walls supporting important surrounding structures that include the bony orbit, zygomaticomaxillary complex (ZMC), nose, and stomatognathic complex.[2,3] The roof of the hexahedrium serves as the orbital floor, and the base functions as the palate. The maxilla provides the supporting foundation for the facial musculature. In doing so, it plays a vital role in facial expression, mastication, speech, and deglutition.[1]

The maxilla is often divided into thirds.[4] The inferior third of the maxilla includes the upper alveolar ridge and palate. It separates the inferior oral cavity from the maxillary sinuses and nasal cavity above, thereby playing a vital role in speech and oral competency. The middle third of the maxilla constitutes the walls of both the maxillary sinuses and nasal cavity. It provides structural buttresses supporting the orbit and skull base superiorly. The upper third of the maxilla forms the lateral orbital walls, floor of the bony orbit/roof of the maxillary sinus, the superior-most aspect of the nasal cavity, and the malar eminence (ZMC). The upper third of the maxilla is responsible for the lateral bony projection of the face.

Ultimately, the maxilla provides three vertical buttresses (nasofrontal, pterygomaxillary, and zygomaticomaxillary) and two horizontal buttresses. Together, the buttresses provide midface projection and vertical facial height.[1,5] The vertical buttresses are imperative to facial aesthetics, whereas the horizontal buttresses have greater functional significance.[6] The importance of these paired buttresses are highlighted in Case Study 37-1.

TABLE 37-1

CORDEIRO AND SANTAMARIA'S CLASSIFICATION FOR MIDFACE DEFECTS

Type	Names	Defect	Ideal Reconstruction
I	Limited maxillectomy	1–2 walls: Anterior/medial wall Palate *not* involved	Radial forearm fasciocutaneous free flap with free bone graft if orbital rim involved
II	Subtotal maxillectomy "Hemi"-maxillectomy Infrastructure maxillectomy	Lower 5 walls Including hard palate	Folded osseocutaneous radial forearm free flap
IIIA	Total maxillectomy Sparing orbit	All 6 walls	Orbital floor; free bone graft wrapped in rectus free abdominus flap
IIIB	Total maxillectomy + orbital contents (extended maxillectomy)	All 6 walls + orbital contents	Rectus abdominus free flap + obturator, if needed
IV	Orbitomaxillectomy	Upper 5 walls + orbital contents (palate intact)	Rectus abdominus free flap

Data source: Cordeiro PG, Santamaria E. A classification system and algorithm for reconstruction of maxillectomy and midfacial defects. *Plast Reconstr Surg*. 2000;105:2331–2346.

Defect Classification

Bony reconstruction of the midface spans a rather large spectrum, from small defects involving localized portions of the palate or alveolar ridge to extremely large defects encompassing the entire maxilla bilaterally. In an effort to optimize the ideal midface reconstruction, numerous classifications have been published based on extent and location of tissue loss.[1,6–8]

One of the most commonly cited classification systems was created by Cordeiro and Santamaria[1] and is summarized in Table 37-1. This classification system and associated reconstructive algorithm emerged following the treatment of 60 patients, the majority presenting with a maxillectomy defect following tumor extirpation. Although the classification system is a comprehensive guide for the reconstruction of the upper maxilla and associated orbital floor, it does not consider palatal reconstruction and dental restoration in great detail.

Reconstructive Goals: Functional and Aesthetic Considerations

Successful midface reconstruction must address a host of important functional and aesthetic mechanisms. The repair can be challenging given the complex, three-dimensional orientation of this anatomical region.[4] In addition to reconstructing the bony defects, most traumatic midface repairs must also address the loss of skin, muscle, and underlying mucosa. Preoperative planning—ideally with a multidisciplinary approach to include the reconstructive team, prosthetics team, oral surgery, dentistry, and speech—is imperative.[9] Computed tomographic scanning is immensely helpful in the planning.[10,11] Not only does it provide vital information about fractures and associated bony defects, but also the images can be used to construct customized stereolithic models that are invaluable in reestablishing occlusion (see Chapter 20, Acute Otological Trauma). In addition, computed tomographic imaging allows for the assessment of the integrity of potential recipient vessels for free tissue transfer. Pre-injury photos may also be of benefit in reconstructive planning.[9]

Midface reconstruction must achieve the following five goals:[5,9,12,13]

1. Provide support to the orbital contents so that the globe position, orbital volume, and visual function are maintained. In cases of orbital exenteration, the goal becomes obliteration of the cavity.
2. Establish a watertight seal, separating the maxillary sinuses and nasal cavity from the inferior oral cavity. This separation, which represents restoring palatal competence, is imperative for preservation of speech, mastication, and deglutition.
3. Provide a stable platform for dental restoration either in the form of a tissue-bearing denture or osseointegrated implants. Combat trauma patients tend to be young, healthy individuals with a long life expectancy. For this reason, total oral rehabilitation remains a goal.[9]
4. Recreate facial contours and projection in an aesthetically acceptable, symmetric fashion. Ideally, missing tissue is replaced with tissue having a similar color match and pliability.
5. Eliminate dead space using soft tissue for obliteration.

The ideal reconstruction for the bony midface would entail a single-staged procedure that successfully addresses all five of the previously described goals. In doing so, it seals the oral cavity from the nasal cavity, restores bony projection, allows for dental rehabilitation, replaces missing tissue with like tissue, and symmetrically reestablishes facial contours. Numerous reconstructive methods have been reported for the midface.[1,12,14] To date, a single reconstructive technique has not been identified to address all of the previously mentioned goals.[1,15] Each case must be assessed on an individual basis, taking into consideration the anatomical defect, composition of the missing tissues, functional implications, associated combat injuries, patient and family wishes, overall prognosis, and surgeon experience.

Unique Considerations in Midface Combat Trauma

Midface injuries sustained during combat often result from high-velocity/high-energy improvised explosive device (IED) blasts and from high-velocity/high-energy missiles.[16] These explosives may contain metal fragments, foreign bodies, and hundreds of metal pellets.[17] Consequently, isolated midface defects are uncommon in the setting of war. Instead, the hallmark of high-energy blast injuries to the midface is highly comminuted craniomaxillofacial fractures that include the mandible and the midface, as well as avulsion of overlying facial tissues and intraoral soft tissues[17] (Figure 37-1).

In an effort to specifically address the unique aspects of midface defects following trauma, as opposed to tumor extirpation, specific algorithms have been established.[9,14] Futran et al[14] outlined a two-staged approach. After the patient is hemodynamically

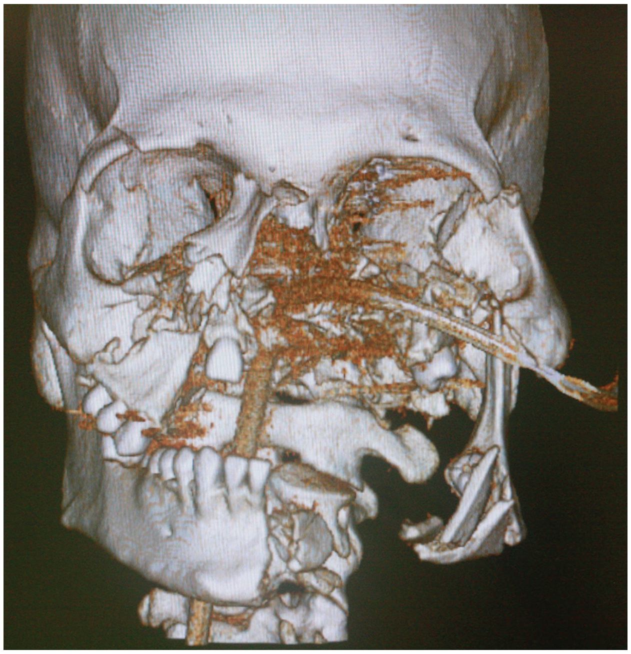

Figure 37-1. Three-dimensional CT (computed tomography) scan demonstrating the hallmark high-energy blast injury to the midface resulting in highly comminuted craniomaxillofacial fractures of both the mandible and maxilla. Associated injuries included avulsion of the overlying facial tissues and intraoral mucosa loss.

stabilized and cleared for surgery, the initial stage entails debridement of all foreign materials and obviously nonviable tissues. It is important to remember that the face is extremely well vascularized. Therefore, aggressive debridement should be avoided. If the viability of tissue remains in question, the area should be observed for 24 to 48 hours to allow for definitive demarcation. This conservative approach is especially important for regions including skin margins, the nose, palate, lips, and medial canthus.[14]

During this initial/acute stage of midface reconstruction, the ophthalmologist will attempt to salvage ruptured globes,[18] and the neurosurgeon will close intracranial defects. At this time, the head and neck trauma surgeon should make every effort to establish the occlusal bite of retained tooth-bearing segments.[14] Small bony fragments lacking periosteum should be removed to avoid future bony sequestrum and infection. However, larger pieces of bone with attached periosteum should be retained. Every attempt should be made to maintain the native soft-tissue envelope, which will avoid the devastating and disfiguring consequences of future wound contracture detailed in Case Study 37-2. Bony fragments stabilized during this initial stage may serve as part of the definitive reconstruction or may merely be used as temporary spacers. Ultimately, the role will be defined at the second stage of reconstruction.

The second stage of midface reconstruction requires exposure of all bony fractures and associated defects. Bony repair—either of retained fractured segments, free bone grafts, or vascularized bone—requires strict adherence to the principles of open reduction internal fixation (ORIF) as set for by AO/ASIF (or the Arbeitsgemeinschaft für Osteosynthesefragen/Association of the Study of Internal Fixation).[19] These principles include

- anatomical reduction;
- functionally stable fixation to avoid mobility and nonunion (titanium plates and associated locking screws are the most common hardware utilized in rigid fixation);
- atraumatic technique with preservation of vascularized tissues to include periosteum; and
- early, pain-free mobilization.

As previously described, combat injuries to the midface are often associated with severe mandibular fractures (see Figure 37-1). Therefore, successful reconstruction of the midface mandates thoughtful consideration of occlusal surfaces, as well as mandibular reconstruction. ORIF principles dictate plating from stable to unstable regions. Even the smallest submillimeter change in occlusion will be noticed by the patient. When severe comminuted fractures involve both the mandible and midface, efforts should be made to reestablish the mandibular integrity first, ideally using three-dimensional imaging, custom stereolithic modeling (see Case 20-2 and Chapter 21, Thermal Injuries), and lingual splints when necessary. Once the integrity of the mandible is achieved, the bony midface can be reconstructed to meet the occlusal surfaces dictated by the restored mandible. As demonstrated in bimaxillary advancement surgery, reconstruction of the bony midface provides increased mobility and surgical options because all six walls of the maxilla do not require restoration. This flexibility provided in midface bony reconstruction is in stark contrast to its mandibular counterpart.

In addition to restoring occlusion via ORIF, a meticulous, water-tight seal of soft tissue is required to close the palate and successfully restore speech and swallowing. Patients sustaining high-energy blast injuries will likely require an open tracheostomy and a percutaneous gastrostomy tube during the initial reconstructive stages and healing phase. It is imperative to remember that home health care and equipment resources are essentially nonexistent for local nationals and coalition forces remaining in theater. For this reason, the definitive reconstructive plan should not include a long-term tracheostomy or feeding tube.

Futran and Mendez[20] provide a comprehensive algorithm for approaching midface and maxillary reconstruction. Defects are divided into three categories:

1. palate
2. inferior maxillectomy, and
3. total maxillectomy with and without orbital exenteration.

This algorithm takes into account both the status of the dentition in supporting a prosthesis and the retention of an intact orbitozygomatic arch. If either is absent, vascularized free tissue transfer is favored over soft-tissue flaps. Thus, the authors advocate local flaps for small, isolated palatal defects and soft-tissue flaps for larger palatal defects. Traumatic loss of the inferior maxilla can be successfully repaired with soft tissue if viable dentition remains to support a prosthesis; otherwise, a vascularized osseous free flap is required to achieve dental restoration. Total maxillectomy defects that do not involve orbital loss can be reconstructed in a similar fashion. In the setting of a total maxillectomy with orbital exenteration, soft-tissue flaps can be utilized in midface reconstruction if the orbitozygomatic complex remains intact. Otherwise, a soft-tissue flap with bone graft or a vascularized osseous free flap is advocated.

Additional traumatic midface/maxillectomy treatment protocols have been established by Rodriquez et al[9] and Peled et al.[17] Although slightly different in the specific designs, all of the previously described algorithms share the common principles of preserving viable soft tissue and bone, early reconstruction to avoid soft-tissue contracture, use of vascularized free tissue transfer in the setting of high-energy trauma, and consideration of dental rehabilitation in the reconstructive planning.

Reconstructive Ladder

Alloplastic Prostheses

Historically, maxillary defects were reconstructed using prostheses comprised of a variety of alloplastic materials, including wood, wax, metal, acrylic, and polyurethane polymers.[21,22] A traditional maxillary prosthesis is an extended denture that functions as an obturator to seal the palate and restore oral competency (Figure 37-2, a–d). The advantage of this technique is that it does not rely on vascularized tissue, which is often compromised in war injuries. In addition, extensive surgery entailing long anesthesia is not required. Alloplastic prostheses have successfully been utilized to restore maxillary, nasal, orbital, and ocular defects with excellent cosmetic results.[23] In the hands of an experienced maxillofacial prosthodontist, acceptable aesthetic reconstructions with excellent color match, fine details, and facial hair restoration can be achieved.

Unfortunately, this cosmetic outcome is often at the expense of functional limitations. Leakage around the prosthesis and inability to achieve suction are common problems in the region of the nasal and oral cavities.[4,24] In addition, rigid alloplastic materials seated in the mobile regions of the midface can lead to tissue breakdown and patient discomfort.[4,5] Larger defects pose a challenge in retaining an obturator, even in the setting of osseointegrated implants. If the defect consists of greater than two-thirds of the maxillary arch, surgical reconstruction will be required to provide adequate bone stock (approximately 10 mm) to accommodate osseointegrated implants that will support the denture.[24] Lastly, maintaining adequate hygiene to avoid offensive malodors requires diligence on the part of the patient who may have sustained concomitant orthopaedic injuries hampering dexterity.

With the advent of microvascular free tissue transplant, the role of maxillofacial prosthesis in the setting of midface reconstruction has diminished. However, this technique maintains a valuable role, especially for those patients who are severely debilitated and unable to undergo extensive surgery. It remains the standard of care for restoration of small, isolated palatal defects.[4] The prosthesis can also serve as a temporary spacer to limit scar contracture until definitive reconstruction is feasible (see Case Study 37-2).

Local Flaps

Local tissue flaps have a limited role in the reconstruction of midface bone defects. Traditionally, these flaps are restricted to small, isolated defects of the cheek, upper lip, palate, or nasal cavity.[4] It is important to remember that IEDs produce blast injuries with associated burns. For this reason, the surrounding tissue is compromised similar to that of an irradiated patient. Given the high-energy blast injuries sustained in theater,[16] availability of well-vascularized, reliable local tissue is limited. It is recommended that the surgeon wait 24 to 48 hours postinjury to ensure tissue viability before moving and rotating flaps.[14]

Pedicled Flaps

Pedicled myocutaneous flaps were introduced as a means of midface reconstruction in the 1960s.[4] The deltopectoral flap[25,26] was initially introduced, followed by the pectoralis major,[27] latissimus dorsi,[28]

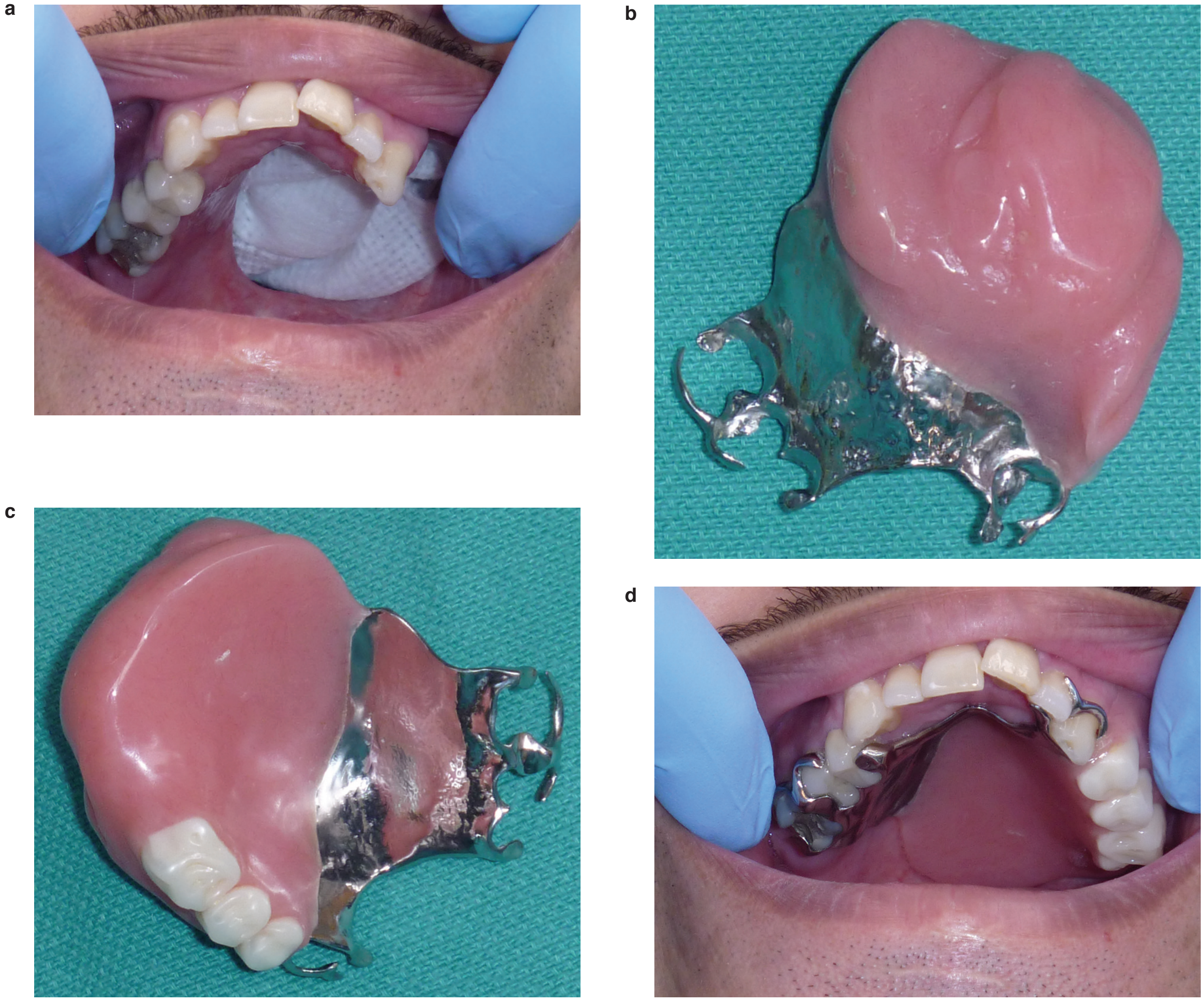

Figure 37-2. (**a**) Isolated hard palate defect. (**b**) Palatal obturator (superior view) demonstrating nasopharyngeal surface. (**c**) Palatal obturator (inferior view) demonstrating palatal surface. (**d**) Retained palatal obturator sealing palate defect.

sternomastoid,[29,30] and trapezius flaps.[31] Pedicled myocutaneous flaps provide hearty, vascularized tissue that can be harvested and inset in a single-staged fashion. The large surface area can be used to obliterate the maxillary sinus. Multiple skin paddles can be designed to reconstruct the palate and the external skin. Thinner, pliable flaps—such as the temporoparietal fascial flap, combined deep temporal fascial flap, and temporalis muscle flaps—have been used with and without calvarial bone to reconstruct smaller scale midface defects.[4,32,33] The anatomy of pedicled flaps is extremely reliable. Unlike microvascular free tissue transplant, specialty-specific training and instruments are not required. However, pedicled myocutaneous flaps have several disadvantages when used for midface reconstruction.[14] The length of the pedicle ultimately limits the arch of rotation and makes reconstruction of the upper midface challenging, especially if the pedicle is inferiorly based. Pedicled myocutaneous flaps provide only soft tissue. If dental restoration is to be achieved, additional surgeries to include vascularized or free bone grafts are required. The bulky nature of the pectoralis major, latissimus dorsi, and trapezius myocutaneous flaps makes folding and contouring extremely challenging, thereby negatively impacting cosmetic appearance, speech, and swallowing.[4]

Today, pedicled flaps have largely been replaced by free tissue transfer. However, this option remains in the midface reconstructive algorithm. Large, complex defects may require multiple flaps, in which case a thoughtfully designed pedicled flap can be used to augment a free flap. The thin, pliable characteristics of the temporoparietal flap and temporalis muscle flap are options in the reconstruction of isolated orbital or lateral palatal defects. In the setting of mass casualties and limited resources, pedicled flaps may be the only available option for injured local nationals, insurgents, and coalition forces remaining in theater for definitive reconstruction. The anatomy and harvest techniques for the previously described pedicled flaps are beyond the scope of this chapter. Readers interested in additional information are directed to flap-specific atlases.[34]

Free Bone Grafts

A host of autogenous, free, nonvascularized bone grafts have been detailed in the literature for midface reconstruction. Studies have found free bone grafts to be superior to alloplastic implants.[35] Donor sites include the split calvarium, iliac crest, fibula, scapula, radius, and rib.[32,35–37] Split calvarium is used most commonly in the setting of midface bony repair because of ease of exposure in this setting, minimal donor site morbidity, and low complication rates.[38–41] The low profile and bony contour of free calvarial bone are ideal in reconstructing the orbital walls, zygomatic arch, and nasal bone. Smolka et al[35] report excellent success in using split calvarium in midface bony reconstruction. Overall bone graft survival reached 95.8%. Of 95 bone grafts studied, 25 were utilized specifically in trauma reconstruction. No grafts failed in this setting. It is important to remember that this study included civilian trauma that is usually low energy/low velocity. The ability to extrapolate the results to combat trauma remains to be determined.

Free bone graft survival relies entirely on the blood supply of surrounding soft tissue that must adequately cover the bone. In an effort to maximize survival, bone grafts are often wrapped in vascularized tissue, such as pedicled flaps to include the buccal fat pad flap and temporalis muscle flap.[1,42–44] Alternatively, free myocutaneous and fasciocutaneous flaps can be utilized. Unfortunately, the long-term success of this technique is unreliable, with partial or subtotal resorption necessitating additional surgeries.[45,46] Whereas free bone grafts are reasonable options in the reconstruction of small bony defects with well-vascularized surrounding soft tissue or as temporary spacers,[5] they will fail miserably in the setting of the large midface defects resulting from high-energy blast injuries sustained by IEDs and missiles.[45,47,48]

Free Tissue Transfer

With current advances in surgical technique, titanium plating, and vascular physiology, microvascular free tissue transfer has become the reconstructive choice for most complex three-dimensional midface defects.[49] This technique allows for healthy soft tissue and bone to be utilized in restoring the midface without the limitations of tissue stock, vessel length, and flap orientation often encountered in the setting of pedicled flaps.[1]

Free tissue transfer revolutionized midface reconstruction, expanding the armamentarium of reconstructive options. In the setting of high-energy blast injuries, the immediate surrounding tissue is often burned and devascularized (see Case Study 37-2). In addition, infection and compromised wound healing are realistic threats, especially if the trajectory traverses the oral cavity. In the setting of low-energy gunshot wounds involving the oral cavity, postoperative healing complications are reported in 39% of cases.[50] This rate reaches a staggering 100% in the setting of close-range injuries.[18] Free tissue transfer allows for wounds to heal with minimal scarring, contracture, and infection because the technique allows for the transfer of healthy tissue that is immediately vascularized.

In addition, free tissue transfer allowed for the shift away from delayed secondary reconstruction to early repair (within 2 weeks of injury).[9,14,51,52] This immediate reconstruction is imperative to maximize cosmetic and functional results. It avoids the inevitable soft-tissue contracture that develops in the delayed setting. Even in the hands of experienced microvascular surgeons, scar contracture and loss of the soft tissue envelope render optimal midface reconstruction nearly impossible[9,14] (see Case Study 37-2).

A variety of free tissue flaps are available, including the myocutaneous and osseous cutaneous radial forearm free flaps, rectus abdominus, anterior lateral thigh, iliac crest, fibula, and scapula.[12,34,49] The osseocutaneous radial forearm free flap has been described as an excellent donor site for the reconstruction of infrastructure and subtotal maxillectomy defects.[53–56] Orbitomaxillary defects include the orbital rim,[57] and zygomaticomaxillary buttress defects[13] have been reconstructed in a similar fashion. The fibula free flap provides up to 26 cm of bony stock, which is amenable to osseointegrated implants, and it offers a long pedicle.[9,34,49] This flap is used ideally in the setting of lower maxillary defects requiring bony reconstruction.[15] However, when traumatic defect also includes absence of the orbitozygomatic buttress or if the traumatic defect extends superiorly to involve the bony orbit, the fibula free flap has limited ability in achieving the ideal reconstruction.[1,15] Instead, the scapula system is better suited for the reconstruction of such large, midface bony defects. The scapular tip is ideal for maxillary reconstruction, and multiple skin paddles can be fashioned to reconstruct external skin defects, as well as internal nasal lining and palatal defects.[58] The iliac crest free flap has been used in a similar fashion and provides bony stock suitable for osseointegrated dental implants. However, many authors do not advocate its use because of limited mobility from the bulky soft tissue and shorter pedicle length.[1,9,49] Alternatively, the rectus abdominus (Figure 37-3) and anterolateral thigh provide significant soft-tissue bulk and multiple skin paddles for soft-tissue obliteration of large midface defects. However, neither free flap allows for dental restoration without additional surgeries to provide free or vascularized bone.

Ultimately, the donor flap will be dictated by the amount, location, and composition (soft tissue versus bone) of the defect, concomitant trauma sustained during combat, status of the dentition, patient preference, and surgeon skill. In the setting of experienced hands, free flap reconstruction for midface trauma has excellent survival rates.[9,14]

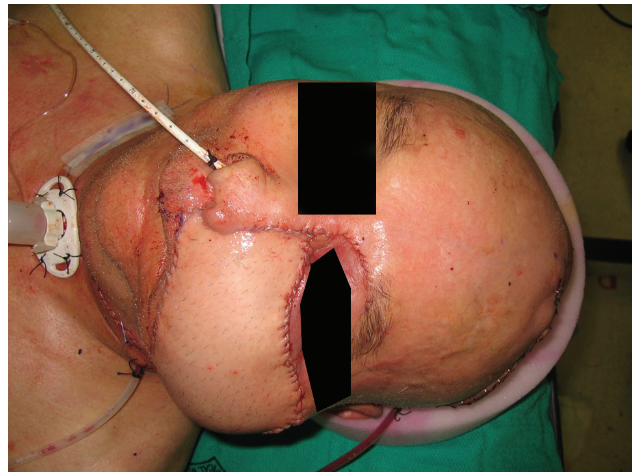

Figure 37-3. Type IIIA maxillectomy reconstruction using free calvarial bone to reconstruct the orbital rim and a large rectus abdominus free flap. The rectus abdominus skin paddle was used for external lining, the muscle obliterated the maxillary sinus, and the internal oblique muscle was used to close the palatal defect and restore oral competency.

SUMMARY

The maxilla and associated midface play a vital role in facial aesthetics, as well as in the function of speech, swallowing, and vision. Injuries sustained to this area in the setting of war usually results from high-velocity/high-energy injuries resulting in bony trauma to the midface and mandible, as well as soft-tissue avulsion. Successful reconstruction must seal the oral cavity from the nasal cavity, restore bony projection, and reestablish facial symmetry and contour. Bony midface reconstructive algorithms share the common principles of preserving viable soft tissue and bone, utilizing early reconstruction to avoid soft-tissue contracture, using vascularized tissue in the setting of high-energy trauma, and considering dental rehabilitation in the reconstructive planning. With continuing research and advances in tissue engineering[1] and face transplant,[59] the field of traumatic midface bony reconstruction will continue to evolve. In the interim, free tissue transfer should be considered the standard of care in the reconstruction of complex three-dimensional midface defects.

CASE PRESENTATIONS

Case Study 37-1: Isolated Midface Reconstruction

A young Afghan police officer sustained a left midface injury secondary to a rocket-propelled grenade (Figure 37-4a). The trajectory of injury was through the anterior left maxillary sinus wall and resulted in fracture of the left orbital rim and associated vertical buttresses. As is often the case in the setting of combat blasts, the injury itself provided adequate access to all fracture sites. After induction of anesthesia, the wound was copiously irrigated, and the inciting metal fragment was removed from the sinus without difficulty (see Figure 37-4b). Whereas small defects of the anterior maxillary wall do not require bony reconstruction, the integrity of the maxillary buttresses must be reestablished to allow for pain-free mastication (see Figure 37-4c). In addition, repair of the comminuted, displaced orbital rim was required to reestablish orbital volume, prevent enophthalmus, and eliminate postoperative diplopia (see Figure 37-4d). ORIF was achieved using locking 2.0 titanium plates and screws designed specifically for the midface.

Significant loss of the overlying soft tissue was not sustained. The wound was clean, without concern for tissue viability, and it was closed immediately in the acute setting. Optimal soft-tissue closure in the setting of blast injuries should include two or more layers whenever feasible. When periosteum is present, every effort should be made to close this layer over the hardware. Heavier 4-0 PROLENE suture was used for the epidermal closure because of the contaminated nature of blast injuries and the often compromised nutritional status observed among the local community. The patient was kept on a short, 5-day perioperative course of antibiotics because of contaminated mechanism of injury and exposure of the plates to the maxillary sinus. His postoperative course was uncomplicated, and he was discharged to home.

This case serves to highlight the ability to successfully perform ORIF in the setting of a blast injury. The well-vascularized surrounding facial soft tissue usually allows for healing without wound contraction, plate exposure, or infection. Given the complex three-dimensional nature of the maxilla, it is helpful to widely expose all midface facial fractures prior to plating. In doing so, it is easy to appreciate how reduction of one fracture site impacts other associated fractures in that region. In addition, it allows for optimal plate selection to ensure that ORIF at one fracture sight does not preclude the ability to plate an additional region. Lastly, this case serves as an example to highlight the import buttresses of the midface that must be reconstructed to reestablish vertical height, restore adequate facial cosmesis, and allow for pain-free mastication.

Case Study 37-2: Complex Midface Reconstruction With Severe Wound Contracture

A young, active duty soldier sustained an IED blast injury to the face while traveling in his Humvee (HMMWV or High Mobility Multipurpose Wheeled Vehicle) (Figure 37-5a). Note the soft-tissue burns and associated devascularized tissue margins common in the setting of high-velocity/high-energy blast injuries sustained in combat. The surrounding soft tissue is often poorly vascularized, similar to that of irradiated tissue, and therefore has an extremely limited role in reconstruction. Local tissue flaps are usually not a viable option in the setting of these combat injuries.

This blast injury resulted in soft-tissue loss of his right oral commissure and surrounding upper and lower lips, avulsion of his nasal tip, loss of his right buccal mucosa, and loss of the right floor of his mouth (see Figure 37-5b). From the bony standpoint, the comminuted segment of his right mandible from the ascending ramus to the right parasymphyseal region was thought to be nonviable and was removed during the initial debridement at an outside facility. In addition, he sustained loss of his right maxillary alveolar ridge. Associated comminuted ZMC and orbital wall fractures occurred.

As is common in the setting of combat injuries, the patient also sustained multiple orthopaedic injuries to his hands and a severe traumatic brain injury necessitating intense specialty inpatient rehabilitation. Given the finite, immediate, critical window for successful traumatic brain injury rehabilitation, definitive reconstruction of his facial injuries was delayed. Without preservation of his underlying native right mandibular segment or the placement of spacers such as a reconstruction bar or free bone graft, severe tissue contracture and loss of the soft-tissue envelope resulted in limited jaw range of motion (see Figure 37-5c), a significant cross-bite (see Figure 37-5d), and difficulties with mastication.

This reconstruction required a team approach, including the head and neck surgeon, plastic surgeon, oral surgeon, prosthodontist, and speech therapist. After aggressive resection of the scarred tissue (see Figure 37-5e), an osseocutaneous fibula free flap was used to reconstruct the mandibular defect and surrounding soft-tissue loss. The mandible was intentionally

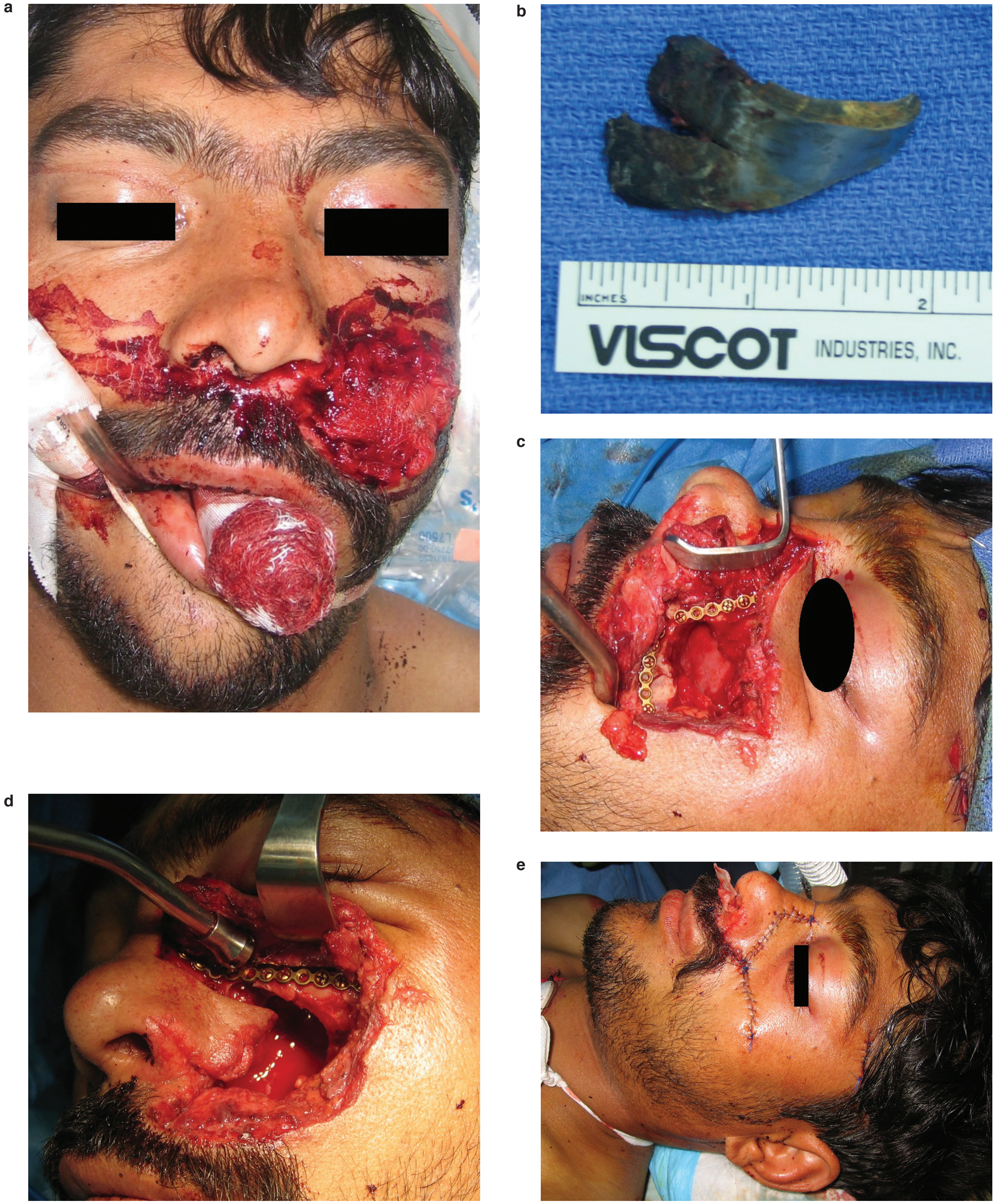

Figure 37-4. (**a**) Left midface injury to the maxilla secondary to a rocket-propelled grenade. (**b**) Inciting metal fragment removed from the sinus. (**c**) Open reduction internal fixation using a 2.0 titanium locking plate and screws to reconstruct maxillary buttresses. (**d**) Open reduction internal fixation of a displaced orbital floor fracture using a low-profile titanium locking plate and screws. (**e**) Primary, multilayered closure of the blast injury following midface bony repair.

Figure 37-5. (**a**) Improvised explosive device blast injury to the midface. Note the soft-tissue burns and associated devascularized tissue margins common in the setting of high-velocity/high-energy blast injuries sustained in combat. (**b**) Complex midface injuries common in the setting of combat. Soft-tissue losses included the right oral commissure, surrounding upper and lower lips, right buccal mucosa, right floor of the mouth, and nasal tip. Associated bony injuries included severe comminution of the right mandible, maxilla, zygomaticomaxillary complex, and bony orbit. (**c**) Severe tissue contracture resulting from delayed reconstruction without retained underlying bone or titanium plate to maintain the native soft-tissue envelope. (**d**) Severe tissue contracture resulting in significant cross-bite and difficulties with mastication. **(Figure 37-5 continues)**

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Figure 37-5 (continued). (**e**) Aggressive resection of the scar band and associated surrounding tissues required to restore native occlusion and oral opening. (**f**) Intraoperative guides for osseointegrated implant placement based on three-dimensional imaging and stereolithic modeling. (**g**) Final reconstruction to include fibula-free flap for mandibular reconstruction and maxillary reconstruction using an osseointegrated retained prosthesis. The patient was able to maintain all of his nutrition orally following the staged reconstruction.

reconstructed first because the native bucket handle construct of the mandible lends itself well to mirror imaging and stereolithic modeling. In addition, bony restoration of the midface allows for multiple osteotomies and advancements to restore occlusion without negatively impacting incisal opening and mastication. The same cannot be said of the mandible.

Radiographic and intraoperative assessments of the remaining right maxilla demonstrated significant bone stock for osseointegrated implants. Stereolithic modeling performed by the prosthodontics team was used to create intraoperative guides for implant placement (see Figure 37-5f). Such planning is imperative if perfect occlusion is to be achieved. Dental rehabilitation of the maxilla was performed by the oral surgery team in the traditional staged fashion. Ultimately, the patient achieved oral competency, was able to maintain all nutrition orally, had his PEG (percutaneous endoscopic gastrostomy) tube removed, and was decannulated. He returned home and is pleased with his cosmetic appearance, declining any further facial plastic surgery of his nasal tip or removing the free flap skin paddle (see Figure 37-5g).

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