Maxillofacial skeletal injuries account for a large proportion of emergency department visits and often result in surgical consultation. Although many of the principles of detection and repair are basic, evolving technology and novel therapeutic strategies have led to improved patient outcomes.

The goal of imaging studies in the trauma setting is to define the number and location of facial fractures, with particular attention toward identifying injuries to functional portions of the face and those with cosmetic consequence. By understanding common fracture patterns and the implications for clinical management, radiologists can better construct clinically relevant radiology reports and thus facilitate improved communication with referring clinicians. This article aims to provide a review of the imaging aspects involved in maxillofacial trauma and to delineate its relevance to management.

**TECHNOLOGY**

Imaging in most emergency departments for significant facial trauma begins with CT scanning. Although plain radiographs were once standard imaging, they do not provide sufficient information to assess injury severity and displacement, two key aspects essential for emergent management and surgical planning. In addition, radiographic positioning is difficult and potentially dangerous for multitrauma patients, in particular patients requiring cervical spine clearance. Modern multi-detector CT (MDCT) scanners have revolutionized trauma imaging and provide a fast, safe, cost-effective, and sensitive means for assessing trauma for bone and soft tissue injuries. Furthermore, with the advent of MDCT, facial scans can now be performed contemporaneously with head, thoracic, and abdominal scans, facilitating a rapid assessment for trauma patients with multiple potential injuries.

MDCT offers excellent spatial resolution, which in turn enables exquisite multiplanar reformations, and 3-D reconstructions, allowing enhanced diagnostic accuracy and surgical planning. These reconstructions assist in the assessment of fracture fragment displacement and rotation as well as identification of fracture patterns. For these reasons, MDCT is the imaging technique of choice in maxillofacial trauma.

Although 2-D transaxial and coronal images are more accurate and sensitive than 3-D reconstructions, 3-D imaging is often preferred by surgeons because it simulates a surgeon’s process of visualizing fractures in operative planning. Nonetheless, it is important to recognize limitations in 3-D imaging, namely the introduction of artifact during
the reformation process, decreased ability to visualize nondisplaced fractures, the lack of adequate soft tissue evaluation, and difficulty viewing deep fractures on surface views.2

At the Bellevue Hospital and Trauma Center currently scans are from the frontal sinus through the hyoid bone to include both the mandible and the facial bones. Scanning is acquired at submillimeter thickness with overlap (0.625 mm × 0.4 mm) to generate high-quality multiplanar reformations and 3-D reconstructions. CT images are reviewed at 2-mm thick reformations oriented parallel and perpendicular to the hard palate to achieve symmetry in both the transverse and coronal planes. Sagittal images are also generated for review. All images are processed using bone and soft tissue algorithms (Fig. 1). Additional oblique or curved reformations and 3-D reconstructions are generated according to the area of interest on a case-by-case basis.

MR imaging may occasionally be used to evaluate soft tissue injury with the advantage of avoiding ionizing radiation while providing excellent soft tissue contrast. MR imaging is particularly helpful in assessing cranial nerve deficits. Although MR imaging also offers multiplanar capabilities, it is limited in its ability to assess cortical bone and is often not a feasible modality secondary to accessibility and availability. In addition, it is usually impractical in the trauma setting due to the need to rule out life-threatening injuries promptly and patient inability to remain still during the lengthy examination. Most importantly, metallic fragments must be excluded before imaging with MR imaging.

Fig. 1. A 22-year-old man, assaulted, with facial pain. (A) CT scout view shows scan range from top of the frontal sinus to the bottom of the hyoid to include the entire facial skeleton, including the mandible. Transaxial images in bone (B) and soft tissue (C) demonstrate a left lateral orbital wall fracture (white arrow) with left periorbital swelling. The globes and lenses are intact. Retrobulbar soft tissues are normal. (D) Coronal reformation reveals fractures of the left zygomaticofrontal suture (short white arrow), left orbital floor (long white arrow), and left zygomaticomaxillary suture (black arrow). Together, with zygomatic arch fracture (not shown), this injury pattern is a ZMC fracture. (E) Oblique sagittal reformation along the plane of the left optic nerve shows the orbital floor fracture to better advantage giving the surgeon an improved understanding of the size and depth of the defect. The optic nerve and superior and inferior rectus muscles are well displayed on this projection. (F) 3-D reconstruction in a Water’s projection shows the overall ZMC fracture pattern (arrowheads) in a single image and aids in surgical planning.
NASAL FRACTURES

Anatomy
The nasal region consists of bony and cartilaginous portions. Whereas the anterior nasal septum is cartilaginous, the remainder of the nasal septum, consisting of the posterior perpendicular plate of the ethmoid, vomer, nasal crest of the maxilla, and nasal crest of the palatine bone, is bony. The upper third of the nasal region (consisting of the nasal bones proper, the frontal process of the maxilla, and the nasal process of the frontal bone) is bony, whereas the middle and lower thirds of the nasal region (composed of the upper lateral and lower alar cartilages, respectively) are cartilaginous.

Injuries
The nose is the most prominent facial projection. Consequently, nasal bone fractures account for approximately 50% of all facial fractures, with the majority involving the distal third of the nose. Because the diagnosis is usually made clinically and radiologic evaluation is usually unnecessary, there is limited role for dedicated imaging. Radiology reports from head CT scans or imaging directed at detecting other facial fractures, however, often bring a nasal bone fracture to the attention of the emergency department staff and facilitate further evaluation, which can prevent clinical complications, such as a cosmetic deformity or a septal hematoma resulting in saddle nose deformity. In these cases, early reduction prevents bony malunion, thus avoiding the need for osteotomy to anatomically reduce fracture fragments.

Several classification systems exist for nasal and septal fractures, grouping fractures according to whether fractures are unilateral or bilateral, degree of displacement, comminution, midline deviation, and septal and soft tissue injury. Generally, nasal trauma with septal fracture or dislocation causing severe alteration of the nasal midline or with severe soft tissue injury requires an open repair, whereas most others can be treated with closed reduction.

NASO-ORBITAL-ETHMOID FRACTURES

Anatomy
The interorbital space is referred to as the naso-orbital-ethmoid (NOE) region; it represents the bony confluence of the nose, orbit, maxilla, and cranium. The space is defined by the thin medial orbital walls laterally, the sphenoid sinus posteriorly, the cribriform plate superiorly, and the bony pillar (the frontal process of the maxilla, nasal process of the frontal bone, and the thick proximal nasal bones) anteriorly. Several key structures lie within this region, including the olfactory nerves, the lacrimal sac, the nasolacrimal duct, the ethmoid vessels, and the medial canthal tendon.

Injuries
Once an anteriorly directed force is sufficient to fracture the nasal bones, the posterior ethmoid air cells offer little resistance and are easily fractured with impaction and resultant telescoping. The fracture pattern then progresses from simple nasal fracture into the NOE type, which additionally involves the medial orbit, septum, and nasofrontal junction. This pattern is most often seen in blunt trauma directed at the nasal bridge.

CT is essential to identifying the location of the injury, pattern type, degree of comminution and displacement, and associated fractures and soft tissue injury. CT typically demonstrates blood in the ethmoid air cells and impacted fractures in

![Fig. 2. Nasal fractures. (A) Transaxial and (B) coronal CT reformations of a 25-year-old male victim of assault shows bilateral comminuted nasal fractures through the frontal processes of the maxillae (arrows), displaced to the right. Nasomaxillary sutures lie just anteriorly (small dotted arrows). (B) Anterior nasal spine identified by the arrow.](image-url)
the NOE region (Fig. 3). Often, with displaced fractures, the nasal septum is buckled on impaction, such that, both clinically and on CT, the nose appears pushed back between the eyes. If left untreated, NOE fractures can result in marked facial deformity with functional and cosmetic implications, including (but not limited to) telecanthus, enophthalmos, ptosis, and obstruction of the lacrimal system. These deformities are extremely challenging to correct secondarily and should be addressed immediately.5

NOE fractures are commonly associated with Le Fort II and III fractures; therefore, the pterygoid plates should be carefully evaluated. One study showed that 65% of patients with NOE fractures had concomitant facial fractures, most commonly a Le Fort maxillary or frontal sinus fracture.6 Disruption of the cribriform plate should be assessed because the olfactory nerves can be disrupted, and more seriously, this injury can lead to cerebrospinal fluid (CSF) leak, pneumocephalus, or tension pneumocephalus after resuscitation efforts. Also, because NOE fractures are associated with high-impact trauma that involve the medial orbital walls, ocular injuries, such as hyphema, vitreous hemorrhage, lens dislocation, and globe rupture, should be excluded.7

Radiologically, one of the key segments of the NOE fracture to evaluate is the medial orbital rim where the medial canthal tendon inserts. Because the medial canthal tendon provides medial support to the globe and keeps the eyelid in apposition to the globe, recognizing potential injury is important to ensure appropriate work-up and treatment. Identification of a fracture through the inferomedial orbital rim at the lacrimal fossa implies disruption of the medial canthal tendon insertion (see Fig. 3B). Injury of the medial canthal tendon is closely associated to injury of the lacrimal drainage system, which can lead to obstruction and epiphora.8

Many NOE classification types have been proposed in the literature. The Markowitz system is among the most common, which categorizes NOE fractures according to the status of the medial canthal tendon along with the degree of comminution of the fragment of bone to which it remains attached.9 Practically speaking, it is important for surgeons to know whether a fracture is unilateral or bilateral and whether it is simple (a large single segment) or comminuted. This, in combination with identifying associated fractures and assessing the internal orbit, determines the amount of exposure, the type of stabilization, and the number and type of surgical approaches needed.10 In general, fractures that demonstrate displacement necessitate open reduction and stabilization. Marked comminution of the medial orbital wall, particularly in the region of the lacrimal fossa, where the medial canthal ligament attaches and the nasofrontal ducts are located, can require transnasal fixation. If the nasofrontal ducts are involved, surgical obliteration is often indicated to prevent the formation of a frontal mucocele. NOE fractures may also extend posteriorly to the optic canal or superiorly to the frontal sinus and intracranial structures, and this should also be noted.

FRONTAL SINUS FRACTURES

Anatomy

There is high variability in the frontal sinus, with regards to anatomy and volume: 10% of individuals have a unilateral sinus, 5% have a rudimentary sinus, and 4% have no frontal sinus. The anterior wall is thick and can tolerate as much as 2200 lb of force before fracturing, whereas the posterior wall is thin and relatively delicate. The dura and frontal lobes lie just posterior to the posterior table, and the orbital roof and nasofrontal ducts lie just inferior. The only drainage port from the frontal sinus is the nasofrontal duct, located at the

![Fig. 3. NOE fracture. A 46-year-old man in a construction accident. (A) Transaxial CT image shows comminution of the nasal bones and ethmoid air cells with impaction as the nose is pushed back between the eyes from frontal force. (B) 3-D CT reconstruction shows the multiple interorbital fractures seen with the NOE fracture pattern. Note the fracture through the inferomedial orbital rim (arrow), implying medial canthal tendon injury.](image-url)
inferomedial aspect of the frontal sinus, which empties into the middle meatus.

**Injuries**

Frontal sinus fractures result from direct anterior upper facial impact at the frontal bone and comprise 5% to 12% of all maxillofacial fractures. They are uncommon, because the nasal prominence usually protects the naso-orbital region. Because of the high G force necessary for fracture to occur, these high-energy injuries result in 75% of patients presenting with significant injury, including shock, brain injury, coma, and associated facial fractures. The force of impact propels the head and cervical spine into extension, leading to concomitant intracranial injury in 38% of patients. One-third of injuries are isolated to the anterior table, whereas two-thirds involve both anterior and posterior tables (Fig. 4).

Prompt and appropriate management is essential, because complications, such as brain abscesses, meningitis, encephalitis, mucoceles, and mucopyoceles, can occur. MDCT should be used as early as possible to exclude injury to the central nervous system and determine the location and extent of injury. Particular attention should be paid to the anterior and posterior tables and the nasofrontal duct, because injuries to these three structures dictate classification and subsequent treatment. Also, if present, pneumocephalus can indicate dural violation, which may prompt neurosurgical intervention.

Injury to the nasofrontal outflow tract is present in 70% of cases and indicated by (1) anatomic outflow tract obstruction, (2) frontal sinus floor fracture, and (3) medial anterior table fracture. Coronal images are particularly helpful for evaluating the base of the frontal sinus at the site of the ostium of the duct. Fracture fragments within the tract are diagnostic of nasofrontal outflow tract obstruction.

Although treatment goals are similar among surgeons, controversy regarding exact management of frontal sinus fractures exists. As long as the nasofrontal duct is uninjured and there is no CSF leakage, nondisplaced fractures of the anterior and posterior walls of the frontal sinus do not usually require surgical treatment. Because of the possibility of delayed infection, however, many recommend long-term follow-up with CT.

Solitary depressed anterior wall fractures can lead to cosmetic deformities and are treated with anterior wall restoration to obtain aesthetically acceptable contours. Nasofrontal duct injury or posterior wall injury with a dural tear or CSF leak usually requires removal of the sinus mucosa and obliteration of the cavity to prevent mucocele or mucopyocele formation. Displaced posterior wall fractures, particularly when there is more than one table width of displacement, can require cranialization to treat ongoing CSF leaks (see Fig. 4).

**Fig. 4.** Frontal sinus fractures. (A) Transaxial CT image of 19-year-old man in a motor vehicle crash with fractures of both the anterior and posterior tables of the frontal sinus. Note pneumocephalus (dotted arrow). (B) Larger frontal sinus in a 45-year-old woman after motor vehicle crash with only fracture of the anterior table (arrowheads). (C) Sagittal CT reformation of a different patient after cranialization of the frontal sinus with anterior fixation (white arrows). Note absence of the posterior table (dotted arrow).
Fig. 4C). This involves mucosal stripping, naso-frontal duct obliteration, and removal of posterior table fragments. In surgical procedures where the frontal sinus is preserved, serial CT scans in the postoperative period are often performed to assess for adequate drainage of the sinus, and failure of the sinus to clear is an indication of impaired drainage that may lead to infection.18 In these cases, aggressive medical therapy and/or endoscopic or open surgical drainage are used.

ORBITAL FRACTURES

Anatomy

Seven bones make up the bony orbit: the frontal bone, zygoma, maxilla, lacrimal bone, ethmoid bone, sphenoid bone, and palatine bone. The optic canal, superior orbital fissure, and inferior orbital fissure are the three openings in the posterior orbit. In trauma imaging, fractures of the orbit are usually referenced in relation to the four orbital walls: the orbital floor, orbital roof, medial orbital wall, and lateral orbital wall.

Injuries

Orbital fractures may be isolated or part of a more complex fracture pattern. They frequently occur in conjunction with zygomaticomaxillary complex (ZMC), Le Fort fractures, and NOE fractures. There are several typical injury patterns that are seen.

The orbital blow-out fracture typically occurs when an object larger than the bony orbit impacts the orbit with sufficient force to increase intraorbital pressure and fracture the thin orbital floor, medial wall, or both (Fig. 5). Blow-out fractures are considered pure when the thick orbital rim remains intact. The free fragment sign on CT demonstrates an isolated fragment within the maxillary sinus with depressed or displaced orbital floor fractures. With an acute injury, hemorrhage into the adjacent sinus should be present. If the sinuses are clear, the injury is likely remote. Fractures through the medial orbital wall that are not blow-out fractures are rarely isolated and should raise suspicion of NOE or Le Fort II or III fracture patterns.

Common complications include extraocular muscle herniation and enophthalmos (discussed later). Orbital emphysema is another complication, in which floor and medial wall fractures allow the release of adjacent paranasal sinus air into the orbit. Although this is usually a self-limited condition, it warrants comment because it can cause mass effect on the adjacent soft tissues and be a rare cause of decreased vision due to either occlusion of the central retinal artery or optic neuropathy.19
The blow-in fracture usually results from a high-energy impact to the frontal bone and consists of fracture and depression of the orbital roof into the orbit (Fig. 6). Blow-in fractures are often associated with intracranial injury and loss of orbital volume leading to exophthalmos. Associated ocular injuries are reported in 14% to 29% of cases.20 If the fracture propagates to the orbital apex, the optic nerve can be injured by direct fracture fragment penetration, hemorrhage into the sheath, avulsion from the posterior globe, or ischemia resulting from increased intraorbital pressure. If there is imaging and clinical evidence of optic nerve impingement, emergent surgical treatment is usually indicated because this can be associated with blindness as well as injury to the cavernous portion of the carotid artery.

The blow-up fracture involves cranial displacement of the orbital roof, which increases orbital volume and is strongly indicative of intracranial injury (Fig. 7). Isolated lateral orbital wall fractures can occur but are more commonly associated with zygoma fractures with disruption of the zygomaticofrontal suture.

CT imaging plays a key role not only in diagnosis of these fractures but also in determining management. Although indications for surgical repair are controversial, evidence of mechanical entrapment or evidence of enophthalmos includes well-established criteria mandating urgent repair.

Particularly with orbital blow-out fractures, there may be resulting herniation of the intraorbital fat and rectus muscles, which can lead to entrapment of the muscles on a free edge of the fracture fragment causing diplopia. Entrapment is a surgical emergency and lack of evidence of entrapment on CT does not exclude the condition, and a careful physical examination is critical. Coronal CT is particularly useful for displaying herniation and can suggest entrapment based on kinking of a muscle or isolation of the inferior rectus muscle (Fig. 8). The inferior rectus muscle normally appears oval on coronal images; if it appears round, pathology should be suspected. Making the diagnosis of herniation is particularly challenging in the case of trapdoor fractures, most common in pediatric patients secondary to more pliable bone. In these cases, the orbital floor is fractured and displaced inferiorly but then snaps back into place; however, the herniated inferior rectus muscle remains trapped across the fracture and is at risk of ischemia. CT findings of this type of herniation are particularly subtle, and the only sign may be the loss of the inferior rectus muscle shadow in the orbit.21

Another parameter in determining the need for surgical intervention is the size of the orbital floor defect, because larger defects increase the risk of future enophthalmos. With this condition, the globe sinks posteriorly and inferiorly into the maxillary sinus. Many surgeons opt for repair in any defect greater than 1 cm², whereas others use a standard of displacement greater than 50% of the orbital floor. Other surgeons judge by the amount of fat or soft tissue displacement. Some use CT to calculate the increase in orbital volume compared with the uninjured side and then use this to determine the risk for postinjury enophthalmos;22 however, no firm data exist to support this approach. Because criteria vary among surgeons, the size of each fracture should be estimated in the radiology report.

Surgical repair can consist of either a bone graft from the outer table of the skull or the use of a titanium or resorbable implant. If an implant is used, the patient should be monitored for new-onset diplopia and, if present, emergent CT scan should be performed to ensure there is no mechanical impedance. When evaluating for placement, care should be taken to ensure that floor implants are directed superiorly to simulate the superior incline of the orbital floor (Fig. 9).

Globe Injury

Injury to the globe, retrobulbar hematoma, and optic nerve injury are considered more emergent than entrapment or enophthalmos; therefore, these soft tissue injuries should be assessed immediately when approaching a facial CT.23

Penetrating ocular injuries can lead to globe rupture secondary to pressure gradients favoring extrusion of the vitreous, because normal intraocular pressure is higher than intraorbital pressure. The flat tire sign, seen on CT as posterior flattening...
of the globe, indicates globe rupture (Fig. 10A). Globe hemorrhage can be intravitreous, sub-scleral, or subretinal (see Fig. 10B).

Lens dislocation is diagnosed by a dependent lens lying on the retina (see Fig. 10C). In the case of partial tear of the zonular fibers, lens subluxation may be seen on CT as an oblique or vertically oriented lens, supported anteriorly on one side. If one lens appears hypodense relative to the contralateral lens, acute lens edema should be suspected because this may lead to a traumatic cataract. The difference in attenuation is usually approximately 30 Hounsfield units.

Often, it is difficult to evaluate optic nerve function clinically in the emergency room setting. Therefore, CT scan plays an important role in evaluation of the optic nerve. Transaxial and oblique sagittal images are particularly helpful in determining the presence of an optic nerve hematoma (see Fig. 5B).

Size and density are important in determining the detectability of foreign bodies. Metallic foreign bodies are readily identified; however, dry wood and plastic appear hypodense on CT, similar to air and fat, respectively. Because it can be difficult to differentiate a foreign body and air, it is helpful to look for a geometric margin. Despite this, at times, a nonmetallic foreign body is difficult to exclude and MR imaging can be helpful, provided that a noncontrast head CT has excluded the presence of a metallic foreign body.24

Lastly, a rare condition that requires emergent intervention and must be assessed in the setting of trauma is the presence of a carotid-cavernous fistula. This is done by evaluating the facial CT for the presence of a dilated superior ophthalmic vein, a nonspecific finding that indicates the need for confirmation with CT angiography or conventional angiography.25

**ZYGOMA Anatomy**

The malar eminence defining the anterolateral cheek projection is formed by the zygoma, which has four principal attachments—the frontal bone, the maxilla, the arch of the temporal bone, and the greater wing of the sphenoid. They therefore
contribute a large proportion of the orbital floors and lateral orbital walls.

Injuries

The prominent position of the zygoma makes it particularly susceptible to traumatic injury. Although the zygoma itself is a strong bone and contributes to the buttress system of the midface, the surrounding sutures and bones that articulate with the zygoma are weaker. A common resulting fracture pattern is the ZMC fracture pattern, which usually results from an anterolateral impact to the cheek and effectively separates the zygoma along its sutural attachments (see **Fig. 1** B–D). This pattern represents a spectrum of fractures varying in the degree of bone loss and displacement. Classically referred to as a tripod fracture, the term is a misnomer and should be avoided, because it overlooks the posterior attachments of the zygoma.

Isolated fractures of the zygomatic arch are uncommon, representing only 11% of zygomatic arch injuries. These do not require operative reduction unless there is severe depression causing a cosmetic deformity or inability to completely close the jaw due to impingement of the depressed arch on the coronoid process of the mandible (**Fig. 11**). Fractures along the zygomaticomaxillary suture often extend across the infraorbital canal and can injure the infraorbital nerve, resulting in malar paresthesia.

CT is crucial in determining operative management of fractures, particularly because swelling often precludes accurate clinical assessment of deformity. Transverse, coronal, and 3-D images are particularly helpful (see **Fig. 1D–F**). The degree of comminution and displacement is important, because severe comminution affects the preferred surgical approach for exposing and subsequently aligning the arch. Concurrent zygomatic arch fractures are not always obvious on CT, and deformity of the arch is sufficient to suggest a fracture. Another frequently overlooked ZMC fracture occurs in the temporal bone portion of the upper transverse maxillary buttress. This angulation must be reduced before other fractures are addressed or facial width is increased and underprojection of the cheek results.

Mandible fractures are the most commonly associated fracture with fractures of the zygomatic arch, accounting for 21% of coexisting fractures. The orbital floor and orbital apex are also...
commonly injured. As discussed previously with orbital floor fractures, there are multiple criteria for orbital exploration, and CT findings of degree of comminution and displacement should be reported. Some studies report that approximately 30% to 44% of patients with ZMC fractures require an orbital incision. For orbitozygomatic fractures, the lateral orbital wall, in particular, should be assessed on the transaxial images, because this is the location of the articulation of the zygoma with the greater wing of the sphenoid. The large width of this articulation facilitates assessment for degree of displacement and malposition of the fractured fragments. Nondisplaced orbitozygomatic fractures can be managed nonoperatively. If, however, displacement of the greater wing of the sphenoid is medial and into the orbital apex, there is resulting danger to the internal carotid arteries and multiple cranial nerves of the cavernous sinuses. Displaced fractures are almost always treated with operative reduction and fixation and should be performed as soon as possible, because osteotomies may be necessary after 3 to 4 weeks.

MAXILLARY FRACTURES

Anatomy

The central midface is occupied by the paired maxillae, which form the upper jaw. The maxillae house the maxillary teeth by way of the alveolus and attach laterally to the zygomatic bones. The facial buttress system highlights lines of inherent strength across the midface, with the strongest buttresses vertically oriented and the horizontal buttresses providing secondary support (Fig. 12).

Injuries

There are three classic fracture patterns of the maxilla, Le Fort I, II, and III, which by definition detach the maxilla from the skull base via fracture through the pterygoid plates (Fig. 13). Most
midface fractures are asymmetric, although Le Fort’s initial descriptions outlined symmetric fracture patterns. Therefore, patients often have an asymmetric Le Fort fracture pattern.

A Le Fort I fracture pattern is the result of direct horizontal impact to the upper jaw creating malocclusion with a free-floating hard palate. This results in a transverse fracture through the maxilla passing above the tooth roots, crossing the floor of the maxillary sinus and lower nasal septum, with posterior extension through the pterygoid plates (Fig. 14). It does not involve the infraorbital rims.

Direct impact to the central midface results in a Le Fort II fracture, which separates the nasal region from the cranium. It is a pyramidal fracture that crosses the zygomaticomaxillary sutures bilaterally, fracturing the inferior orbital rims medially, and traverses the nasal bridge. Posteriorly, there is fracture of the pterygoid plates (Fig. 15).

Complete craniofacial disjunction is referred to as Le Fort III fracture. The fracture is suprazygomatic and transversely extends across the nasofrontal suture and across the medial and lateral orbital walls, separating the zygomaticofrontal sutures and zygomatic arches and terminating through the pterygoid plates (Fig. 16).

Because Le Fort fractures usually result in marked damage to both the facial buttresses and the more fragile posterior bones, these fractures cause significant functional and cosmetic deficiencies. Often, similar to NOE fractures, there is backward displacement of the central midface. Additionally, damage to the vertical buttresses can lead of loss of facial height. Given the high incidence of concurrent facial fractures, surgical repair after these injuries is usually complex.

Of particular concern are the highly associated concomitant fractures of the hard palate, dentoalveolar units, and/or mandible, which disrupt occlusion. Reestablishment of normal occlusion must occur before attempting to surgically anchor the upper midface to the maxilla. Similarly, injury to
the frontal bar from concurrent ZMC, NOE, or frontal sinus fractures requires correction before resuspending the midface from the frontal bar.

Degree of comminution is another important factor, because severe comminution may preclude adequate restoration of facial height and projection, thus necessitating bone grafting.

Unfortunately, many Le Fort fractures can traverse the orbital apex. As discussed previously, the orbital apex is associated with injuries to the carotid canal. Because the surgical repair mechanism for Le Fort fractures generally entails the use of significant manual force on the part of a surgeon, it is important for the surgeon to know preoperatively how close the fracture line extends to the orbital apex and carotid canal so that a more gentle reduction technique can be used.

MANDIBULAR FRACTURES

Anatomy

The mandible is a horseshoe-shaped bone consisting of a curved anterior horizontal portion, the body, with two perpendicular posterior vertical struts, the rami. There is a superior anterior projection from each ramus, the coronoid process, which serves as the attachment for the temporalis muscle, as well as a superior posterior projection from each ramus, the condyle, which articulates with the temporal bone at the temporomandibular joint. The temporomandibular joints are the only mobile segments of the facial skeleton and are complex synovial joints that permit hinge, translation, and rotational movements. The mandible forms the lower jaw and holds the mandibular teeth in place. It contains the inferior alveolar nerve canal, which houses the inferior alveolar nerve as well as serving as an attachment for the muscles of mastication.

Injuries

Mandible fractures represent a large proportion of facial fractures and are typically caused by assault. They are classified according to anatomy (symphysis, parasymphysis, body, angle, ramus, coronoid, subcondylar, and condyle), and at least 50% are associated with a second fracture. The most common 2-part fracture is the parasymphysial fracture with a contralateral subcondylar fracture (Fig. 17). A flail mandible is a symphyseal fracture with bilateral subcondylar fractures that necessitates surgery to restore preinjury facial width and height (Fig. 18).

Once a fracture is identified, the primary goal is to restore preinjury occlusion, with management ranging from nonoperative to mandibulomaxillary fixation with arch bars and occlusal wiring, to open reduction and internal fixation or, in the case of a contaminated wound, external fixation.31

Fig. 15. Bilateral Le Fort II fractures in a 40-year-old man after motor vehicle crash. (A) Coronal CT image shows fractures through the lateral maxillary walls (long arrows), inferior orbital rims (short arrows), and across the medial orbital walls (arrowheads), creating a pyramidal fracture characteristic of the Le Fort II pattern. (B) Coronal image posteriorly shows comminution of the pterygoid plates (arrows). (C) 3-D reconstruction shows the Le Fort II fracture pattern in a single projection (arrowheads).
CT is nearly 100% sensitive in detecting fractures of the mandible, which is superior to the 86% sensitivity of curved panoramic (Panorex) radiographs. CT is often insufficient, however, to evaluate dental structures, and the Panorex radiograph can better visualize dental root fractures, particularly when the fracture is located at the angle.32 Panoramic radiographs are thus often used in conjunction with the CT and particularly helps elucidate the relationship of fractures at the mandibular angle to the surrounding teeth (most importantly, the third molars). Cervical spine clearance is necessary before the acquisition of the Panorex radiograph.

Fractures through the tooth socket and alveolus are open fractures. Acute tooth loss is implied by a radiolucent socket and should prompt further evaluation for aspirated or ingested tooth fragments. Many surgeons consider most mandibular fractures as open fractures, therefore regarding them as contaminated, an indication for antibiotic prophylaxis. Some surgeons recommend tooth extraction if the fracture contains a tooth or if there is evidence of abscess.

Fig. 16. Bilateral Le Fort I, II, and III fractures in a 30-year-old woman pedestrian struck by truck. Coronal reformatations from anterior (A) to posterior (C). Le Fort I fractures shown by dashed line in (A) and (B). Le Fort II fractures shown by dotted line in (A) and (B). Le Fort III fractures shown by transverse solid line (B) and arrows through the posterior zygomatic arches in (C). (C) Pterygoid plates are comminuted (arrowheads).

Fig. 17. Mandible fracture in a 19 year old male post assault. Panoramic curved CT reformation shows subcondylar fracture on the right (long arrow) and parasymphyseal fracture on the left (short arrow).
SUMMARY

Maxillofacial fractures are common, and knowledge of fracture patterns and their implication for management is crucial to facilitating effective and efficient communication between the radiologist and the referring physician. When possible, pertinent details should be delineated in radiology reports.

REFERENCES

20. Lawrason JN, Novelline RA. Diagnostic imaging of facial trauma. In: Mirvis SE, Young JWR,