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Chapter 93 – Fractures of the Upper Facial and Midfacial Skeleton

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Depending on the point of impact and the degree of force, the upper facial and midfacial bones can sustain isolated or characteristic fracture patterns. A single blow from a fist to the midface often results in a displaced nasal fracture, the most common midfacial fracture, or in a tripod fracture of the zygomatic complex (ZMC). The midfacial bones tend to fracture in areas where they are thin and weak, such as the nasal bones, the anterior maxillary sinus wall, the orbital floor, the medial walls, and the nasal-orbital-ethmoid (NOE) complex. Suture lines also provide a natural cleavage plane for fractures to occur. If the facial bones are struck in strong thicker areas, the force is transmitted to the suture lines or thinner bony areas.

When severe or multiple midfacial fractures occur or when such fractures are associated with lacerations or penetrating injuries, significant hemorrhage can occur. Patients are often brought by emergency medical personnel on spine boards and in cervical collars. These restraints can lead to airway compromise, so measures to suction and control hemorrhage are essential. A significant number (>5%) of patients with frontal sinus or multiply displaced midfacial fractures will have an injury to the cervical spine.[1] When the airway needs to be secured, emergency tracheostomy or cricothyrotomy is generally the safest and most predictable course of action. It is difficult to perform direct laryngoscopy while maintaining in-line cervical spine traction. Fiberoptic intubation (either nasally or orally) is usually hampered by blood obstructing the view. Attempts at "blind nasal intubation" should be undertaken only by skilled individuals once a fracture of the NOE complex and possible fracture of the cribriform plate (with their potential for false passage into the anterior cranial fossa) have been excluded.

Control of hemorrhage can be accomplished by injection of local anesthetic containing vasoconstrictors, tacking sutures, localized packing, and less frequently, direct clamping of vessels. Blind clamping or electrocautery should not be undertaken in injured areas along the course of the facial nerve. Some blood loss during facial fracture surgery is unavoidable, but the use of injected vasoconstrictors and topical agents with nasal packing will greatly reduce oozing throughout the surgical procedure. Local infiltration may be repeated as often as necessary if the vasoconstrictors wear off. Bleeding vessels should be ligated or cauterized. The patient must be kept warm and the proper coagulation mechanism should be evaluated. The anesthesiologist must make every effort to maintain normotension or a systolic blood pressure of 110 mm Hg or lower. This should be done only when appropriate and neurologically and systemically tolerated by the patient.

Before general anesthesia, a gross visual acuity check of both eyes and assessment of facial motion must be made. This information is invaluable when correlated with computed tomography (CT) during treatment planning.

Goals of treatment of facial fractures are to restore the patient to the preinjury facial form with normal function. Re-establishment of the proper anterior facial projection without abnormal widening of the face is essential.[2] There is a tendency for a broad, flat face to occur as a result of blunt force and the direction of displacement. Severe midfacial fractures are often associated with multiple fractures of the mandible, which further compounds this situation.

Precise repositioning plus fixation prevents malocclusion and shortening of the midface. Horizontal relationships are maintained by buttresses at several levels, including the supraorbital rims and frontal bone, the zygomatic arch, the infraorbital rims, the nasal bones, and the maxillary alveolus. These horizontal relationships determine facial width, malar projection, occlusal relationships of the maxillary dentition, orbital position, and the width of the base of the nasal pyramid.

In addition to anatomic repositioning of the facial skeleton, surgical treatment must also consider the importance of restoring function, including an intact blood-brain barrier; mucociliary clearance of the frontal, maxillary, and ethmoid sinuses; nasal breathing; lacrimal drainage; dental occlusion; and conjugate movement of the extraocular muscles. The latter depends on establishing proper orbital volume and position of the globe.

PATIENT SELECTION AND PREOPERATIVE EVALUATION

Although each anatomic entity will be discussed separately, the surgeon should bear in mind that midfacial fractures are frequently multiple, have associated soft tissue injuries, and may be accompanied by neurologic injuries.

Maxilla

Direct blunt force trauma to the maxilla results in several classic fracture patterns that are designated by a Le Fort classification (Fig. 93-1). A Le Fort I fracture is a horizontal maxillary fracture of the horseshoe-shaped dentoalveolar complex (above the tooth roots) through the midmaxillary sinus and base of the lateral nasal walls. A Le Fort II fracture is a pyramidal break of the nasomaxillary complex with separation at the frontonasaljunction, through the inferior orbital rims, and then laterally along the anterior maxillary sinus wall, below the zygomatic buttresses. To clinically differentiate a Le Fort I from a Le Fort II fracture, the examiner should grasp the anterior maxillary teeth and alveolar ridge while stabilizing the forehead with the opposite hand. Anterior-posterior, or side-to-side, force should be applied to the anterior maxilla while observing for symmetrical motion of the entire maxilla (Le Fort I versus an isolated dentoalveolar fracture) or the maxilla and nasal complex together (Le Fort II). Complete craniofacial dysjunction is termed a Le Fort III fracture. Here, the entire facial complex, including the zygomatic buttresses, moves with applied maxillary force. Generally, Le Fort fracture patterns are not "pure" and have additional lines of fracture (i.e., dentoalveolar component), comminution, combinations (such as Le Fort I and III levels), or associated midfacial fractures (i.e., ZMC or orbit). Typically, the direction of the force fracturing the maxilla displaces the maxilla upward and back. This results in an anterior or lateral open bite and malocclusion. The face is flattened and elongated.

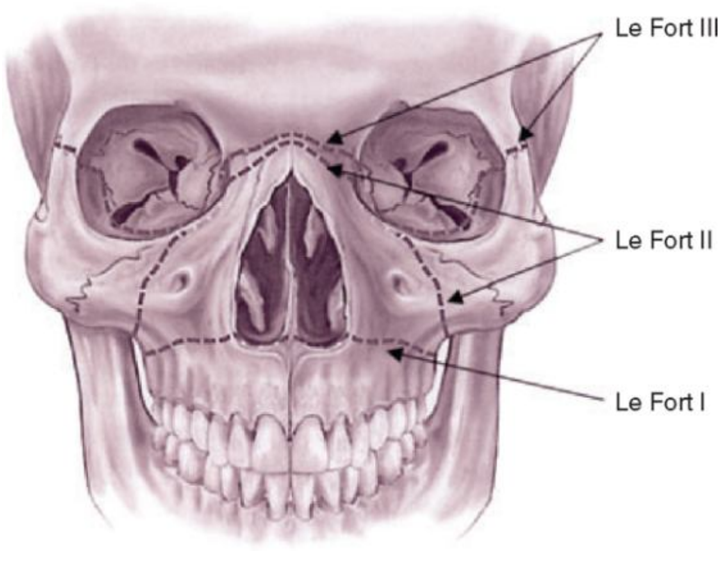

Figure 93-1 Le Fort classification of midfacial fractures. A Le Fort I fracture courses along the base of the nasal septum and floor or the midmaxillary sinus walls with separation at the pterygoid plates. A Le Fort II fracture traverses along the anterior maxillary wall and through the medial orbital rim, coupled with the nasal complex. A Le Fort III fracture has breaks at the zygomatic frontal sutures, frontonasal junction, zygomatic arches, and pterygoid plates. In essence, the entire midface is separated from the cranium (craniofacial dysjunction).

Patients sustaining Le Fort fractures demonstrate malocclusion, severe bilateral facial and periorbital edema, epistaxis, and ecchymosis (especially in the maxillary vestibule). These patients will often have paresthesia of the midface because of edema and pressure on the infraorbital nerves. Palpation of the maxillary vestibule, orbital rims, and nasal complex can reveal bony steps or detect motion while manipulating the maxilla. Edema and pain while palpating can readily mask these deformities. Tears in the gingiva or palatal mucosa should be sought because they are indicative of segmental fractures of the dentoalveolar complex and may alter the treatment plan. Traumatic open gaps in the dental arch should be accounted for either by an avulsed and missing tooth or by displacement or splaying of the fractured maxillary segments. Any watery or clear rhinorrhea should be collected and sent for β_2-transferrin assay to determine whether a cerebrospinal fluid (CSF) leak is present.

If there is strong clinical suspicion of a maxillary fracture, fine-cut (1.5 mm) axial CT scans through the entire facial complex offer the best imaging information for surgical planning and have replaced plain radiographs such as a Waters view, which offer little precise information. It is advisable to carry the CT scan through the mandible because there are invariably mandibular injuries such as condylar fractures that can be difficult to diagnose clinically or with plain films. Intravenous contrast material in the setting of acute facial trauma does not provide any additional detail and is not indicated.

Zygoma

Fractures of the ZMC are the second most commonly occurring facial fracture. They typically occur as a result of lateral blunt force, such as a blow to the face with a fist. These fractures are also termed "tripod" fractures because they are breaks along the zygomaticofrontal and zygomaticomaxillary junction (infraorbital rim and anterior sinus wall) and the zygomatic arch.[3] Usually, the zygomatic buttress is driven medially inward, inferior, and slightly posterior. There will be flattening of the malar projection, but this can be masked by edema. Frequently, clinical signs and symptoms include inferior displacement of the lateral canthus, tenderness of the frontozygomatic suture (located 1 cm above the lateral canthus), lateral subconjunctival hemorrhage, pain or limitation while opening the mouth, paresthesia of the cheek/lip, midfacial edema, and limited range of ocular motion (secondary to an orbital floor component). Palpation of the inferior orbital rim may reveal a step at the mid or medial half of the rim. Visual acuity should be assessed to rule out the possibility of a retrobulbar hematoma. Limited opening of the mouth is generally mild and due to the pain associated with masseteric muscle pull. However, with severe displacement of the ZMC, there can be direct impingement of the coronoid process and marked limited opening (1 cm interincisally). In anticipation of oral intubation for surgical repair, it is helpful to ask the patient to deviate the mandible to the contralateral side of the ZMC fracture and to assist the individual with opening. This often clears the path for the ipsilateral coronoid and allows adequate opening.

Isolated fractures of the zygomatic arch are usually due to a focused blow, such as with an elbow or a hardball, directly to the midarch. Typically, there are three separate vertical fracture lines with inward displacement in a V- or W-shaped pattern (Fig. 93-2). An indentation and tenderness in the area directly over the fracture may be noted or camouflaged by edema. Mild limited opening because of muscular pain is often present.

Figure 93-2 Isolated fracture of the right zygomatic arch. The *diagram* shows an inferior view of a classic fracture pattern with three breaks that typically occurs after a focused blow with a blunt object. The submental vertex radiograph reveals an inwardly displaced fracture of the right zygomatic arch and a normal left zygoma.

Radiographic imaging of fractures of the ZMC can initially include a Waters view to look for opacification or an air-fluid level in the maxillary sinus or a teardrop sign in the maxillary sinus caused by sagging of the periorbital contents through the orbital defect. Separation or widening of the zygomaticofrontal suture line is often difficult to ascertain except with extreme displacement. Axial CT offers the best views to determine thedirection and degree of displacement of the ZMC. Direct coronal views or, less ideally, reformatted images can provide additional details of the orbital floor component if repair of this area is contemplated. Minimally displaced or nondisplaced fractures of the ZMC will heal uneventfully with sinus precautions, decongestants, and antibiotics, if indicated. In patients with minimally displaced or nondisplaced isolated fractures of the ZMC, orbital floor, or anterior maxillary wall, one should not operate for V2 paresthesia alone. The infraorbital nerve does not need to be decompressed, and "surgical exploration" will only further traumatize the nerve and not hasten recovery. Surgical repair is directed toward realignment, restoration of midface form, and unrestricted motion of the globe and mandible.

Isolated zygomatic arch fractures can be imaged with a submental vertex or "jug-handle" view. These inexpensive plain radiographs are adequate for planning surgical treatment. If further images are to be obtained, an axial CT scan is the image of choice. Isolated arch fractures are usually treated by open reduction through limited incisions in the temporal area, lateral aspect of the brow, or transorally and then not plated. Therefore, early operative intervention (preferably within the first 24 to 72 hours) is desirable to improve stability of the reduction and prevent the fragments from sagging back inward.

Orbit

Isolated fractures of the orbit constitute 10% of all facial fractures. If one includes fractures of the orbit that extend outside the confines of the orbit into the facial skeleton, the incidence approaches 40% to 55%. Fractures involving the orbit can be classified as ZMC, NOE, or internal orbital fractures.[4] Internal fractures of the orbit can occur in numerous patterns and can be described as *linear, blowout,* and *complex*. Linear fractures maintain periosteal attachments and do not generally result in a defect, but they can cause entrapment or impingement of the extraocular muscles or the capsulopalpebral fascia (Tenon's capsule). This most commonly occurs with linear fractures of the orbital floor, especially in pediatric patients, whose facial bones are more pliable and momentarily expand or displace open at the time of impact and then snap back closed and entrap soft tissue. These patients will have firm, fixed limitation on upgaze or, more commonly, on downgaze. The patient may exhibit head tilting, nausea, and episodic bradycardia. Early repair (within 24 hours) and freeing of entrapped tissue are essential to prevent ischemia and fibrosis of the tissues with long-term restriction. Any equivocal entrapment or ocular restriction can be assessed by topically anesthetizing the globe and performing forced duction by grasping the insertion of the inferior rectus muscle through the lower eyelid fornix and attempting to move the globe superiorly and inferiorly.

Blowout fractures of the orbit are the most commonly occurring orbital injury and are limited to one wall, with the defect being less than 2 cm in diameter. Blowout fractures most frequently occur in the anterior or medial part of the orbital floor; however, they can occur in the medial wall or orbital roof, where they can be manifested as *blow-in* fractures. Orbital floor blowout fractures occasionally cause entrapment and limited ocular motility, but they more commonly result in expansion of the orbital volume with sagging of the orbital contents into the maxillary sinus. Initially, enophthalmos may not be apparent, but with clearance of hemorrhage and resolution of edema, the condition may become evident.

The decision to undertake surgical repair or reconstruction of these defects is based on functional limitations or cosmetic deformity.[5] Defects of 25% or less of the surface area without entrapment generally heal uneventfully without any intervention. Repair of intermediate defects involving 25% to 50% of the surface area is based on the degree of displacement, the amount of volume expansion, and any coexisting enophthalmos, even with edema. Larger or comminuted defects (>50%) with significant disruption are best treated by early repair (within 7 days) because some degree of enophthalmos or diplopia is the norm when left unrepaired. Fractures of the lateral wall rarely result in entrapment or volume changes since this area is well supported laterally by the bulky temporalis muscle. The lateral wall is most frequently fractured at the junction of the zygoma and greater wing of the sphenoid (one third of the way back from the rim), and it is usually a component of a ZMC fracture. Medial wall fractures rarely cause entrapment but can result in significant volume changes with a shift of orbital content into the ethmoid air cell spaces. In this instance, repair and reconstruction are usually indicated.

Exploration, repair, or reconstruction of fractures of the orbital roof (or any combination of such procedures) may be indicated if a dural tear is suspected or to prevent the development of a "pulsatile globe." This inward and outward movement of the eye is due to the arterial pulsations and respiratory fluctuations that occur in the overlying cerebral hemisphere. The *pulsatile globe* phenomenon often becomes apparent after resolution of edema and hematoma in unrepaired defects of the roof of the orbit and causes persistent blurred or double vision.

Complex fractures consist of extensive fractures that affect two or more orbital walls; they often involve the posterior orbit and may involve the optic canal. Superior orbital fissure syndrome or orbital apex syndrome can occur.[6] The former consists of dysfunction of cranial nerves III, IV, V, and VI as a result of compression by bone fragments or hematoma. Orbital apex syndrome consists of superior orbital fissure findings with the addition of injury to the optic nerve. High-dose systemic steroids, blood pressure control, and elevation of the head of the bed can be palliative. Surgical intervention with decompression is based on correlation of CT with physical findings, the degree of optic nerve compromise, and the patient's neurologic, hemodynamic, and systemic stability. Retrobulbar hematoma can be treated on an emergency basis by performing a lateral canthotomy or inferior cantholysis (or both) and evacuating the clot by inserting a small curved hemostat along the lateral orbital wall and spreading it. A small Penrose drain can then be inserted.

Fractures of the orbital complex are usually associated with fractures of the facial skeleton outside the orbital framework (Le Fort II or III fractures or frontal sinus fractures) and are classified as *combined fractures*. A systematic approach to assessment of both orbits will further define the functional and anatomic defects associated with injuries to the orbit. The initial ophthalmic evaluation should include a periorbital examination and testing of visual acuity, ocular motility, pupil responses, and visual fields, as well as a funduscopic examination. The eyelids and periorbital areas should be inspected for edema, ecchymosis, lacerations, ptosis, asymmetric lid droop, injury to the canaliculus, and disruption of the canthal tendon.

Once the clinical assessment is complete, fine-cut (1.0 to 1.5 mm) axial CT images can be correlated with abnormalities or deficits. Direct coronal images are beneficial in evaluating defects of the walls of the sinus, and three-dimensional reformatting can be useful in patients with complex facial trauma or in instances of delayed or secondary repair. Magnetic resonance imaging has been used to identify wood or nonmetallic foreign bodies in penetrating injuries. These objects can be misdiagnosed by CT as intraorbital air and should be suspected when the apparent air collection within the post-traumatic orbit does not resorb rapidly.

The timing of any orbital repair is based on the urgency of the clinical findings (optic nerve compromise or muscle entrapment), the extent of the defects, associated facial fractures, or the patient's medical condition and health (Fig. 93-3). Early repair (within 5 to 7 days) offers the best results. Interval repair (within 7 to 14 days) can be undertaken once the edema and hematoma have resolved, a clear functional or cosmetic reason to intervene exists, and the patient is stable enough to undergo surgery with general anesthesia. Late repair (after 14 days) generally yields suboptimal outcomes because of malunion and unfavorable soft tissue adaptation.

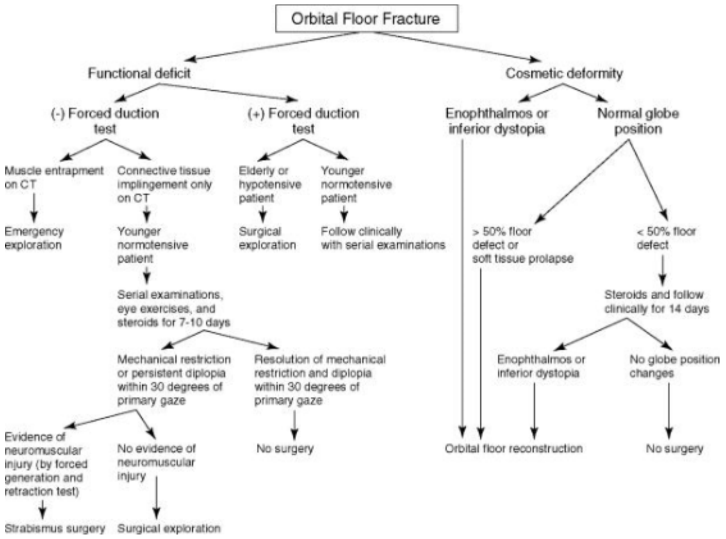

Figure 93-3 Management of a fracture of the orbit floor. The two primary indications for surgical intervention are to restore normal function of the globe and extraocular muscles and to repair a cosmetic deformity that would be noticeable. CT, computed tomography.

Nose

Fractures of the nose are the most common fracture of the face and are usually due to blunt force trauma. Lateral or oblique blows to the nose cause inward depression of the area of impact and lateral bowing of the contralateral side. A concomitant fracture of the nasal septum may accentuate the C-shaped deformity of the nasal dorsum. The degree of displacement can be masked by soft tissue swelling. Direct anterior force to the nasal bridge creates a depression of the nasal bridge and splaying of the nasal bones overlapping the frontal process of the maxilla (Fig. 93-4). Higher-energy impacts in this area can result in fracture of the ethmoid sinuses and NOE fractures. Frontal sinus and anterior basilar skull fractures are commonly associated with NOE fractures.

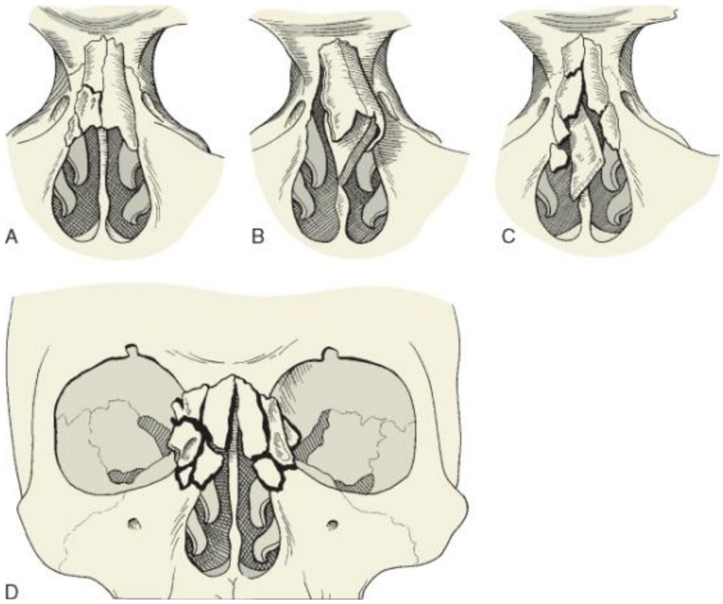

Figure 93-4 Patterns of fractures of the nose. **A,** Bowing or C-shaped deformity caused by direct lateral force. The ipsilateral nasal bones are depressed. **B,** Greater force causes fractures of the nose and deviation of the septum with lateralization of the contralateral nasal bones. **C,** Comminution secondary to more midline and heavy force with fracture of the septum results in loss of anterior projection and dorsal support. **D,** Fracture of the nasoethmoid complex caused by an extreme anterior impact. The fractures extend posteriorly to involve the medial orbital walls with typical splaying of the medial canthal tendons.

Fractures of the nose are primarily diagnosed by clinical examination. Patients sustaining a nasal fracture typically have epistaxis, nasal airway obstruction, localized pain, and an altered appearance of the nose. Physical examination requires proper lighting, suction, and intranasal application of vasoconstrictors by either aerosol spray or cotton pledgets. External signs of trauma such as lacerations, ecchymosis, or deviation of the nasal bridge should be noted. Edema often masks more subtle nasal fractures, and follow-up examination in 3 to 5 days is advisable if there are equivocal signs of nasal fracture. All areas of the nasal bones and cartilage should be palpated lightly to detect any bony crepitus, steps, focal tenderness, or loss of support. Once the internal nares have been adequately cleared of clots and the vasoconstrictor has taken effect, speculum examination may reveal mucosal tears, septal deviation and hematoma, and protrusion of fractured bony segments or displaced cartilage intranasally.

The patient should be questioned regarding any preexisting nasal trauma, deformity, or septal deviation because many of these patients will have previously sustained a fracture. Significant or obstructive nasal septal deviation with pink, firm, normal overlying mucosa is suggestive of chronic septal deviation and not an acute injury. The point of attachment of the upper lateral cartilage to the nasal bones should be carefully assessed for disruption or detachment.

Plain radiographs of the nasal bones are seldom useful in the diagnosis or treatment decision making related to isolated nasal fractures. Normal suture lines and old healed fracture lines may be indistinguishable from acute fractures. In addition, fractured or displaced cartilaginous structures are not visualized by plain radiographs. If the need for a radiographic diagnosis exists, CT is the preferred imaging modality. CT scans clearly delineate the hard and soft tissue nasal structures, and signs such as lack of mucosal edema or asymmetric inferior turbinate size and shape suggest a previous injury or chronic nasal septal deformity.

Acute nasal bleeding is best managed by topical measures: vasoconstrictors, external pressure, ice compresses, and elevation of the head of the bed. More severe bleeding is managed by nasal packing.

The need for reduction of nasal fractures and stabilization is based on the patient's cosmetic appearance and the patency of the nasal airway. Nasal fractures elevated and reduced within the first 48 hours are generally very stable. However, it may be necessary to wait 3 to 5 days to allow resolution of edema so that evaluation and proper alignment can be achieved. Most simple nasal fractures can be reduced with closed techniques under local anesthesia or intravenous sedation in an ambulatory setting.

Nasal-Orbital-Ethmoid Complex

Impacts of higher force to the nasal complex can result in fractures of the nasal bones, splaying, and posterior displacement into the ethmoids (Fig. 93-4C). Clinical signs of a fracture of the NOE complex are severe edema, telecanthus, lack of nasal projection, persistent epistaxis, occasionally CSF rhinorrhea, and periorbital ecchymosis. Blurred or altered vision may be present and is usually due to the edema and not to ocular restriction.

Fine-cut (1.0 to 1.5 mm) axial CT scans should be obtained to fully evaluate fractures of the NOE complex. Even with overlying lacerations, the medial canthal tendons are still usually attached to the bony anterior lacrimal crest.[7] The telecanthus is due to lateral displacement of the central portion of the frontal process of the maxilla. These segments are typically rotated outward and inferiorly displaced. The canaliculi should be evaluated for possible disruption.[8] If uncertainty exists, exploration of the wound plus repair under general anesthesia is warranted. Any copious, watery, or clear drainage should be collected and sent for β_2-transferrin assay to determine whether CSF rhinorrhea has resulted from fracture of the cribriform plate or anterior basal skull.

Open nasal fractures and coexisting septal fractures are best treated under general anesthesia because of patient comfort, the degree of manipulation required for reduction, and the possibility of excessive bleeding during instrumentation. An oropharyngeal pack is helpful to have in place so that clots do not pool in the hypopharynx. NOE fractures require open reduction, internal fixation, and often transnasal wiring under general anesthesia.

Frontal Sinus

Fractures of the frontal sinus occur almost exclusively in adults. The frontal sinuses are two separate bony cavities formed either by invagination of the nasal cavity into the frontal bone or by extension of superior ethmoidal air cells into the same area. The frontal sinus is not radiographically evident until 6 years of age and becomes fully formed around the age of 15 years. The frontal sinus drains into the middle meatus of the nasal cavity via a foramen or ostium (85%) and less frequently through the frontal nasal ducts. Five percent of the adult population have either a unilateral frontal sinus or almost no frontal sinus. The anterior sinus wall, or outer table, is relatively thick and resistant to fracture. The posterior table is thin membranous bone with adherence to the surrounding dura and periorbita. The frontal sinus wall and ducts are lined with cuboidal respiratory epithelium that invaginates into small bony depressions. These depressions (foramina of Breschet) allow venous drainage of the sinus mucosa. After trauma or incomplete removal of the mucosa, mucocele formation may arise from these remnants.

Fractures of the frontal sinus require high-impact force such as that experienced by passengers in a motor vehicle accident without safety restraints. Fractures of the frontal sinus account for less than 15% of fractures of the mid and upper portion of the face. The majority of the time these fractures are associated with overlying lacerations of the forehead. Palpation and inspection through an open laceration of the forehead can reveal a depressed deformity or bony ledge indicating a fracture of the frontal sinus. It is common to have associated nasal, NOE, and orbital and maxillary fractures. Intracranial injuries such as cerebral contusion, subdural hematoma, epidural hematoma, dural tear, intraparenchymal bleeding, pneumocephalus, and CSF leak are also often associated. A hyperextension injury or a fracture of the cervical spine should be considered in this high-risk group.

When fracture of the frontal sinus is suspected, an axial CT scan (1.5- to 3.0-mm cuts) should be obtained to assess the fracture and the degree of displacement of the anterior and posterior tables. Displacement of a frontal sinus fracture is defined as overlap by the amount of thickness of the adjacent cortical bone. Intermediate distinctions such as *mild* or *moderate* are confusing and have no clinical relevance. Both the anterior and posterior tables should be categorized as fractured or not involved and displaced or nondisplaced. A displaced posterior table (overlapped fracture margins) is often associated with tears of the dura or cerebral injury requiring neurosurgical intervention.

Management of fractures of the frontal sinus should follow a logical decision-making process, as outlined in Figures 93-5 and 93-6. Open fractures of the frontal sinus require emergency exploration and treatment. Open fractures can be treated by primary cutaneous repair and delayed treatment of the injury to the frontal sinus, if necessary. A fractured frontal sinus usually fills with blood and mucus after trauma. Prophylactic antibiotics that cover most sinus microorganisms (ampicillinwith clavulanate) or a first-generation cephalosporin is generally recommended. Patients with involvement of the posterior table and displacement are often administered a broader-spectrum antibiotic that can cross the blood-brain barrier. Cervical immobilization should be maintained until cervical spine injury can be definitively excluded. Sinus decongestants are of potential benefit and should be considered in patients with frontal sinus trauma.

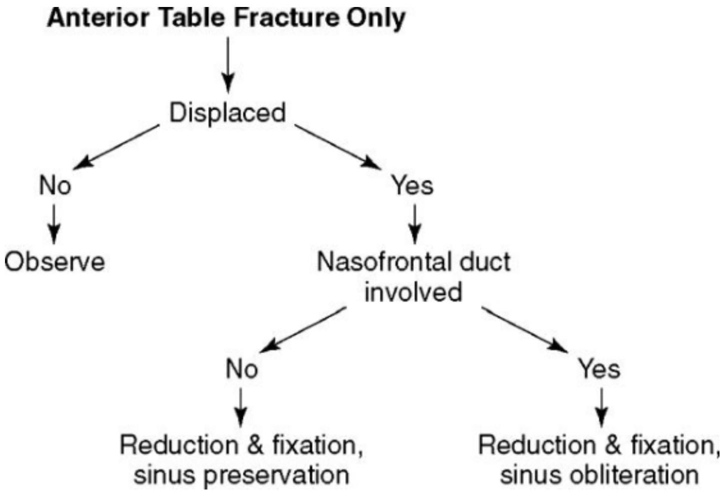

Figure 93-5 Fracture of the frontal sinus with appropriate management.

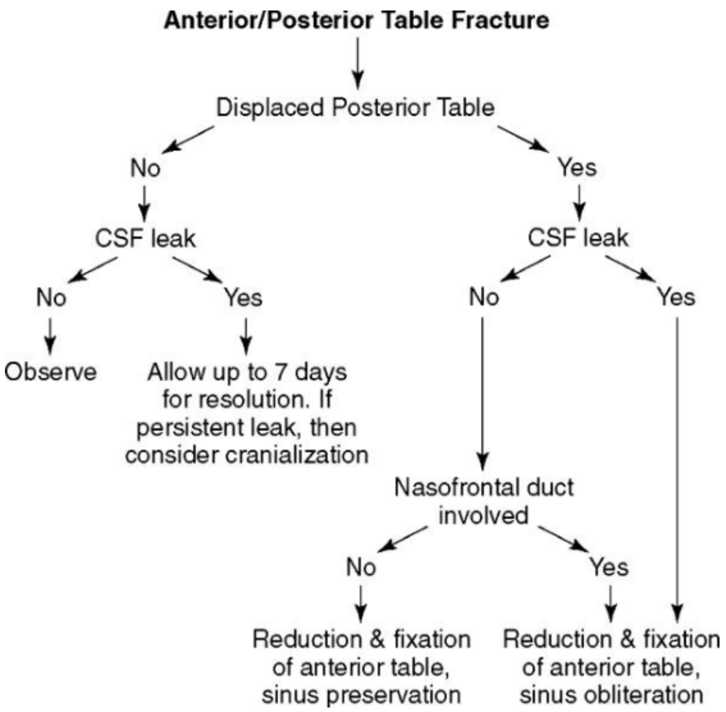

Figure 93-6 Fracture of the frontal sinus involving the posterior table requires further evaluation, and more treatment options exist, depending on the alignment of the posterior table and whether a cerebrospinal fluid (CSF) leak is present.

Definitive treatment of fractures of the frontal sinus depends on the extent of the fracture.[9] If the drainage system of the sinuses is significantly compromised, obliteration or cranialization is generally recommended. If only the anterior table is fractured and nondisplaced, surgical treatment is not usually necessary. A displaced fracture of the frontal sinus that is extensive enough to create a cosmetic deformity can be accessed directly through the fracture or via a liberal sinusotomy. The mucosal lining is then completely removed by curettage and drilling to deter formation of a mucocele, typically years later. The nasofrontal ducts can then be obliterated with fascia or bone grafts and the frontal sinus can be obliterated with autologous fat, bone, pericranium, or alloplastic material.

If only the anterior table is displaced without involvement of the nasofrontal ducts, primary repair without obliteration can be performed. Significant involvement or displacement of the posterior table usually requires direct exploration, with repair or cranialization depending on the degree of damage.[10] Smaller frontal sinuses in young patients can be cranialized by simply removing the posterior wall of the sinus, smoothing the edges, removing the mucosal lining, and obliterating the frontonasal ducts. Such treatment in older patients and those with large frontal sinuses may predispose to the development of chronic subdural fluid accumulations. With displaced fractures of the posterior table, the presence of associated tears of the dura requiring neurosurgical management is the rule rather than the exception.

SURGICAL APPROACHES

Airway Management

Special consideration should be given to secure the airway when repair of midfacial and panfacial fractures is undertaken.[11] A coordinated strategy and discussion of issues that affect the airway, such as the complexity of the injury, the length of the procedure, the surgical approach, the use of intraoperative or postoperative maxillomandibular fixation (MMF), and the route and method of intubation, should take place between the surgeon and anesthesiologist. Cervical collars, Mayfield head holders, and the direction of the anesthetic tube, including the method of securing it, should also be considered. Patients with isolated nasal or zygomatic fractures should be orally intubated. Patients with Le Fort I–level fractures can be safely intubated nasally with a standard tube or nasal RAE tube. Cervical spine precautions may necessitate that intubation be performed fiberoptically. Patients with Le Fort II, Le Fort III, and NOE fractures may not be suitable for nasal intubation as a result of the need to repair or manipulate the nasal bones and septum. Oral intubation is often not possible because of full dentition and the need for MMF during surgery to re-establish the occlusion and align the fracture segments. If adequate edentulous space exists for insertion of the oral endotracheal tube between the teeth in MMF, this is an option. The tube can be secured to the sound adjacent teeth with 26-gauge circumdental wire. Passing the tube distal to the second molars in a fully dentate patient is often not satisfactory because of kinking of the tube, interference with surgical access, or potential displacement during surgical manipulation and turning of the head. In this instance or when concern for violation of the cribriform plate exists, a tracheostomy should be performed at the start of the procedure and a reinforced cuffed endotracheal tube placed, its position confirmed, and the tube secured with suture.

Sequencing of Treatment

Generally, arch bars are first applied to the maxillary and mandibular dentition as described in the previous chapter.

An intact mandible provides an excellent reference for re-establishing proper midfacial projection and transverse alignment with the use of MMF. It is often preferable to then open all fracture sites that require reduction and plating. It is usually easiest to start plating around points of broad, solid bony contact such as the frontozygomatic sutures, frontal sinus, zygomatic arches, and zygomatic buttresses along the posterior maxilla. The thinner piriform rims, anterior maxilla, and nasal bones are fixated last. If the mandible is fractured, it is still best to place arch bars first, apply MMF, and then re-establish mandibular continuity by anatomic reduction and plating of the more anterior fractures (symphysis) and progressively working to the more posterior fractures, with condyles treated last. If both condyles are fractured, it is beneficial to open and plate at least one side to help re-establish proper posterior vertical dimension and a stable hinge axis point. When a patient is edentulous in one or both arches, best-fit anterior reduction plating is practical. If dentures exist, they can be secured to their respective arch by circum-mandibular wiring or screwing to the palate through holes predrilled in the lateral palatal shelves of the denture itself. In most instances, dentures interfere with surgical access, are ill-fitting or unstable, and do not greatly aid in fracture reduction. Repair or reconstruction of internal orbital fractures and defects is generally performed last because stable and aligned orbital rims help guide and stabilize the repair.

Maxillary/Le Fort Fractures

Le Fort I fractures are approached through a maxillary vestibular incision placed 1 cm from the outstretched mucogingival junction from first molar to first molar. Distal extension beyond this point invites herniation of the buccal fat pad and additional bleeding. Subperiosteal dissection is then accomplished with minimal stripping and soft tissue reflection on the inferior (or dental-bearing) segment that will just permit plate and screw placement. Infiltration of the maxillary vestibule with local anesthetic containing a vasoconstrictor minimizes oozing, and placing the patient in MMF before incision helps stabilize the maxillary segment and facilitates soft tissue dissection. Subperiosteal placement of toe-up Obwegeser retractors along the lateral maxillary “pockets” provides excellent “hands-free” exposure. Once the entire anterior maxillary fracture line is exposed with adequate areas for plating, the MMF is rechecked and tightened slightly, if needed, because of stretching of the wire. Any debris or small free-floating piece of bone is removed, and the fracture is reduced by applying upward vertical pressure on the mandibular angles bilaterally. Digital pressure in the submental region or chin often provides what appears to be improved reduction of the fracture, but at the expense of slight distraction of the condylar heads from the fossae. Plating in this position results in an immediate anterior open bite on release of the MMF wires, or it can occur postoperatively when the patient's masticatory muscles seat the mandibular condyles. Therefore, it is best to plate and fixate the maxilla with slight anterior wall contact irregularities because the fractured heavier posterior maxilla and pterygoid regions may not allow complete vertical reductions either. With the condyle seated by applying constant pressure to the angle region, the maxilla is fixated with 1.7- or 2.0-mm miniplates in the piriform and zygomatic buttress regions.[12] Generally, four plates are applied, and L shapes seem to work the best because two screws can be placed in the inferior segment of each plate without violating any tooth roots (Fig. 93-7). Irrigation should be used during drilling to prevent overheating of the thin maxillary bone. Placing the anterior plates 2 to 3 mm laterally from the edge of the piriform rims and slightly medially inward allows engagement of both the anterior maxillary and lateral nasal walls and thus provides improved stability.[13] Screws 4 to 5 mm in length are the norm. Once all plates are placed, the MMF wires (not the arch bars and circumdental wires) are cut and removed, and the occlusion is checked by applying intermittent mild pressure on the mandibular angles. The circumdental wires and arch bars are removed only after adequate fracture reduction and fixation are confirmed and the surgeon is confident that there will be no need for a period of postoperative MMF or elastic guidance.

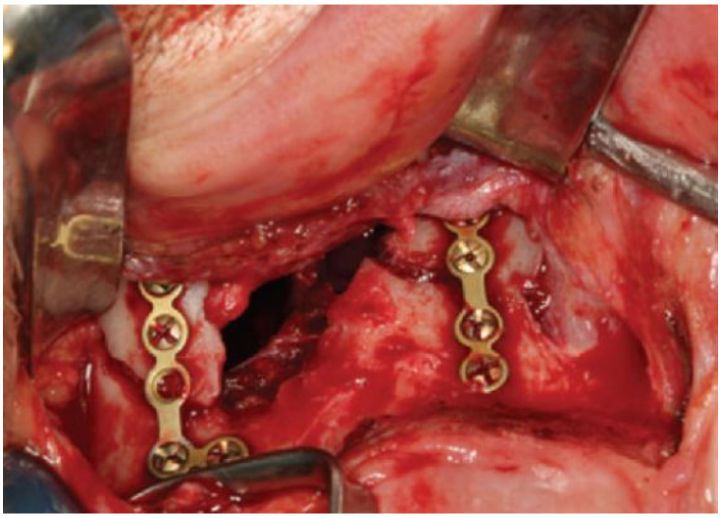

Figure 93-7 Le Fort I fracture repair. The right maxillary vestibular incision was made 1 cm above the mucogingival junction. Arch bars were secured and the patient placed in maxillomandibular fixation. The anterior maxillary bony reductions appear slightly off, but this is typical because it is usually impossible to fully reduce a fractured posterior maxilla with the condyles seated by pressure at the angles of the mandible. The maxilla is fixated with miniplates and 2.0-mm screws in the areas of heaviest bone: the buttress *(left)* and the piriform rim *(right)*. No attempt is made to “reconstruct” the anterior maxillary wall defect, and it should heal uneventfully. Any free bone fragments should be removed from the sinus.

For closure, a nasal cinch suture that engages the underside or inner aspects of the alar bases is placed and secured to draw the ala together to the preinjury/presurgical position. Closure of the muscular layer is then performed on each side with several interrupted 4-0 Vicryl sutures (braided polyglactin suture, Ethicon). The maxillary mucosal incision is closed with 3-0 or 4-0 chromic suture in a running horizontal mattress stitch. The pack should be removed from the throat and an orogastric tube passed. The area should be suctioned and then the tube withdrawn before extubation.

Treatment of a Fort II fracture is similar to treatment of a Le Fort I fracture but usually requires higher medial dissection for plating. Generally, plating of the frontonasal or high medial nasomaxillary fracture lines is unnecessary. However, if comminution or lack of stability dictates the need to fixate in this region, access via a coronal incision is preferred over an “open-sky”approach (H shaped; combined medial brow and glabellar and lateral nasal incisions). Sometimes an existing laceration can be accessed and extended slightly for plating. Fixation of the frontonasal junction with bilateral smaller plates along the lateral nasal/medial orbital rim contours is less palpable than fixation with a miniplate directly over the midforehead and nasal dorsum.

Le Fort III fractures generally require both a maxillary vestibular incision (because there are usually additional maxillary lines of fracture) and a coronal approach to access and fixate the frontonasal, zygomaticofrontal, and zygomatic arch fractures. The coronal incision is a wavy line that is placed approximately 2 cm posterior to the hairline (midline) and extended posteriorly and then inferiorly in the preauricular region (Fig. 93-8). The wavy line facilitates “turning the flap over” and has the added benefit of being less noticeable when the hair is wet, such as during swimming, and when mild hair loss has occurred. The incision is carried through skin, subcutaneous connective tissue, galea aponeurotica, and loose areolar tissue in the midline and extended laterally in the supraperiosteal plane to the superior temporal line bilaterally.

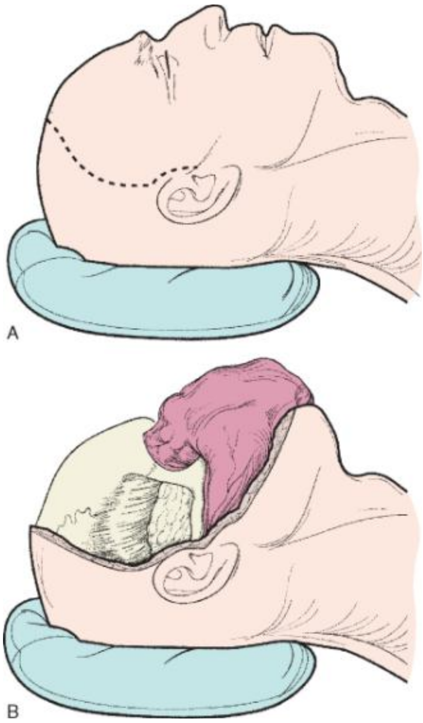

Figure 93-8 Design of a coronal flap. **A,** The preauricular incision is not extended below the lower edge of the tragus. Going below and deep to this invites injury to the main trunk of the facial nerve. At the superior extent of the auricular attachment the incision is curved posteriorly for about 0.5 cm to help avoid cutting the superficial temporal artery (STA). The STA can generally be left intact and reflected forward with the coronal flap. **B,** A soft wavy line rather than a straight side-to-side incision allows ease in turning the flap over.

The subgaleal plane of dissection is contiguous with a plane deep to the parietotemporal fascia in the area of the temporalis muscle. Dissection is carried anteriorly to the frontal bone, and a horizontal incision is made through the periosteum approximately 2 to 3 cm superior to the orbital rim (Fig. 93-9). This incision is carried laterally to the superior temporal line and is joined with the preauricular area inferiorly through the superficial layer of the deep temporal fascia to protect the temporal branch of the facial nerve (Fig. 93-10). The frontal branch or superior division of the facial nerve courses in a plane superficial to the deep temporal fascia approximately 1 to 2.5 cm from the tragus along the zygomatic arch. This approach provides access to the entire medial, lateral, and superior orbital frame. Closure may include suspension of the cut temporal fascia over the temporalis muscle and should include deep closure of the galea aponeurotica, subcutaneous tissue, and skin. Miniplates secured with 3- to 4-mm-length screws are adequate for fixation (Fig. 93-11). It is desirable to use burrs with drill stops (ledges that prevent drilling beyond predetermined depths) when working around the orbital rims. The lateral canthalattachments to the internal orbit (Whitnall's tubercle) should not be disturbed during dissection and therefore do not require reattachment.

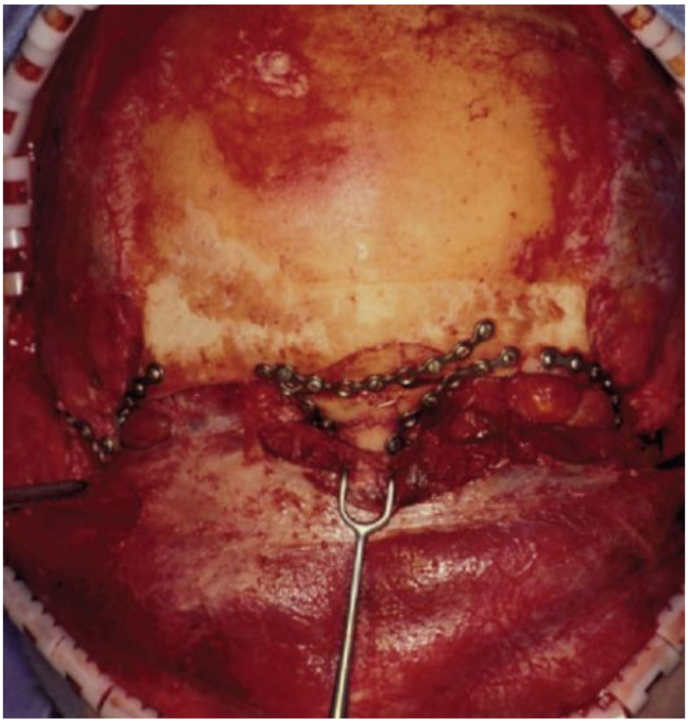

Figure 93-9 Frontal view of a reflected bicoronal flap. The pericranium is cut horizontally 2 to 3 cm above the superior orbital rims. The supraorbital nerves were in notches (not foramina) and were freed for full exposure of the nasal complex and superior medial orbital walls. Reduction of the fractures of the nose and orbit completely reduced the telecanthus, and therefore transnasal wiring was unnecessary.

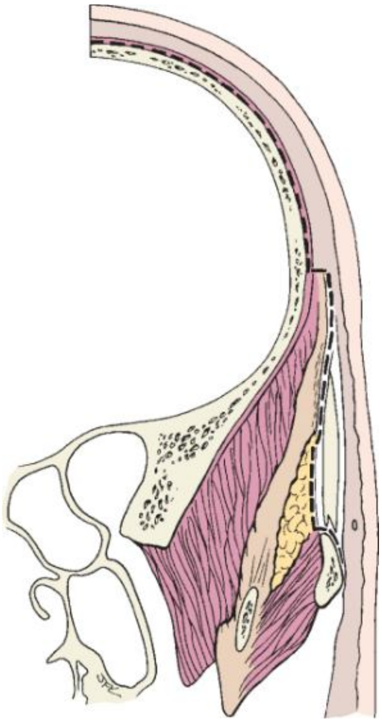

Figure 93-10 Left coronal view of the incision through the superficial layer of the deep temporal fascia just below the temporal line. The dissection should be deep to this layer to protect the frontal branch of the facial nerve and be confluent and deep to the periosteum of the zygomatic arch to protect the superior division of the facial nerve.

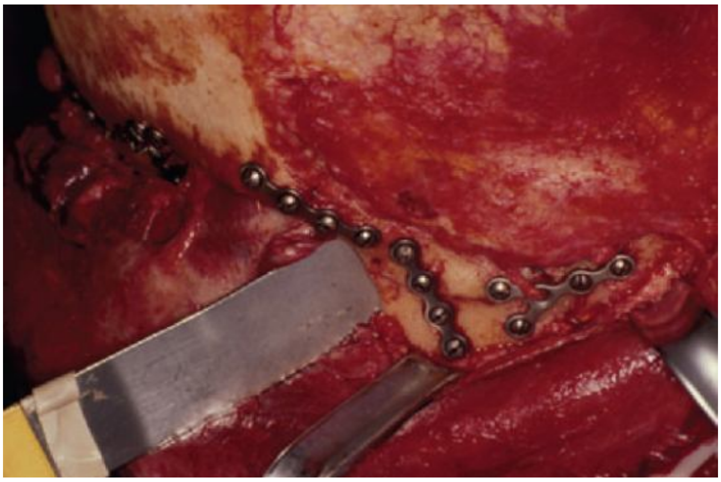

Figure 93-11 Left lateral view of a bicoronal dissection and plating of the arch and lateral orbital rim. Note that clean reflection of the superficial temporal fascia along with the arch periosteum led to a safe and dry field.

Skeletal suspension wires from the intact portion of the facial bones (frontal or circumzygomatic) can aid in stabilizing the maxillary fractures or can be used as a sole means for accomplishing closed reduction by securing them through intermediate wires to the mandibular arch bar or circum-mandibular wires (Fig. 93-12).

Figure 93-12 Skeletal suspension wires as seen on a lateral cephalogram. Bilateral frontal suspension wires (24- and 26-gauge "pullout wires") and circum-mandibular wires (24 gauge) were passed with awls and secured to arch bars to support and immobilize a Le Fort I fracture. The frontal and circum-mandibular suspension wires were secured to each other with a 26-gauge intermediate wire loop. Open treatment was not performed because of cervical spine injury and the patient's critical status. A tracheostomy had been performed previously to secure the airway.

After repair of any Le Fort fracture (I, II, or III), the nasal septum should be inspected to make sure that it is not subluxated or laterally displaced. The nasal septum can be repositioned or slightly trimmed at the inferior aspect, if necessary, to allow positioning in the midline. Once the fractures are reduced and fixated, a forced duction test of both eyes should be performed to rule out entrapment of muscle because the majority of these fractures have an orbital component.

Zygomatic Fractures

Isolated fractures of the zygomatic arch are best repaired within 72 hours of the injury. In this time frame the arch tends to reduce easily, with excellent indexing and stability and no need for internal fixation or external splints. Fractures of the arch can be approached through a limited lateral brow incision with blunt dissection down to the supraperiosteal plane or via a Gillies (2.5-mm oblique temporal hairline) incision and avoidance of the superficial temporal artery.[14] The temporal fascia is exposed, and a Freer elevator is used to create a small pocket between the fascia and temporalis muscle. With either approach, a blunt stout instrument (curved Kelly clamp, urethral sound, or Rowe zygomatic elevator) is inserted beneath the arch. It is often helpful to palpate with the opposite hand intraorally in the posterior buccal sulcus to detect a slight deflection from the tip of the instrument. The arch is then elevated with lateral and superior force while taking care to not lever off any other facial bones. An audible crack or pop indicates that the fracture has been reduced, and palpation of a convex contour confirms the reduction. The subcutaneous and skin layers are closed, and the patient is advised to avoid contact to the area for several weeks. A maxillary vestibular (buccal sulcus) approach can be used, but it might be accompanied by bleeding from the masseter muscle and has the risk of inferior/lateral orbit violation if the arch elevator is overinserted beneath a moderately depressed arch fracture.

Fractures of the ZMC can be approached by a variety of incisions: lateral brow, modified blepharoplasty, hemicoronal, transconjunctival, infraciliary, and maxillary-vestibular. The degree of injury and the displacement often dictate which areas of the ZMC must be accessed and fixated.[15,16] Although a single miniplate at the frontozygomatic suture may suffice for healing, it may not provide absolute rigidity to maintain malar projection and ideal contours. Typically, at least two points of fixation and plating are used to achieve rigidity. We generally prefer plating at the frontozygomatic suture because it is easily indexed and has heavy bone stock for fixation. The second area of fixation can be either across the zygomatic buttress (maxillary vestibular incision) or at the infraorbital rim. The latter is chosen when exploration of the orbital floor or reconstruction is anticipated (Fig. 93-13). These approaches and materials for repair are fully discussed in the next section.

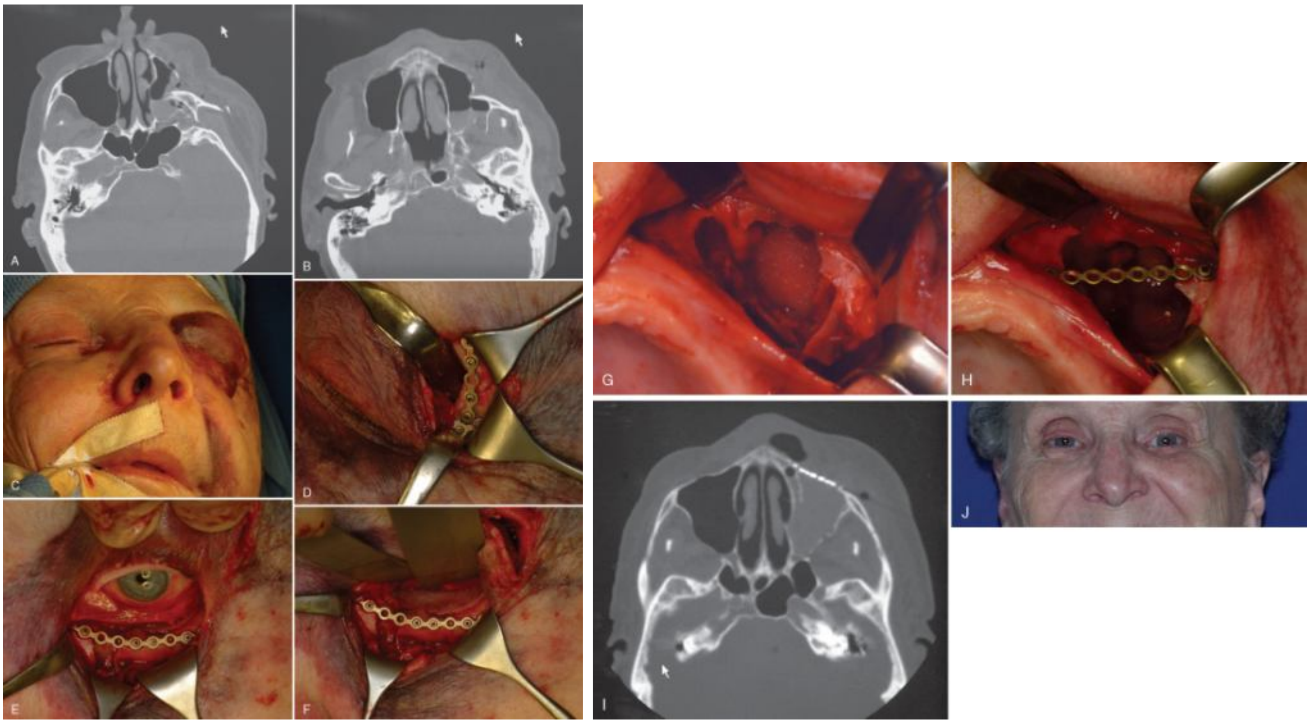

Figure 93-13 Severely displaced fracture of the left zygomatic complex. **A,** Axial computed tomography (CT) scan showing the buttress driven inward to the posterior maxillary sinus and approaching the pterygoid plates. The *cursor arrow* overlies the area of impact, and a depression is seen despite tremendous soft tissue swelling. **B,** Slightly inferior CT scan demonstrating the fractured posterior zygomatic arch component with probable mechanical impingement on the tip of the coronoid process. Difficulty opening the mouth for oral intubation should be anticipated and evaluated. The soft tissue swelling "masks" the degree of bony displacement. **C,** Facial appearance as the patient was prepared for surgery urgently because of a tense left periorbita and decreased vision in the left eye. She was taking warfarin (Coumadin) for atrial fibrillation and suffered significant localized bleeding and in essence "a compartment syndrome" of the orbit. **D,** The left lateral brow incision was first undertaken and the entire zygomatic complex grossly reduced. A miniplate was fixated with 1.7-mm-diameter, 3 mm-long screws after the inferior orbital rim and zygomatic buttress were exposed and reduced. **E,** Orbital rim plated after transconjunctival retroseptal dissection and inferior cantholysis. The rim was stabilized with a miniplate and 1.3-mm-diameter screws. **F,** The floor of the orbit had been almost completely destroyed. It was reconstructed with a 0.85-mm-thick sheet of Medpor (high-density porous polyethylene) that was fixated inferolaterally to the intact floor ledge with a single 5-mm-long, 1.7-mm-diameter screw to prevent migration or "unflexing" of the gently curved Medpor. Forced duction of the globe should be performed at this stage to ensure that none of the orbital contents have become entrapped or tethered by the repair or fixation. **G,** Maxillary vestibular view of the reduced zygoma and resultant anterior maxillary wall defect that was not reconstructed. The Medpor orbital floor repair is visible from below. The patient's edentulous maxillary ridge can be seen in the lower left area. **H,** The zygomatic buttress was fixated with a miniplate and 1.7-mm-diameter screws. **I,** Postoperative axial CT scan obtained the following day showing symmetrical alignment. **J,** Facial view 1 month after surgery.

Before plating any fracture lines, all sites are exposed, and the ZMC is reduced to satisfaction in each area.[17] The ZMC is then fixated with miniplates (1.7- to 2.0-mm systems) while taking care to maintain the plates several millimeters away from the orbital rim so that they will not be visible or palpable. If associated facial fractures (Le Fort, frontal sinus) or comminution exists, it may be necessary to obtain direct access to the entire zygomatic arch for fixation and stabilization.[18] This is accomplished via a coronal or hemicoronal approach. Care should be exercised to not "overelevate" the arch at its midpoint. The zygomatic arch has a slight curve at its anterior and posterior extents but is flat in the middle. Overprojection of the arch should be avoided because it causes a tumor-like protrusion postoperatively that will persist.

Orbit

Once it has been determined that a patient requires surgical intervention for a fracture of the orbit, several factors must be considered when selecting the surgical approach and method of reconstruction. The primary consideration is to determine which walls need to be repaired. Associated facial fractures, lacerations, and surgeon preference are other important factors.

Three basic incisions provide access to the orbital floor: infraorbital, subciliary, and transconjunctival (Fig. 93-14). The subciliary and transconjunctival incisions, because of their superior aesthetics, are the most commonly used today.[19,20] In the subciliary approach, the skin is incised several millimeters below the lid margin in a skin crease and dissected from the orbicularis oculi for a few millimeters before splitting the muscle fibers down to and anterior to the orbital septum. Division of skin and muscles at different levels helps prevent direct scarring and retraction of the eyelid. The dissection is then carried down to the orbital rim, the periosteum is incised 2 mm below the orbital rim (below the arcus marginale), and the dissection is extended posteriorly along the orbital floor to elevate the orbital contents and reduce the floor fractures. One can safely dissect 30 mm back along the floor because the optic canal is 40 mm from the anterior lacrimal crest and is superiorly and medially located. After repair is complete, several tacking sutures can be placed in the periosteum at the rim, and only the skin is closed with cutaneous 6-0 nylon suture.

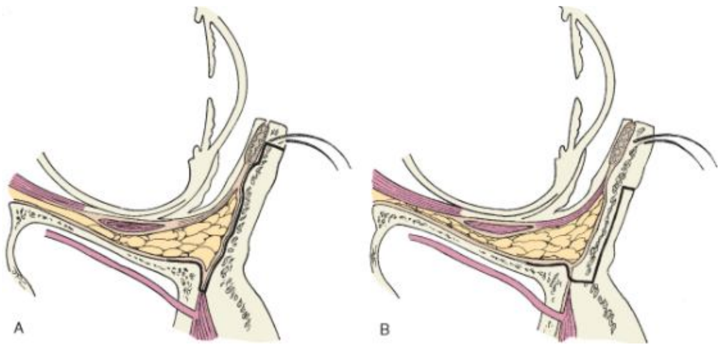

Figure 93-14 Inferior lid approaches. **A,** Subciliary dissection with the initial skin incision just below the lash line through orbicularis oculi muscle and staying anterior to the orbital septum and carried inferiorly to the rim. The periosteum is incised several millimeters below the rim (level of the arcus marginale and orbital septum attachment) and then reflected to gain access to the orbital floor. **B,** Lower eyelid skin crease approach to the inferior orbital rim and floor. After incising the skin, the inferior dissection is performed anterior to the orbicularis oculi muscle.

The transconjunctival approach has two variations: retroseptal and preseptal. The retroseptal approach is a more direct approach to the orbital floor, but it exposes the extraconal fat, which can obstruct the surgeon's view. For this reason the preseptal approach is preferred. To avoid excessive tension and stretching of the lower eyelids, many surgeons prefer to start by performing a lateral canthotomy (3-mm skin incision in a crow's foot line) and inferior cantholysis, which consists of division and release of only the inferior leaflet of the lateral canthus (Fig. 93-15). The lid is then held out and forward with fine forceps, and the palpebral conjunctiva and inferior lid retractors (smooth muscle that is an extension of the capsulopalpebral fascia) are undermined and incised 2 to 3 mm below the inferior edge of the tarsus. If one undermines and incises at the depth of the fornix and aims toward the caruncle (small yellow mound of tissue) medially, injury to the tarsus and inferior canaliculus can be avoided.

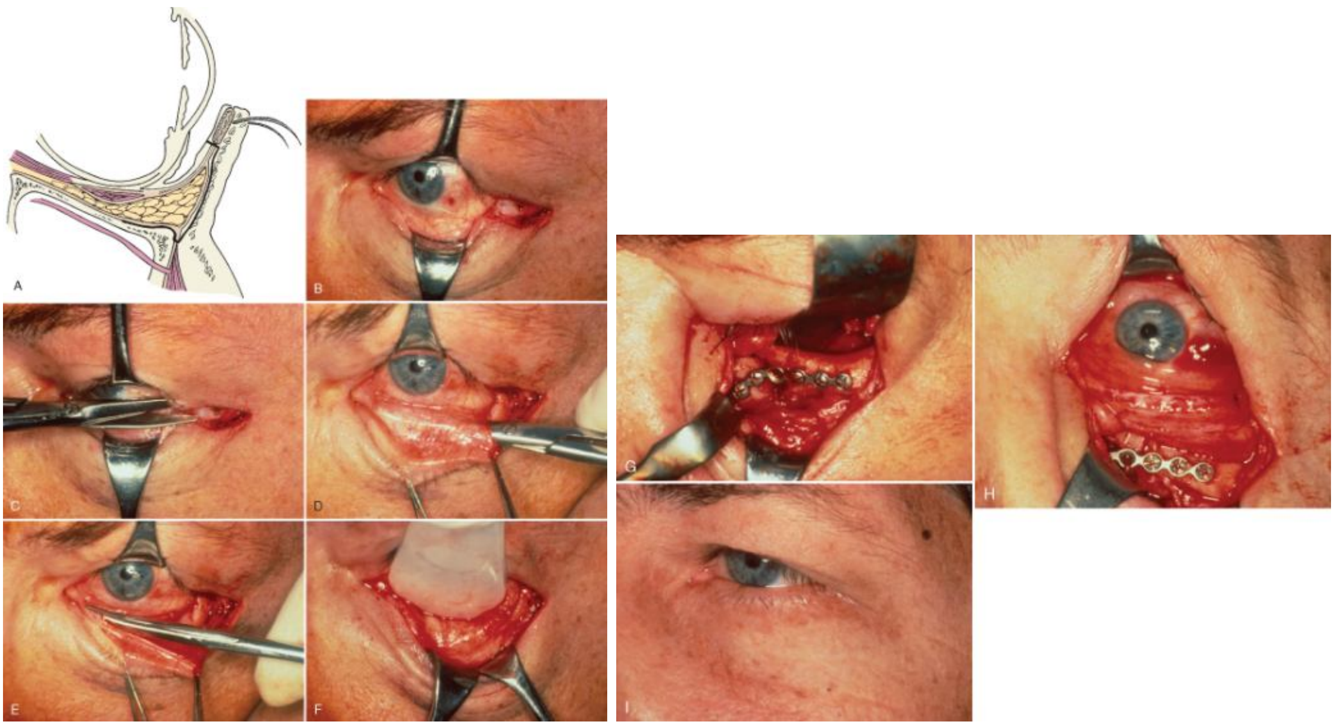

Figure 93-15 Transconjunctival preseptal approach. **A,** The palpebral conjunctiva and inferior lid retractors are incised below the inferior edge of the tarsal plate. The inferior dissection is anterior to the septum to avoid herniation of orbital fat into the operative field. **B,** Left lateral canthotomy incision. Generally, it is only 5 to 7 mm in length and carried through the orbicularis oculi muscle. **C,** Inferior cantholysis performed with tenotomy or iris scissors. It is helpful to angulate the tips of the scissors slightly downward to ensure division of only the inferior canthal tendon and leaving the superior leaflet intact. The tips of the scissors are just superficial to the periosteum of the rim when the cut is performed. The cut lateral edge of the lid is grasped with 0.5-mm pickups, and additional "snipping" of the canthal attachments is performed until the lid can be adequately mobilized for the following step. **D,** The lid is gently held outward at two points by the assistant while the surgeon undermines the palpebral conjunctiva and inferior lid retractors (smooth muscle). This is toward the depth of the fornix, and the tip of the blunt scissors is pointed medially toward the caruncle. **E,** These same layers are then divided. **F,** Desmarres retractors are used to reflect the lower lid inferiorly. A Lucite lid plate or malleable retractor rests on the inner edge of the rim to retract the septum and orbital contents inward during incision of the facial periosteum several millimeters below the rim. **G,** The fracture of the zygoma has been reduced and the rim aligned and fixated with a miniplate and 1.7-mm screws. **H,** Generous access as a result of inferior cantholysis and a clean field secondary to the preseptal approach. **I,** Postoperative appearance at 6 weeks.

The dissection is then carried inferiorly along the plane superficial to the septum (to avoid herniation of fat) down to the orbital rim, and the periosteum is incised on the facial aspect. After orbital repair the periosteum is approximated with several fine interrupted sutures. The conjunctiva is closed with several 6-0 fast-absorbing gut sutures. If there is any uncertainty in reapproximating the correct layers, do not suture. Tacking the orbicularis oculi to the periosteum of the orbital rim will result in acute ectropion, lid retraction, and a "hound dog eyes" appearance. If this occurs, have the patient vigorously massage the area to stimulate its release. If the situation does not resolve within several weeks, reopen the site and release it. It may be advisable to place a reverse-Frost (modified tarsorrhaphy suture) for 24 hours. Reattachment of the inferior leaflet of the lateral canthus is accomplished with 4-0 Mersilene double-armed suture on an S-2 needle. The needles are passed internally to externally along the lateral orbital rim (cut margins) to ensure proper insetting of the lid.

Access to the superior orbital rim and the frontozygomatic suture can be achieved with an eyebrow incision, an upper blepharoplasty incision, or coronal dissection. The eyebrow and blepharoplasty incisions, because of their excellent aesthetics, are most often used. The coronal incision is used when extensive facial or skull fractures are present. The eyebrow incision is placed on the lateral aspect (1.5 cm) above the brow and parallel to the hair follicles. Sharp dissection with electrocautery can be carried down through the subcutaneous tissue, orbicularis oculi muscle, and periosteum. This provides excellent access to the lateral rim and plating at the frontozygomatic suture, which is 1 cm above the lateral canthus. The upper blepharoplasty incision is similar to the brow incision, but slightly more inferior and more horizontal. It is placed in one of the skin creases of the upper eyelid and carried through the subcutaneous tissue, orbicularis oculi, and periosteum. A 1.0- to 1.5-cm incision is all that is necessary because of the mobility and laxity of the lid tissues. Closure requires suturing of the periosteum and skin.

Access to the medial orbital rim and superior aspect of the medial orbital wall can be obtained through a coronal (see Fig. 93-9) or a lateral nasal incision. Access to the inferior medial orbital wall can be achieved via a transconjunctival approach. The lateral nasal approach involves a vertical, 1.5-cm curvilinear incision approximately 0.5 to 1.0 cm anterior to the medial canthus. Care must be taken to not place the incision too close to the medial canthus, which can result in scar contracture and “webbing.” Dissection is carried through the skin, subcutaneous tissue, orbicularis oculi, and periosteum. The periosteum can then be reflected posteriorly and superiorly to the medial orbital rim and wall. The medial canthal tendon, which envelopes the lacrimal sac, lies posterior and inferior to the incision. A single subcutaneous suture and multiple interrupted skin sutures are all that is required for closure.

The goal of primary reconstruction of internal fractures of the orbit is restoration of mobility and function of the globe, re-establishment of normal volume, and elevation of prolapsed soft tissues from the paranasal sinuses.[21] Isolated linear fractures are reduced, and any entrapped soft tissues are freed. No grafting is required, but a piece of Gelfilm or fine (0.85 mm) Medpor (porous polyethylene, Porex Surgical) can be laid over the site if the surgeon is concerned about impingement or risk of re-entrapment.[22]

Blowout and larger defects can be reconstructed with a variety of materials: split calvarial bone, Medpor, and titanium mesh. The graft should not extend all the way to or over the inferior orbital rim. This creates a posterior ramping effect on the globe and does not restore the normal contours of the orbital floor. The orbital floor dips down several millimeters immediately behind the inferior rim and has a gentle concave curve from side to side and anterior to posterior. Overgrafting with excessive reduction of orbital volume or placing the graft too anterior with posterior sloping tends to prop the globe too far superiorly and creates a vertical dystopia with the possibility of persistent enophthalmos. Attempts should be made to rest the graft on intact bony ledges and to position the graft beyond the equator of the globe posteriorly. The grafts can be secured with screws or sutures, depending on the nature of the reconstruction (Fig. 93-16). Unsecured grafts can migrate forward to the rim and be palpable or angle and protrude into the paranasal sinuses.

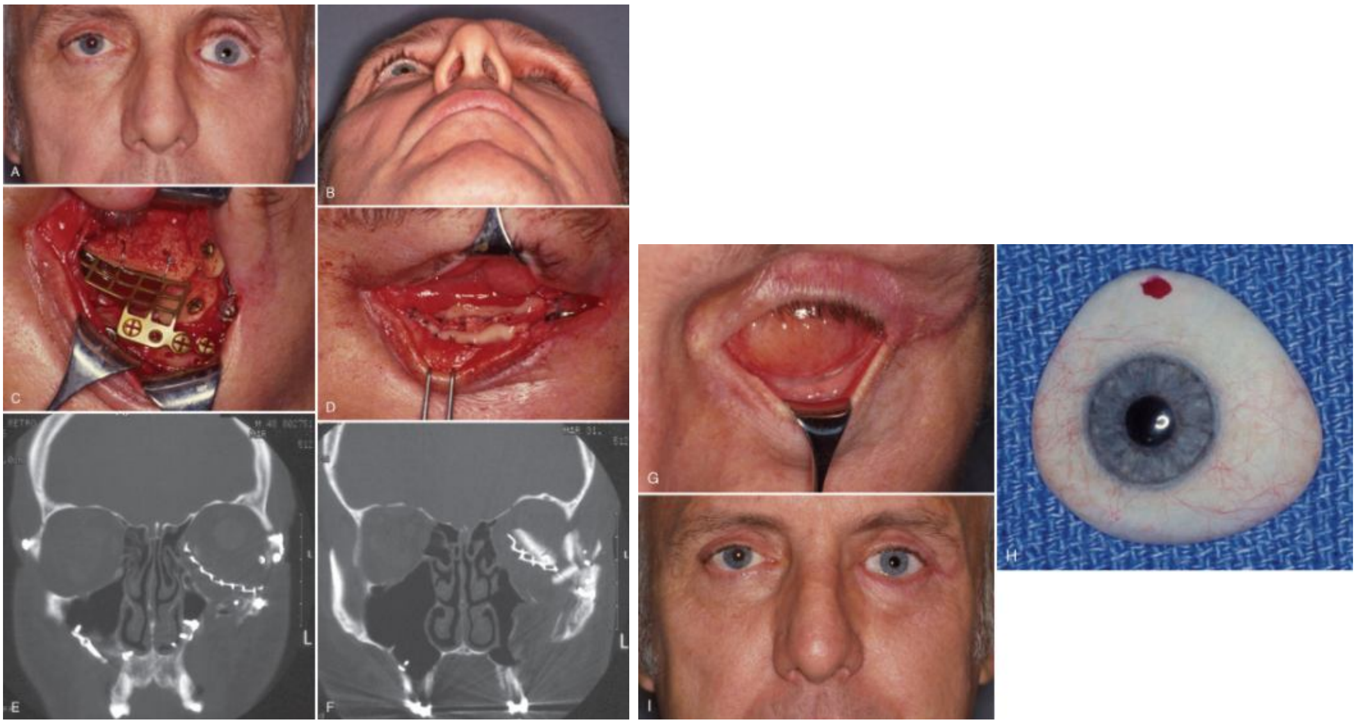

Figure 93-16 **A,** Frontal view of a 53-year-old man who had fallen from a tree and sustained a fracture of the zygomatic complex (ZMC) and a ruptured left globe. He had been treated at another center by open reduction and internal fixation of the left ZMC, enucleation of the globe, and insertion of a 12-mm hydroxyapatite (HA) sphere. He complained that his prosthesis would dislodge and that his left “eye” appeared sunken in and down. **B,** Submental view showing significant left enophthalmos (>10 mm). The HA implant sphere was too small and the orbital volume was too large. **C,** The left orbit was reconstructed with a titanium mesh plate that served as a scaffold for multiple calvarial split-thickness grafts. The grafts were placed posteriorly and laterally behind the equator of the HA globe. **D,** To restore lower lid length and reconstruct the fornix, a free mucosal graft was harvested from the buccal aspect of the mouth and inset and the form supported by 6-0 Prolene sutures and a Telfa bolster. **E** and **F,** Postoperative coronal computed tomography scans demonstrating the reduced orbital volume with mesh and grafts in place. **G,** Fornix and anterior projected mucosalized HA sphere 6 weeks after surgery. **H,** New and thinner prosthesis (eye contact lens) with a red dot that helps the patient orient it for insertion. **I,** Facial appearance 2 months after the procedure.

Fractures of the orbital floor should not be overtreated. If there are no firm findings—entrapment, greater than a 50% floor defect with orbital herniation, acute enophthalmos—allow the edema to resolve, reevaluate the wound, and intervene only if a functional deficit or cosmetic deformity warrants repair.

Nose

Nasal and septal fractures should be repaired as soon as possible but can be delayed 7 to 10 days to allow resolution of edema and reassessment. Closed reduction is all that is required for most nasal and septal fractures. It can be accomplished under topical anesthesia, local anesthesia, intravenous sedation, or general anesthesia. Topical anesthesia and vasoconstriction are achieved with the insertion of cottonoids (0.5 × 3 inches) or cotton pledgets saturated with 2% to 4% lidocaine and the vasoconstrictor of choice (1 : 50,000 epinephrine, 1 : 10 dilution of 0.25% phenylephrine [Neo-Synephrine], 0.05% oxymetazoline). These objects are inserted high into the nasal vault between the nasal bones and septum, at the base of the septum, and at the lateral inferior turbinates.

It is beneficial to inject local anesthetic at each site (0.5 mL) along the lateral nasal bones, at the infraorbital nerve externally, and at the base of the anterior septum. Even if general anesthesia is used, the local anesthetic with vasoconstrictor facilitates direct vision and minimizes bleeding and postoperative pain. After waiting a full 10 to 15 minutes for the vasoconstrictive action, the pledgets are removed. A blunt elevator (Goldman elevator, knife handle) is inserted a predetermined amount with the thumb pressed against the external skin overlying the nasal bone to be elevated. Slight thumb pressure allows rotational or twisting motion as the nasal bone is elevated and aligned (Fig. 93-17). The nasal bones and dorsum are then inspected and palpated for midline alignment, projection, and symmetry. In general, the nasal bone fractures are reduced first, and then the nasal septum is inspected with a speculum and aligned as needed. Asch forceps are inserted bilaterally into the nasal cavity; they can be placed higher in the nasal vault to provide additional anterior force and elevation of the nasal bones or, more commonly, along the base and midseptum to bring the structures into midline. The reduced septum should provide support to the overlying nasal bones and allow a patent bilateral nasal airway. After final inspection of the nasal bones and septum, internal silicone splints can be placed bilaterally along the septum, and a 3-0 silk transfixion suture should be passed through both splints and the anterior septal cartilage to secure them.

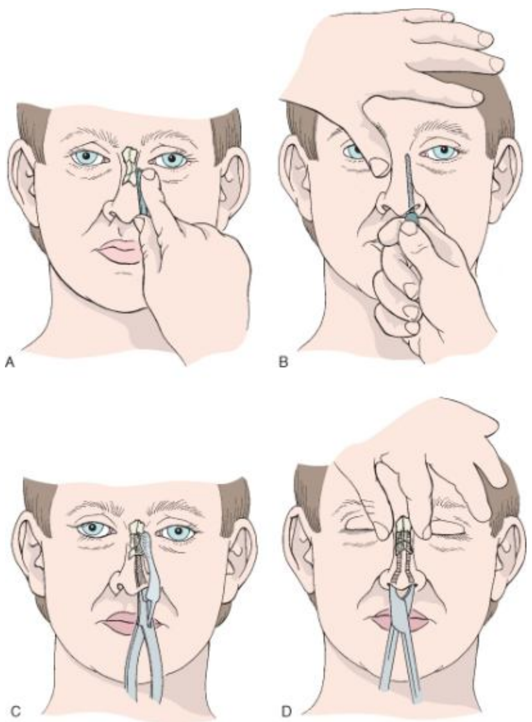

Figure 93-17 Reduction of a fracture of the nose. **A** and **B,** The bowed or C-shaped deformed nasal complex is reduced with a blunt elevator. **C** and **D,** Reduction of fractures of the nose that are telescoped is accomplished with Walsham and Asch forceps.

The nasal skin is then dried and "defatted" with alcohol wipes and a small amount of topical adhesive solution applied, followed by porous paper tape or Steri-Strips. A thermoplastic splint can then be trimmed, heated, and adapted to the external nasal contours and secured with adhesive tape. These coverings are generally left in place for 1 week. Compound nasal fractures should be repaired earlier. Direct access to the bones through the laceration may allow wiring or plating for stabilization if necessary. Closed reduction is accomplished with a similar sequence and protocol. External splinting, even over sutured lacerations, is acceptable. Attempts should be made to close mucosal lacerations over the nasal and septal cartilage with absorbable 5-0 suture.

Nasal-Orbital-Ethmoid Complex

NOE injuries result in significant aesthetic deformities. Injuries to the nasal airways and lacrimal system can also occur. Injuries to the lacrimal system can be managed by placing small silicone tubes (Crawford tubes) within the superior and inferior canaliculi down through the lacrimal sac, retrieving them intranasally with a Crawford hook below the inferior turbinate, and then tying them together. Repair of NOE injuries is recommended within the first week after injury because soft tissue collapse and readaptation cause permanent thickening of this region. Medial rectus entrapment with NOE injuries is uncommon. The primary defects that occur with NOE injuries are splaying of the nasal bones, posterior displacement with lack of support, and lateral canthal displacement.

Isolated medial orbital wall defects are best approached directly through lateral nasal incisions. Approaches to the inferior orbital rim and floor, such as the subciliary or transconjunctival approaches, are often necessary for fixation of displaced segments of bone or fixation of graft material (alloplastic or autogenous bone) to stable bone. Coronal approaches may be necessary when there are associated frontal sinus fractures; however, these approaches offer limited access for isolated NOE fractures.[23] Access through any combination of overlying laceration, coronal incision, or lateral nasal incision is generally required to adequately treat these injuries (Fig. 93-18).

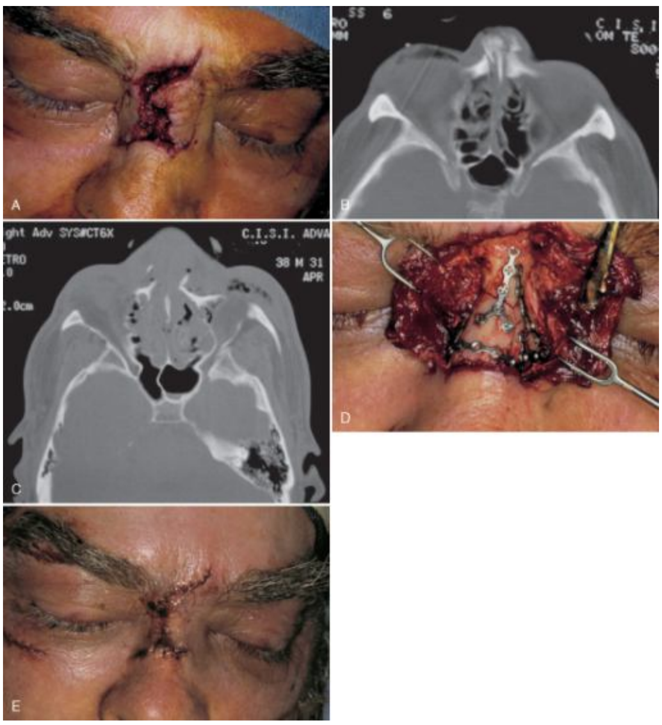

Figure 93-18 **A,** An elderly trucker struck the bridge of his nose on the steering wheel during a rollover accident. Portions of the comminuted nasal-orbital-ethmoid fracture and splayed nasal bones were palpable through the overlying laceration. **B** and **C,** Axial computed tomography scans demonstrating the typical posterior depression and outward splaying of the nasal bones with ethmoid disruption and a fractured buckled septum. **D,** Microplates with 1.2-mm screws were used to meticulously piece all the fragments into place. No transnasal wiring was necessary because the medial canthal tendons remained attached to the bony lacrimal crests and were reduced with the fracture repair. **E,** Sutured laceration and narrowed canthi at the end of the procedure.

Traumatic telecanthus should be treated by direct fixation techniques with 1.0- to 1.7-mm plating systems. External splinting rarely yields satisfactory results. With NOE fractures, the medial canthal tendons usually maintain their attachments to the bony segments. Proper reduction plus fixation of the bony skeleton to the surrounding stable bone (maxillary, orbital, or frontal) often corrects the telecanthus deformity. With more severe injuries it is often necessary to perform transnasal fixation. A fine stainless steel wire (30 gauge) can be directly secured or sutured to the canthal tendon for this purpose (Fig. 93-19). The wire is inserted just posterior and superior to the lacrimal fossa by a wire-passing burr or curved needle. The two limbs of the wire can then be twisted gradually around a short section of plate in the opposite orbit to adjust and "fine-tune" the canthal position. Avoid nasal packing to stabilize or align the nasal septum. The packing tends to bow the nasal bone reduction out and creates a permanently full and broad-appearing nose. If the septum is not in the midline, realign the septum surgically or trim the base and stabilize with thin Silastic internal splints bilaterally. Inadequate narrowing of the nasal bones when treating NOE fractures leads to persistent telecanthus and lack of nasodorsal projection. Transnasal wiring during the initial repair avoids this complication, which is extremely difficult to correct later.

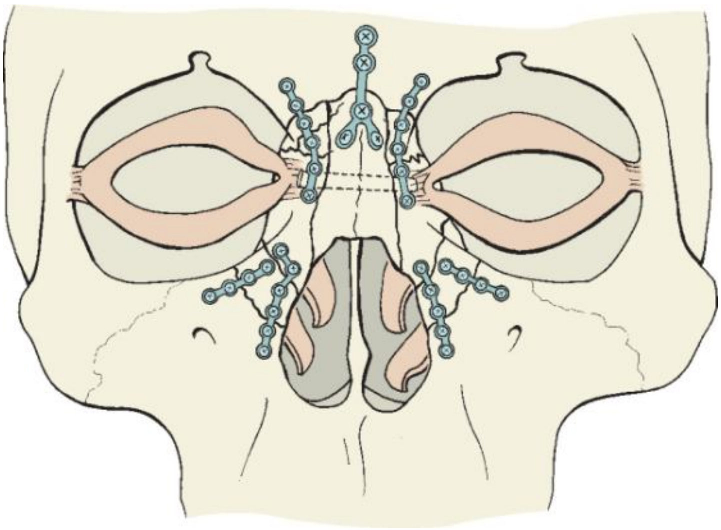

Figure 93-19 Fracture of the nasal-orbital-ethmoid complex repaired with miniplates and the medial canthi reduced and narrowed with transnasal 30-gauge wires sutured to the tendons.

If nasal dorsal strut grafts, such as split calvarial bone or alloplast, are being contemplated, the health and adequacy of the overlying soft tissue and skin must be assessed. If maceration or significant soft tissue devitalization is present, secondary reconstruction of the nasal dorsum is advisable (Fig. 93-20). The decision whether to perform immediate reconstruction or delay grafting is made on an individual case basis. Before undertaking any secondary reconstruction of an NOE injury, it is helpful to obtain a CT scan with three-dimensional reformatting. This aids greatly in surgical planning, preparation, and selection of graft materials (Fig. 93-21).

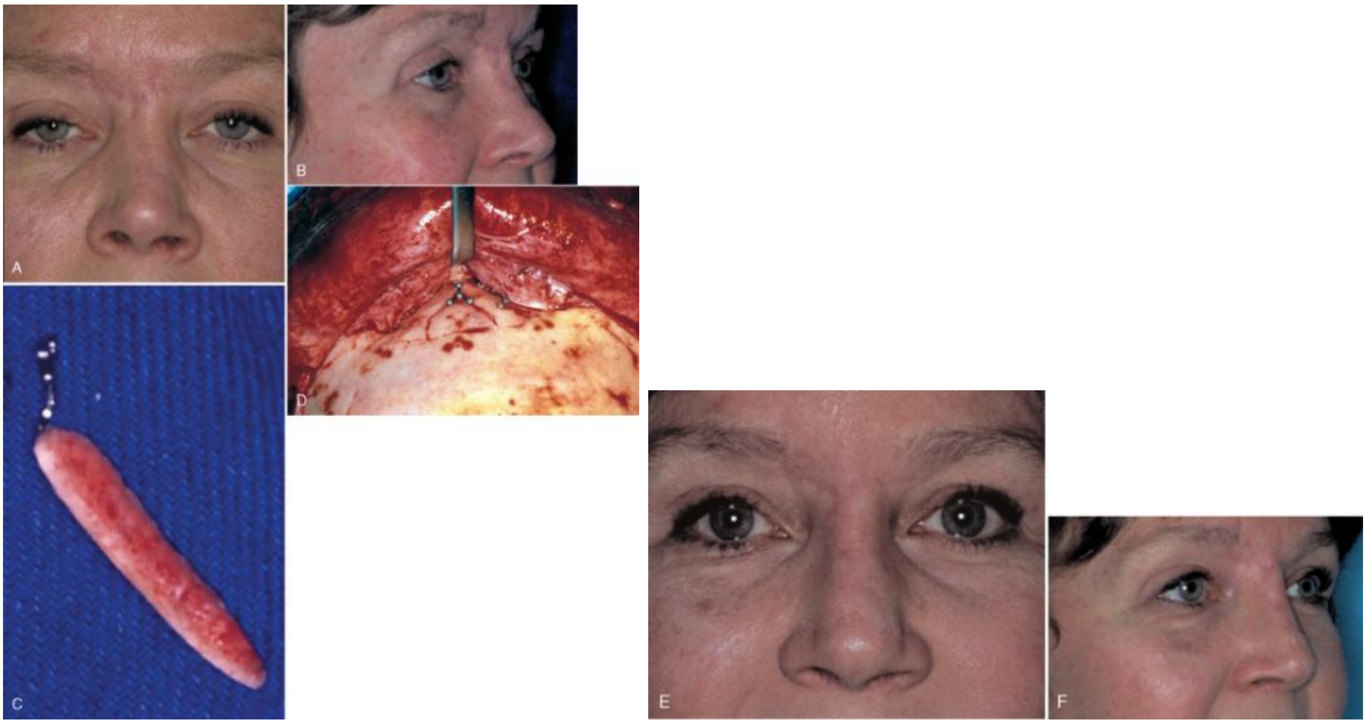

Figure 93-20 **A,** Facial appearance of a woman with a fracture of the nasal-orbital-ethmoid complex, laceration, and wound breakdown because of a postoperative infection. The nasal dorsum is sunken in with a saddle deformity, and there is the appearance of telecanthus despite an intercanthal distance of 29 mm. **B,** Right oblique view showing a short, upturned nose. **C,** A split-thickness calvarial graft was contoured and plated on the underside with 1.7-mm screws so that they would not be palpable with any graft remodeling or soft tissue thinning. **D,** The graft is inset via a coronal approach after bluntly developing a soft tissue pocket that extends down to the cephalad extent of the medial crura of the lower lateral cartilages. This length is beyond the native nasal bones, and it is necessary to adequately restore proper projection of the dorsum and tip without the nares being fully visible from the frontal view. **E,** Facial view 6 weeks after surgery. No canthopexy or scar revision was performed, yet the scars are less noticeable because they are stretched over a smooth convex framework and the canthi appear narrower as a result of proper anterior projection and volume of the nasal dorsum. **F,** Right oblique view.

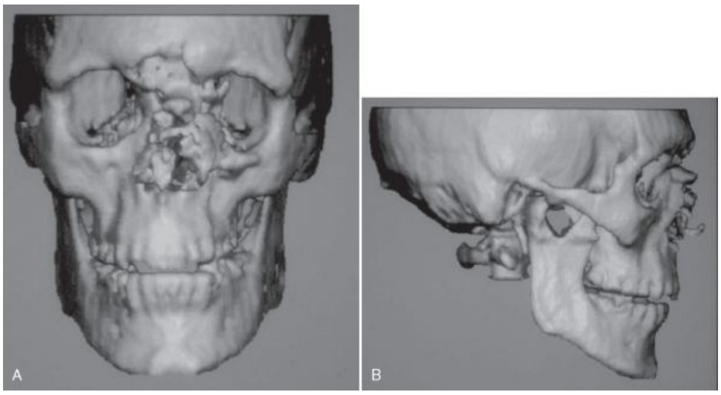

Figure 93-21 Three-dimensional computed tomography scans. **A** and **B,** Reformatted frontal and lateral views of a young man who was assaulted with a pipe and sustained a fracture of the nasal-orbital-ethmoid complex that was not repaired at his local hospital because of severe brain injury and a questionable chance for survival. These images greatly aid in preoperative planning for secondary reconstruction. The healed fracture edges have remodeled and smoothed, so osteotomizing or attempting to "reduce" the segments generally leads to a poor result. Reduction and recontouring of any excess or full areas and grafting onto stable areas for projection and contour with debulking of scarred soft tissue yield a better result. Several revision procedures should be anticipated.

Frontal Sinus

The coronal approach provides the best access for repair of fractures of the frontal sinus. Only extensively large and degloving lacerations permit adequate direct exposure. Smaller lacerations should be repaired and a coronal approach undertaken. During reflection of the coronal flap, any free or loose anterior bone fragments should be preserved on the back table and oriented for later replacement and reconstruction. Displaced fractures of the anterior table should be elevated and the sinus floor, ostia, and posterior wall inspected. Patency of the nasofrontal ducts or foramen may be difficult to discern visually. Saline or methylene blue can be irrigated into the openings with an 18-gauge angiocatheter and then observed to emerge from the middle turbinate or collect in the posterior pharynx, thereby confirming patency. If the posterior table and nasofrontal ducts are free of injury, the anterior table can be reassembled and fixated with low-profile miniplates (1.0- to 1.7-mm systems) or titanium mesh. Mesh is useful in covering noncritical defects (<1.0 cm in diameter). With larger defects, though rarely necessary, consideration should be given to harvesting split calvarial grafts and recontouring.

If the posterior table is fractured, one should determine radiographically and clinically whether the fracture is *displaced*. Displacement is defined as a discrepancy that is equal to or greater than the thickness of the adjacent fractured bony edges. The fracture is either displaced or nondisplaced. Intermediate terms, such as mildly displaced or angulated, are confusing and do not help direct clinical decision making. Displaced fractures warrant neurosurgical consultation. Oftentimes an osteotomy of a larger section of the frontal bone or the entire frontal bar (including the supraorbital rims) must be carried out and removed to permit adequate visualization and access for management of cerebral injuries and dural repair (Fig. 93-22). Care should be taken to avoid entry into and damage to the sagittal sinus, which will result in severe hemorrhage. In cases in which there is severe cerebral contusion with anticipated postoperative edema or a moderate or small frontal sinus, cranialization of the frontal sinus is preferred. Cranialization involves complete removal of the posterior wall of the sinus, removal of all sinus mucosa, and smoothing of the bony margins (Fig. 93-23). Any dural tear is repaired primarily or patched with fascia, lyophilized dura, synthetic patch, or pericranium. Tissue sealants such as fibrin glue can be used to help reinforce the repair. Dural tacking sutures to the overlying reconstructed anterior table can help prevent acute or chronic subdural fluid accumulation. Before reassembling and plating the anterior table, the sinus mucosa in the nasofrontal ducts should be reflected downward into the nasal cavity and the orifice obliterated with local bone fragments, harvested temporalis muscle, or free pericranium.

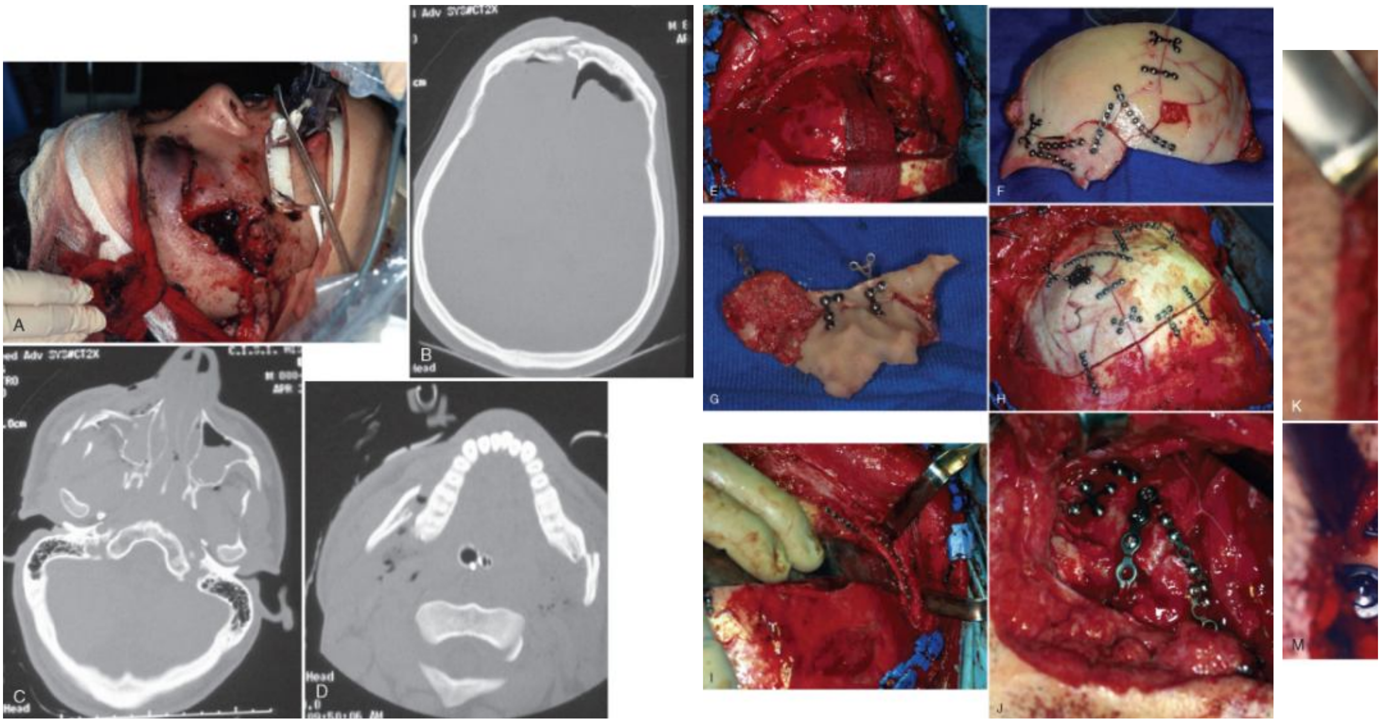

Figure 93-22 **A,** Lateral view of a young man whose left face was impaled by a crane hook and who then fell several stories from a steel building frame. His cervical spine was stabilized and he was orally intubated. A tracheostomy was performed. **B,** C
the mandible and a right subcondylar fracture not seen on this lower cut. **E,** The neurosurgeon osteotomized the frontal bone and skull beyond the areas of fracture to gain adequate access for dural repair without excessive retraction on the injured frontal l
1.7-mm system. The right superior orbital rim is in the right lower corner of the field. **G,** A large portion of the anterior cranial fossa was free floating. It was retrieved during dural inspection and repair, "preplated" so that it could be slid between the frontal lo
suspension of dural tacking sutures to discourage epidural blood accumulation. **I,** Fixated right zygomatic arch as viewed from above. **J,** The right zygoma and orbit were repaired through the gaping cheek exit wound with 1.7- and 1.3-mm miniplates. The
through the submandibular entry wound after placing arch bars and wiring the patient into maxillomandibular fixation. **L,** Next, the oblique fracture of the right angle and posterior body is fixated with a 2.0-mm tension band plate and a bicortical inferior bord
restored facial dimensions. **P** and **Q,** Three months after repair, Z-plasty of the medial canthal scar and mechanical dermabrasion of the cheek wound were performed. **R,** Facial appearance 6 month after injury. He had returned to full-time construction wo

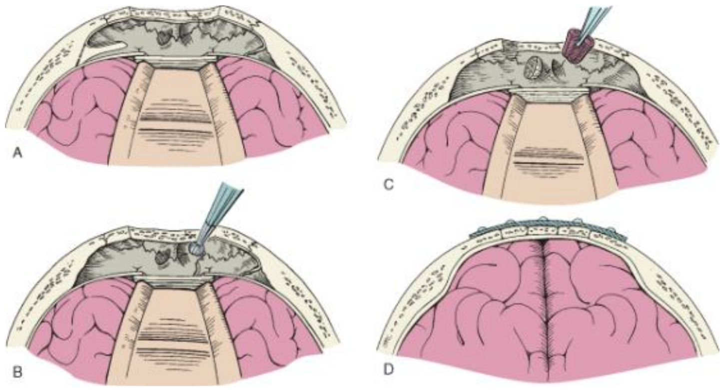

Figure 93-23 Steps in cranialization of a fractured frontal sinus. **A,** The dura is repaired and the posterior sinus wall is removed through a bicoronal approach. **B,** Mucosal remnants are removed by burring the anterior wall and floor. **C,** The nasal frontal ostia are plugged. **D,** The anterior table is reconstructed with microplates, and the brain accommodates and fills the space.

If the nasofrontal ducts are fractured or obstructed, the patient is at risk for the development of sinusitis, meningitis, or osteomyelitis.[24] If the ducts are injured or if the frontal sinus is to be obliterated with grafted fat (harvested from the abdomen), bone, pericranium, or acceptable alloplastic material, or cranialized, the ducts should be obstructed and sealed off as described. Obliteration of the nasofrontal duct is necessary to seal off the frontal sinus or intracranial space from nasal contamination. Sinus obliteration is undertaken to eliminate dead space, discourage fluid accumulation, and provide an additional barrier between the nasal cavity and the brain.

When obliteration of the nasofrontal duct and sinus and cranialization are undertaken, it is critical to remove all remnants of sinus membrane and mucosa. Vigorous use of the curette and sometimes curettage with a round diamond burr are required for complete removal. Mucosal remnants can lead to mucocele formation and infection many years later. With more limited unilateral sinus injuries or with limited access through a laceration via endoscopic visualization to ensure that no free fragments are located within the sinus, lateral nasal incisions (Lynch) and elevation of the anterior fractures can be performed. This should be attempted only by an individual skilled in functional endoscopic surgical techniques and only for mild unilateral injury.

POSTOPERATIVE MANAGEMENT

The postoperative course and regimen are dependent on the variety and severity of the facial fractures. Routine orders include cold compresses for the face, elevation of the head of the bed, decongestant nasal sprays, and wire cutters at the bedside if the patient is maintained in MMF. Instructions on how to cut the wires in case of emergency are useful. However, if the arch bars are left in place, soft wax can be given to the patient to place over any wire causing irritation, and nutrition consultation is also advisable. For patients not in MMF but who have undergone repair of Le Fort fractures, a soft diet that does not require chewing is recommended for 4 to 6 weeks. The patient should be instructed in oral hygiene and saline rinses. Perioperative steroids administered intravenously can greatly aid in reduction of soft tissue swelling. Methylprednisolone (125 mg intravenously every 6 hours) is preferable over dexamethasone (8 mg intravenously every 8 hours). This regimen should not be confused with the high-dose steroids that are given to patients with traumatic optic neuropathy and visual compromise. In these instances, intravenous methylprednisolone (3 mg/kg) and subsequent doses of 1.5 mg/kg every 6 hours are administered to reduce edema and optic nerve compression.[25] Evaluation of visual acuity should be performed frequently within the first 24 hours after any orbital surgery. Even with significant periorbital edema the eyelids should be separated and pupillary reactivity and adequate vision confirmed. Any equivocal or worrisome findings should prompt an emergency ophthalmic consultation. Occasionally, proptosis or chemosis of the bulbar conjunctiva with exposure develops. Lubrication of the eye should be applied frequently (every 2 hours) to avoid desiccation or ulceration. Any lid retraction or ectropion should be assessed and managed by direct massage, steroid injection, or surgical revision. Paresthesia and dysesthesia of the supraorbital and infraorbital nerves are common after injury and repair. Unless surgically transected, most will recover fully within 3 to 6 months.

Blurred vision and mild diplopia are common after fractures of the orbit and usually resolve when the edema subsides. Marked diplopia or decreased vision should be evaluated on an emergency basis by an ophthalmologist. Evacuation of a retrobulbar hematoma, high-dose steroids, and other sight-preserving maneuvers can be performed as indicated. Serial examinations are important for early detection of decreased vision.

Any persistent clear or watery fluid from the nose should be evaluated with a β_2-transferrin assay to rule out CSF rhinorrhea. Radionuclide studies can be performed to localize the source of the CSF rhinorrhea, and transnasal endoscopic patching of the CSF leak along with placement of a lumbar drain for 3 to 5 days is usually successful.

Perioperative antibiotics are frequently used in the care of patients treated for facial fractures. Intravenous antibiotics are usually given before and for 24 hours after surgery. Beyond this time, there is no proven benefit of intravenous antibiotics. Antibiotics should provide gram-positive and staphylococcal coverage. Amoxicillin with clavulanate and clindamycin are good first-line choices. Sinus precautions should be instituted in patients who have undergone repair of maxillary or ZMC fractures. Early wound infections are often due to nonviable bone, breakdown of soft tissue, retained tooth fragments in the line of fracture, or mobility across fracture lines. Attempts should be made to ascertain the cause and direct therapy toward the same. Simply administering antibiotics fails to completely resolve the infection and delays the necessary inevitable treatment of débridement, surgical drainage, or refixation of fractures.

Late infections (>6 weeks) are usually due to paranasal sinus obstruction and possibly a devitalized maxillary tooth requiring extraction or root canal therapy. Clinical examination, local sensitivity, and radiographic imaging can help identify the source, and appropriate treatment can be rendered.

Pressure dressings can be applied to suit the patient's needs, particularly with coronal flaps, or when extensive soft tissue stripping has been performed. Suction drains can be placed beneath the coronal flaps and maintained for 24 hours. Generally, drains are unnecessary, except in the presence of excessive oozing during closure.

Postoperative radiographs can be useful in assessing the adequacy of reduction, alignment of fixation, and skeletal relationships. They also serve as a baseline if future occlusal changes, shift in segments, or infection or loosening of hardware occurs. These radiographs can include Panorex, a posteroanterior or lateral cephalogram, a Waters view, or skull films. Follow-up CT scans are generally required for complex orbital repairs and frontal sinus repairs with intracranial injury. Patients should avoid strenuous physical activity for 6 weeks and avoid contact sports for an additional period if warranted by the injury.

Malocclusion discovered immediately after surgery or within the first week is usually due to improper reduction of the fractures and fixation in that position. The most common postoperative malocclusion is an anterior open bite deformity caused by upward pressure on the chin with displacement of the condyles while plating midfacial fractures. If the anterior open bite is slight (less than 2 mm), vertical elastic traction on the arch bars may resolve the situation satisfactorily. A large open bite must be addressed by revision surgery with plating in the correct anatomic position while seating the mandibular condyles. Excessive amounts of box elastics to close malocclusions can lead to loss of fixation, nonunion, and damage to the teeth.

Malocclusion that occurs later (during the healing phase) is usually due to loss of fixation, use of plates with inadequate rigidity, or backing out of screws because of overheated bone at the time of surgery or infection. The patient may also be overactive and eating a normal diet, or infrequently the patient sustains additional facial trauma and may not report it to the surgeon. Grasping the maxillary complex to detect mobility and comparing current radiographs with ones taken immediately postoperatively may reveal loss of fixation or shift of the bony segments. Generally, reoperation plus reapplication of fixation is required to address this situation. Meticulous passive plate adaptation and the use of locking screw systems can help avoid torquing segments and misalignment.

PEARLS

- A thorough preoperative evaluation with a logically sequenced treatment plan helps avoid complications and unfavorable outcomes.
- The patient's imaging studies must be reviewed personally by the surgeon, who should correlate any radiographic fractures with the physical findings.
- When grafting defects of the orbital floor, reconstitute the defect and restore the normal orbital floor contour, which is not flat.
- Do not operate on nondisplaced ZMC, isolated anterior maxillary wall, or orbital floor fractures for the purpose of improving V_2 paresthesia or anesthesia.
- When treating moderate or severely displaced ZMC fractures, accessing at least two fracture points and fixating them along both areas aids in reduction and helps ensure proper alignment and adequate postoperative stability.

PITFALLS

- Nasal and zygomatic arch fractures treated after 48 hours of injury do not reduce as precisely and tend to be less stable and drift back into the injured position.
- When closing eyelid incisions, either infraciliary or transconjunctival, improper reapproximation and suturing unlike layers will result in lid tethering and possibly ectropion.
- Serial perioperative visual acuity checks or patient complaints indicating decreased vision must be taken seriously and should prompt immediate evaluation and appropriate treatment.
- Early postoperative malocclusion (<24 hours) is usually due to fixation of fracture segments that were improperly aligned.
- Later postoperative malocclusion is probably due to nonunion or shift of bony segments secondary to inadequate fixation, infection, or excessive use.