Facial Fractures: Beyond Le Fort

Rebecca E. Fraioli, MD a, Barton F. Branstetter IV, MD a,b, Frederic W.-B. Deleyiannis, MD, MPhil, MPH a,c,*

Department of Otolaryngology, University of Pittsburgh Medical Center, Eye and Ear Institute, 203 Lothrop Street, Suite 500, Pittsburgh, PA 15213, USA
Department of Radiology, University of Pittsburgh Medical Center, 200 Lothrop Street, Pittsburgh, PA 15213, USA
Division of Plastic Surgery, Departments of Surgery and Otolaryngology, University of Pittsburgh Medical Center, 6B Scaife Hall, 3550 Terrace Street, Pittsburgh, PA 15261, USA

The management of facial fractures begins with the establishment of an accurate fracture diagnosis. All too often, radiology reports contain a “laundry list” of fractures without clinical context, without an understanding of fracture patterns, or without categorization by fracture severity, fracture criticality, or the need for surgical repair. For example, a radiology report that focuses on nasal septal fractures, but ignores a medial canthal avulsion, can be annoying or even misleading to the surgeon.

Fracture complexes are reproducible, and the terminology of fracture complexes allows for efficient communication between physicians of intricate fracture patterns in the midface. This type of communication requires that the radiologist understand common mechanisms of injury and the fracture complexes that result.

The best-known categorization scheme for fracture fractures is that of Rene Le Fort. However, Le Fort’s work was based on low-speed impact, and does not completely reflect the breadth of trauma that is encountered in modern medicine. The purpose of this issue is to provide a broader classification scheme for midface fracture complexes, which incorporates, and yet goes beyond, Le Fort’s classification. The goal is to encourage more clinically relevant radiology reports, so that surgeons will know what to expect, and radiologists will know what to provide, in the CT evaluation of facial fractures.
fractures. Variables that affect surgical management will be emphasized. At the end of each section, there is a short list of pearls for creating clinically relevant radiology reports.

This issue is focused on midface fractures; mandibular and skull base fractures are intentionally excluded to retain this focus.

**Frontal sinus fractures**

Fractures of the frontal sinuses comprise about 5% to 15% of maxillofacial fractures [1–3]. These fractures are generally classified by involvement of the anterior wall (anterior table) or posterior wall (posterior table). In addition, fractures of either wall may be comminuted or noncomminuted, and displaced or nondisplaced. Finally, involvement of either the nasofrontal duct or the anterior cranial fossa dura has important implications for the clinical management of these fractures.

The importance of the radiologic diagnosis of frontal sinus fractures is underscored by the fact that before the advent of routine CT scanning for head trauma, 50% of frontal sinus fractures were not identified until after the patient had left the emergency room [4]. The frontal bone is the strongest of the facial bones, and a large amount of force (800 to 2200 lb) is required to fracture the frontal sinuses [5]. The presence of frontal sinus fractures may therefore be considered an indicator of a high-force injury, and should alert the physician to search for other injuries. Additional craniofacial injuries are present in 56% to 87% of patients with frontal sinus fractures [4,6–11]. An associated cerebrospinal fluid (CSF) leak is present in 13% to 33% of patients with frontal sinus fractures [4,6,8,10,12]. Mortality secondary to other associated injuries has been reported at rates of approximately 9% of patients with frontal sinus fractures [6].

**Structures involved**

Each wall of the frontal sinus serves a dual function. The anterior wall of the frontal sinus, formed by the frontal bone, is responsible for the aesthetic contours of the forehead and the superior orbital rims. In addition, this structure serves as the frontal bar, one of the key horizontal buttresses of the facial skeleton (Fig. 1). The frontal bar helps to maintain the horizontal dimension of the face and to provide a stable foundation for the vertically oriented facial buttresses (see Fig. 1) that support the forces of mastication. Fractures of the anterior table may be clinically important either by disrupting the aesthetic contour of the forehead or by destabilizing the frontal bar from which the other facial bones are suspended [13]. The posterior wall of the frontal sinus forms the anterior wall of the anterior cranial fossa, and serves to separate the sinus contents from the cranial vault. Posterior table fractures are therefore skull fractures, and must be recognized and managed as such. The floor of the frontal sinus forms the medial orbital roof; it also
houses the ostium to the nasofrontal duct in its posteromedial aspect [9]. The nasofrontal duct forms the drainage pathway of the frontal sinus into the nose, so obstruction of this pathway can lead to mucocele, mucopyocele, osteomyelitis, and epidural or subdural abscess [12].

Variables affecting treatment

There are three main variables to consider when assessing the need for surgical intervention for frontal sinus fractures. These are involvement of the anterior table, disruption of the nasofrontal duct, and involvement of the posterior table. When assessing the involvement of the anterior or posterior tables, the degree of fracture displacement and comminution are also important. An additional factor involved when assessing the posterior table is the likelihood of dural penetration or nasofrontal duct disruption.
Anterior table fractures

Nondisplaced anterior table fractures require no surgical intervention. Displaced anterior table fractures may cause cosmetic deformity because of facial stepoffs, asymmetry, or flattening of the normally convex glabella. Repair of these defects is ideally performed within 10 days of the injury, a time during which soft tissue edema resulting from the trauma may mask the cosmetic deformity. Consequently, radiologic estimates of the degree of displacement of the anterior table and the resultant cosmetic deformity are critical in making the determination of whether to proceed with surgery.

Posterior table fractures

The management of posterior table fractures remains somewhat controversial. Nondisplaced posterior table fractures are frequently treated conservatively with close follow-up [2,11]. Follow-up should include early and repeated CT scans of the sinuses [3,11]. In contrast, comminuted or displaced posterior table fractures are generally felt to increase the risk of complications and thus merit exploration [3,14]. The presence of pneumocephalus, although not specific, may indicate dural violation, and also may be an indication for surgical exploration of the fracture [14]. Posterior table fractures may be managed with sinus obliteration if the floor of the sinus is not comminuted and there is not a large amount of bone missing (Fig. 2). Severely comminuted or displaced posterior wall fractures frequently require cranialization (Fig. 3) [6,14,15].

Involvement of the nasofrontal duct

If the nasofrontal duct is disrupted, operative intervention is necessary. A few recent reports suggest that conservative management with an endoscopic Lothrop procedure when necessary to reestablish the frontal sinus drainage pathway may be an option; however, the most trusted method of management is to obliterate the sinus and nasofrontal duct ostium [11,16–19]. Disruption of the nasofrontal duct may be difficult to assess on CT, and intraoperative exploration is often necessary to make the final determination of future nonfunction of the duct. However, the CT report should indicate the likelihood of duct disruption based on the location and degree of displacement of the fracture. Nasofrontal duct disruption is most likely in cases where there is a displaced anterior table fracture medial to the supraorbital notch and involving either the floor of the frontal sinus, the naso-orbital-ethmoidal (NOE) complex (see “Naso-orbital-ethmoidal (NOE) fractures”), or both [16].

Clinically relevant radiology reports: Frontal sinuses

1. Indicate whether the fracture involves the anterior wall, posterior wall, or both, as well as the degree of displacement and comminution of the fracture.
2. For posterior wall fractures, indicate the presence or absence of pneumocephalus with an estimation of the likelihood of dural violation and the degree of bone loss in the posterior wall and floor of the sinus.
3. Indicate the likelihood of nasofrontal duct obstruction based on the fracture location.
4. Comment on any associated brain injury. This is especially important for posterior table fractures.

**Zygomatico-maxillary complex (ZMC) fractures**

The malar eminence of the zygoma is the most anterior projection of the lateral face. This prominent position makes the zygoma susceptible to trauma;
one study demonstrated zygomatic complex fractures to be the most common type of facial fracture in patients admitted to the hospital following blunt facial trauma [20]. The central portion of the zygomatic bone is sturdy, and contributes to the vertical buttress system of the midface (see Fig. 1); however, the projections of the zygoma by which it articulates with the surrounding facial bones, and the articulating bones themselves, are weaker. This often results in fracture of the zygoma at its suture lines, classically labeled as a “tripod” fracture in reference to the three anterior suture lines that are fractured: the zygomaticfrontal (ZF), zygomaticotemporal (ZT), and zygomaticomaxillary (ZM) sutures (Fig. 4). However, the zygoma has a fourth articulation site with the sphenoid bone, which is also fractured, and radiographically, five distinct fractures are demonstrated (lateral orbital wall, orbital floor, anterior...
maxillary wall, lateral maxillary wall, and zygomatic arch). Thus, the name “tripod fracture” is technically inaccurate. A more compelling reason to avoid the term “tripod fracture” is because it fails to recognize that this fracture complex is intermediate on a spectrum of injuries that range from an isolated, nondisplaced fracture limited to the zygomatic arch to severe displacement and comminution of the zygoma and surrounding bones. This spectrum of fractures all have similar mechanisms of injury, but differ in the amount of...
force applied and therefore in the degree of bone loss and displacement [20]. For this reason, it is preferable to classify this entire spectrum of fractures together as zygomaticomaxillary complex (ZMC) fractures.

**Structures involved**

The zygoma is an approximately quadrilateral-shaped bone. The body of the zygoma forms the malar prominence, which is an important aesthetic feature of the face. A prominent malar eminence has been described as “a sign of youth and beauty” [21]. Through its attachments to the surrounding facial bones, the zygoma also helps to determine midfacial height and width [22]. From the laterally oriented malar prominence, the zygoma sends four projections that articulate with the surrounding facial bones. Superiorly, the zygoma articulates with the frontal bone at the narrow frontozygomatic suture; medially, it has a wider articulation with the maxilla, involving both the anterior and lateral walls of the antrum. The curved bony strut of the zygoma lying between these superior and medial projections forms the lateral orbital wall and the lateral aspect of the infraorbital rim and orbital floor. Posteriorly, the zygoma articulates with the sphenoid bone, and laterally it extends as the zygomatic arch to attach to the temporal bone at the zygomaticotemporal suture.

The presence of the thick bone of the zygoma at the lateral corner of the midface allows it to act as a cornerstone to provide support to the other facial bones [23]. The maxilla directly contacts the frontal bone at the frontomaxillary suture line and the sphenoid bone posteriorly above the maxillary tuberosity and anterior to the sphenopalatine foramen. The zygoma then overlies and reinforces this area through its attachments to the underlying frontal, maxillary, sphenoid, and temporal bones.

**Variables affecting treatment**

The goal of reconstruction in ZMC fractures is to restore the height, width, and projection of the malar eminence. The degree of fracture displacement and comminution determines the extent of the surgical exposure needed for repair. Nondisplaced and minimally displaced fractures frequently do not require surgical intervention [20]. Displaced and comminuted fractures generally require open reduction and fixation. The first and most critical step in management of ZMC fractures is achieving adequate reduction [24]. When fractures are not significantly comminuted, as is the case in a classic tripod fracture, the entire zygoma may be reduced as a single unit. In such cases, ZMC fractures may be managed through the use of limited incisions, in particular an upper gingivobuccal (UGB) incision and a lateral upper blepheroplasty (LUB) incision. Reduction can, in these cases, be accurately assessed by confirming reduction at the ZM suture (through the UGB incision), the ZF suture (through the LUB incision), and the ZS suture (through the LUB incision).
Accurate depiction of ZMC fracture displacement can be accomplished with CT (Fig. 5). The malar eminence is often displaced posteriorly, but the degree of displacement may be masked clinically by soft tissue swelling (see Fig. 5A). The malar eminence may be rotated internally or externally (see Fig. 5B, C). Occasionally, the zygomatic arch fracture that accompanies ZMC fractures will not be evident radiographically as a discrete linear hypodensity. Abnormal curvature of the zygomatic arch should be considered equivalent to a discrete fracture in this setting (see Fig. 5D).

Accurate reduction is more difficult to assess in comminuted fractures. When the zygoma itself is comminuted, it cannot be reduced as a single unit, and accurate reduction at one suture line does not imply adequate

Fig. 5. ZMC variants. (A) Axial CT shows posterior displacement of the ZMC (double arrow). This displacement would be masked clinically by soft tissue swelling (note symmetry of facial soft tissues). (B) Internal rotation (arrow) of a ZMC fracture. Note the increased interzygomatic distance. (C) External rotation (arrow) of a ZMC fracture. Note the decreased interzygomatic distance. (D) Zygomatic arch angulation. Although no discrete fracture line is seen through the arch, it is abnormally angulated (arrow), which is sufficient for the diagnosis of ZMC fracture.
reduction at the others. In such cases, additional incisions may be necessary for fracture reduction and fixation. Eyelid incisions (ie, transconjunctival incision with a lateral canthotomy or subciliary incision) provide exposure to the orbital rim. A coronal access incision may be necessary for wider exposure of the zygomatico-sphenoid suture line, lateral orbit, and zygomatic arch. In addition, the high-energy trauma required to create comminuted zygoma fractures frequently also results in comminuted fractures of the surrounding bones. Le Fort, NOE, and panfacial fractures frequently coexist with ZMC fractures [20]. Identification of these coexisting fractures is critical for determining accurate reduction of the ZMC. Failure to recognize coexisting fractures may mislead the surgeon into aligning the ZMC with another segment of the buttress system that is itself displaced; this in turn may result in postoperative cosmetic deformity [24].

Another major variable affecting the surgical management of ZMC fractures is the status of the orbital floor. The zygoma contributes to both the lateral and the inferior orbital walls. Displacement of these walls frequently occurs in ZMC fractures, and may result in an increased volume of the bony orbit. This increase in orbital volume is the most common cause of posttraumatic enophthalmos [25]. Restoration of the pretrauma orbital volume is therefore a primary goal of ZMC fracture management. Before the advent of routine CT scanning for these injuries, the decision of whether or not to explore the orbit was made on a clinical basis. CT scan has been shown to be a reliable method of making the decision of which orbits require exploration [24,26,27]. The ability to make this determination based on the CT scan allows those patients without significant orbital volume expansion to be spared the morbidity of a subciliary or transconjunctival incision. Some degree of ectropion and scleral show may complicate as many as 20% of these incisions [28]. Radiologic criteria suggesting the need for orbital exploration include severe comminution or displacement of the orbital rim, displacement of greater than 50% of the orbital floor with prolapse of the orbital contents into the maxillary sinus, an orbital floor fracture greater than 2 cm², and the combination of an inferior and medial wall fracture [26,28]. Based on these or similar criteria, approximately 30% to 44% of patients with ZMC fractures require an orbital incision [24,26].

A final variable to consider in ZMC fractures is the status of the orbital apex. The orbital apex is the posterior portion of the orbit that contains the optic nerve and lies in close apposition to the internal carotid arteries and cavernous sinuses. Injury to this area may result in a number of serious injuries resulting from injury to the carotid arteries and to cranial nerves II, III, IV, V1, and VI [29]. The lateral wall of the orbital apex is formed by the greater wing of the sphenoid. This bone also contributes to the lateral orbital wall and articulates anteriorly with the zygoma. ZMC fractures may result in displacement of the greater wing of the sphenoid [29]. It is important to note whether this displacement occurs laterally or medially (into the orbital apex). The medial wall of the orbital apex is formed by contributions
from the ethmoid and palatine bones and the body of the sphenoid bone. Fractures in these areas should also alert the radiologist to possible orbital apex involvement.

**Clinically relevant radiology reports: ZMC fractures**

1. Recognize that a range of injuries from an isolated zygomatic arch fracture, to a classic tripod fracture, to a displaced, comminuted zygoma all represent fractures of the zygomaticomaxillary complex (ZMC).
2. Comment on the degree of displacement and comminution of the ZMC fracture. The more displaced and the more comminuted the involved bones are, the more complex the surgical repair with a need for wider surgical exposure and more points of fixation.
3. Comment on the extent of orbital involvement. Fractures involving more than 50% of the orbital floor will likely require open reconstruction.
4. Identify whether the medial orbital wall (lamina papyracea) is involved. An isolated medial orbital wall fracture is generally not a cause of clinically significant orbital volume loss; however, when found in combination with a floor fracture, it may require repair.
5. Comment on the involvement of the orbital apex and the direction of displacement of the lateral orbital wall.

**Nasal-orbital-ethmoid (NOE) fractures**

The nasal bones lie in close apposition to the ethmoid sinuses and the medial orbital walls. Low-force nasal trauma often remains limited to the nose, resulting in isolated nasal bone fractures. By contrast, high-force trauma is often transmitted through the nasal bones to also involve the underlying ethmoid sinuses and orbit [30]. Because of the intimate physical and functional relationship of the bony structures in this area, it is useful to consider the nasal-orbital-ethmoid region as a single unit when dealing with high-velocity facial trauma.

**Structures involved**

The nasal bones articulate superiorly with the nasal process of the frontal bone, laterally with the frontal process of the maxilla, and medially with one another. Just deep to the nasal bones lie the thin bones and air spaces of the ethmoid sinuses. The lateral boundary of the ethmoid sinuses is the medial orbital wall, which is formed by contributions from the frontal process of the maxilla as well as the lacrimal, frontal, ethmoid, sphenoid, and palatal bones [31]. As discussed in the preceding paragraph, high-velocity trauma to this area is generally transmitted to involve all of these bones to varying degrees. Evolutionarily, there is great advantage to the design of these thin bones and air-filled spaces: they form a low-resistance “crumple zone” that
allows the traumatic force to be dissipated. The critical structures such as the brain and optic nerve lie within stronger bone behind this crumple zone and are thus relatively protected from injury [32].

Despite the protective nature of this design, significant cosmetic and functional deficits may arise from high-force NOE injury. Midface retrusion and nasal shortening occur as a result of the nasal bones telescoping inwards into the crumple zone. The medial canthal tendon (MCT) inserts on the anterior and posterior lacrimal crests and the frontal process of the maxilla. Telecanthus arises from displacement of the MCT fragment or disruption of the MCT from its bony insertions. Epiphora is another frequent complication of fractures in this area. The lacrimal drainage pathway extends from the lacrimal puncta at the medial canthus through the canaliculi, nasolacrimal sac, and nasolacrimal duct. These structures are closely related to the lacrimal and maxillary bones as well as to the medial canthal tendon; disruption of any of these related structures places the lacrimal drainage pathway in danger of obstruction [30,33–35]. Persistent posttraumatic epiphora has been reported in 5% to 31% of patients with NOE fractures [35]. Damage may also occur to the frontonasal duct (see “Frontal sinus fractures”).

Variables affecting treatment

Status of the medial canthal tendon

Markowitz and colleagues [36] classified NOE fractures based on the status of the medial canthal tendon and the degree of comminution of the fragment of bone to which it remains attached (Fig. 6). Type I injury occurs when fracture lines leave a central segment of bone with the medial canthal tendon attached (Fig. 7). These are the simplest to reconstruct, as this central segment can be plated to the surrounding facial bones. Type II fractures involve comminution of the central fragment, but the MCT remains firmly attached to a definable segment of bone. Type III fractures result in severe central fragment comminution with disruption of the MCT insertion sites. Type II and III injuries are the most difficult to repair, and require transnasal wiring (Fig. 8) of the medial canthal tendon-bearing bone fragments (Type II) or the MCT (Type III). Clinically, identification of these injuries is often difficult because of the presence of soft tissue edema. Thus, it is critically important to identify displacement or comminution of the medial canthal tendon insertion radiographically.

Degree of bony injury: comminution and posterior displacement

In addition to the degree of comminution of the central fragment, the degree of comminution of the surrounding nasal, maxillary, and orbital walls also plays an important role in the reconstructive plan. Severe comminution, posterior displacement, or loss of bone in the midface precludes reconstruction with plates and screws alone, and serves as an indication to
the surgeon that bone grafting will be necessary to reestablish adequate facial projection. Bone grafting is frequently necessary following NOE fractures to restore orbital volume and nasal projection (see Fig. 7) [36,37].
Associated injuries

The cribiform plate forms the roof of the nasal cavity; as such, it is at risk for involvement in cases of NOE fracture. The nasofrontal duct may also be injured at the site of its outflow in the anterior ethmoid sinuses. Finally, NOE fractures are associated with high-force trauma involving the medial orbital wall and have been associated with several ocular injuries, including hyphema, vitreous hemorrhage, lens dislocation, and globe rupture [30]. These associated injuries should be sought and commented upon in the radiology report.

Clinically relevant radiology reports: NOE fractures

1. Recognize that a nasal bone fracture in combination with a fracture of the medial orbital wall and frontal process of the maxilla represents
disruption of a facial unit known as the nasal-orbital-ethmoid (NOE) complex.

2. Indicate whether the central fragment of the medial orbital wall (to which the medial canthal tendon attaches) is displaced and/or comminuted.

3. Comment on the degree of displacement of the nasal root (nasal bridge), either posteriorly into the ethmoids or superiorly into the anterior cranial fossa.

4. Comment on the degree of comminution of the nasal bones, frontal processes of the maxilla, and nasal processes of the frontal bones, as comminution in these areas may require the surgeon to plan for bone grafting.

5. Comment on the presence or absence of commonly associated injuries, including cribiform plate fracture, nasofrontal duct injury, and ocular injury.

**Orbital wall and floor fractures**

There are two main types of orbital fractures. The first type occurs when one or more of the bony walls of the orbit are fractured. The inferior orbital rim, in particular, is frequently fractured and displaced inward into the orbit. The displaced bone directly impacts the more delicate bones of the orbital walls and orbital floor, resulting in secondary fractures in these regions. Because the inferior orbital rim is derived largely from the zygomatic bone, fractures of the zygoma or its attachments that result in displacement of the zygoma frequently cause secondary fractures of the orbital walls and floor [38]. The second type of orbital fracture is what is
commonly known as an orbital “blowout” fracture. In this type of fracture, the orbital rim remains intact, but the force of impact is transmitted to the delicate bones of the orbital floor, roof, and medial wall (Fig. 9), causing fractures in these bones without disrupting the continuity of the stronger inferior, lateral, and superior orbital rims.

**Structures involved**

The orbit is shaped like a cone, with the apex posteriorly. The greatest diameter is not at the inferior orbital rim, however, but approximately 15 mm posterior to it, at a point where the medial wall, roof, and floor of the orbit are all concave relative to each other [39]. Posterior and posteromedially to this, the orbital floor becomes convex. This configuration has important implications for reconstruction of orbital fractures, as failure to reconstruct the convex portion (including the medial orbital wall) is one of the common causes of postoperative enophthalmos [40].

**Variables affecting treatment**

The primary determination to make when assessing the CT scan is whether the orbital fracture is an isolated blowout fracture or part of a larger fracture pattern. Orbital fractures occur in combination not only with ZMC fractures but also with Le Fort and NOE fractures. If the orbital fractures consist only of fractures of the orbital floor, roof, or medial wall without fracture of the firm orbital rims, then the treatment algorithm for orbital blowout fractures applies. Orbital fractures occurring along with other fracture patterns are more likely to be the result of a high-force injury, and frequently require a more extensive surgical repair.

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**Fig. 9.** Orbital blowout fractures. Although orbital floor fractures (arrow, A and B) are the most common type of blowout fracture, medial wall fractures (arrowheads, A) and superior wall fractures (arrow, B) may also be seen.
There are three main indications to treat isolated orbital wall fractures. The first is entrapment of any of the extraocular muscles. Entrapment of the muscle can cause ischemic damage, and permanent dysfunction can occur if the fracture is not reduced and the muscle released expeditiously [41,42]. Entrapment is diagnosed on clinical exam and cannot be directly assessed on CT. However, herniation of the extraocular muscles beyond the bony margins of the orbit is suggestive of entrapment and should be sought on CT. The radiologic diagnosis of herniation may be especially difficult in children, as the more pliable bone may result in “trapdoor” fractures (Fig. 10). These fractures result when the bone of the inferior orbit is displaced inferiorly and forms a greenstick fracture. The pliable bones

Fig. 10. Orbital “trapdoor” fracture. (A) The small mass of soft tissue at the maxillary sinus roof could be confused with blood, but it actually represents a herniated and incarcerated right inferior rectus muscle. Note the loss of the inferior rectus muscle shadow (compare with right eye, arrowhead). (B) The fracture is subtle on bone windows because the displaced bone has snapped back into place. (C) Postoperative coronal CT scan showing reduction of the fracture with reappearance of the inferior rectus muscle shadow within the orbit.
then snap rapidly back into a near-normal position, but the inferior rectus muscle can become trapped in the fracture line in the process. This may occur without any evidence of bone loss in the orbital floor or blood or soft tissue in the maxillary sinus. CT findings in trapdoor-type fractures can be quite subtle, and may be overlooked if they are not actively sought [41]. One characteristic finding in such fractures is the loss of the inferior rectus muscle in the orbit (see Fig. 10). Coronal reformats are critical in the evaluation of the orbital floor.

The second indication for treatment is to prevent postoperative globe malposition and its resulting complications of diplopia or enophthalmos. Because of the diffuse soft tissue edema associated with facial fractures, it can be difficult to assess in the acute setting whether or not a patient’s fractures will result in globe malposition after the swelling has resolved. Although there is no set rule, many surgeons believe that orbital reconstruction is necessary in the following situations: (1) early clinical enophthalmos, before the soft tissue edema has dissipated, (2) displacement of greater than 50% of the orbital floor (Fig. 11), (3) orbital volume change greater than 1.5 mL (5% of normal orbital volume), and (4) significant fat or soft tissue displacement [39–43].

The third indication for surgery of the orbit is when the force of the impact is so severe that the lateral orbital wall (orbital plate of the sphenoid bone) impacts into the orbital apex or middle cranial fossa (Fig. 12). In such cases, surgery may be indicated for decompression of neural structures [39]. The surgeon should be cautioned, however, that surgical intervention may worsen a tenuous situation, (ie, secondary to intraoperative compression/

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Fig. 11. Large orbital floor fracture. Coronal reformatted CT shows a fracture encompassing almost the entire orbital floor (arrowheads). Fractures of greater than 50% of the orbital floor are usually repaired surgically.
manipulation of the orbital apex), and preoperative consultation with an ophthalmologist is recommended.

**Clinically-relevant radiology reports: Orbital fractures**

1. Note the presence or absence of extraocular muscle herniation. Muscle entrapment is a surgical emergency, so when herniation is identified on CT, the surgeon should be notified immediately.
2. Determine whether the orbital fracture is an isolated blowout fracture, or part of a larger fracture pattern (ZMC, NOE, Le Fort).
3. Identify which orbital walls are fractured: when one wall is fractured, look carefully at the other walls.
4. Estimate the size of each of the fractures (ie, in cm² or in percentage of floor/walls) and the degree of displacement of fat and soft tissues.

**Le Fort fractures**

More than 100 years ago, Rene Le Fort devised a classification system for midface fractures. This classification scheme is based on his finding that blunt trauma tends to cause fractures along three particular lines of weakness inherent in the design of the facial skeleton [38]. Le Fort based his system on his observation of experimental fractures made in cadavers. Fractures occurring in 21st-century, real-life situations (in particular, high-velocity motor vehicle accidents) often deviate from this classification system, and “pure” Le Fort fractures are rare. Nevertheless, the Le Fort
classification system is widely known, and it provides a method for concise communication of fracture patterns between clinicians and radiologists.

**Structures involved**

There are three types of Le Fort fractures (Fig. 13). Each Le Fort level describes not an isolated fracture, but rather a pattern of fractures involving multiple facial bones. The most consistent and uniting feature of the Le Fort fractures is the presence of bilateral pterygoid fractures. Pterygoid fractures are found in all three classes of Le Fort fractures, and are the key to establishing the diagnosis [44]. If a CT reveals bilateral pterygoid fractures, a Le Fort fracture should be suspected. Conversely, if the CT scan does not reveal pterygoid fractures, the Le Fort fractures can be excluded [44].

The Le Fort I fracture is a horizontal fracture through the maxilla, cephalic to the maxillary dentition. Bones fractured in a Le Fort I pattern include the lower nasal septum, the inferior portion of the piriform apertures, the canine fossae, both zygomaticomaxillary buttresses, the posterior maxillary walls, and the pterygoid plates. The Le Fort II fracture is often described as being pyramidal in shape [44]. It traverses the nasofrontal junction and extends laterally across the medial orbital wall, orbital floor, infraorbital rim, and then through the zygomaticomaxillary suture line. It also proceeds posteriorly through the nasal septum and pterygoid plates. The Le Fort III fracture is a complete craniofacial separation, resulting in separation of the facial bones from the cranium along the line of the nasofrontal and zygomaticofrontal suture lines. As in Le Fort II fractures, the fracture transverses the nasofrontal junction and extends laterally through the orbit; however, Le Fort III fractures involve not only the medial and inferior orbital walls but also the lateral orbital wall, zygomaticofrontal suture line, and zygomatic arch. As with the other Le Fort fractures, the fracture line also extends posteriorly through the nasal septum and pterygoid plates.

Each Le Fort fracture pattern has at least one unique component fracture that is easily recognizable and separates it from the other Le Fort fractures [44]. Rhea and Novelline recently used these unique identifying fractures to design a simple method for identifying and classifying facial fractures [44]. Only the Le Fort I fracture involves the lateral aspect of the piriform aperture. Only the Le Fort II fracture involves the inferior orbital rim and zygomaticomaxillary suture line. Finally, only the Le Fort III fracture involves the zygomatic arch and the lateral orbital wall. When midfacial fractures are present and a Le Fort fracture pattern is suspected, the authors recommend first looking at the pterygoid plates. If there is a bilateral pterygoid fracture, a Le Fort fracture is likely present. The next step is to inspect the three defining fractures discussed above: the lateral piriform apertures, the inferior orbital rim, and the zygomatic arch. The presence or absence of each of these fractures determines whether a fracture of that type is present.
or absent [44]. For example, the absence of a lateral piriform fracture rules out a Le Fort I; the presence of a zygomatic arch fracture makes it likely that a Le Fort III fracture is present.

The final step is then to look systematically for fractures of the other bones that are involved in the Le Fort levels. This is important because it is possible to have a Le Fort fracture on one side and an isolated ZMC or NOE fracture on the other side. The presence of the key indicator fractures does not definitively diagnose the Le Fort level; instead, it serves to alert the radiologist to the high likelihood of a particular Le Fort fracture. The other associated fractures must still be identified. Finally, it is possible to have more than one Le Fort level on a single side of the facial skeleton [44]. For this reason, all three key indicator fractures must be examined, allowing each Le Fort level to be ruled in or ruled out, regardless of whether there is a coexisting Le Fort fracture of a different level [44].

Variables affecting treatment

Le Fort fractures result in both a cosmetic and a functional deficit. As discussed above, the facial skeleton is formed by a combination of the relatively strong bones forming the midfacial buttresses, and the more fragile bones containing air-filled sinuses that lie deep to the buttresses (see Fig. 1). Le Fort fractures generally disrupt both. These fractures are caused by forces strong enough to break the buttresses, which then collapse internally and result in the secondary fracture of the more fragile internal bones. The result, as with NOE fractures, is retrusion of the central midface. In addition, Le Fort fractures may result in a loss of the vertical height of the face as a result of interruption of the vertical buttresses. Finally, the force required to cause a Le Fort fracture generally results in other facial bone fractures, and these add to the difficulty of the surgical repair.

Fractures of the hard palate or dentoalveolar units are frequently associated with Le Fort fractures (Fig. 14). The presence of such fractures is clinically important, as they further disrupt the patient’s occlusion, adding significantly to the complexity of fracture repair. To achieve normal midface projection, normal occlusion must be restored before anchoring the upper midface to the maxilla. Similarly, the presence of a coexisting mandibular fracture will affect the occlusion. For Le Fort II and III fractures, associated ZMC, NOE, or frontal sinus fractures must be recognized. The frontal bar must be reconstructed before the midface can be resuspended to it.

The goals of treatment are thus to restore occlusion, facial height, and facial projection. Knowledge of the Le Fort levels involved on each side is crucial when making the operative plan, as the surgical access incision depends greatly on the level of fracture. Le Fort Level I fractures may be accessed via a gingivo-buccal sulcus incision, whereas Le Fort II and III fractures may require a coronal and possibly an orbital access incision such as the transcon junctival or subciliary approach [45]. The final consideration is the
degree of comminution of the involved bones. The buttresses must be recreated to restore facial height and projection. If the buttresses are severely comminuted, they may be inadequate for this function, and bone grafting may be necessary.

A final consideration, as with other high-energy fractures, is the orbital apex. Many Le Fort fractures extend to the anterior cranial base, and in doing so the fracture lines traverse the orbital apex. Although not described by Le Fort, some authors refer to this type of fracture as a “Le Fort IV” fracture [29,45]. Le Fort fractures are frequently reduced with disimpaction forceps and a great deal of manual force. Fracture lines through the orbital apex and close to the carotid canal must be identified on preoperative CT scan to alert the surgeon to use a more gentle reduction technique to avoid disrupting the fractured bones in these critical areas [29].
Clinically relevant radiology reports: Le Fort fractures

1. Indicate which Le Fort levels are involved. Le Fort levels may differ between the two sides of the face, and fractures may occur through more than one Le Fort level on the same side of the face.

2. Other facial fracture patterns such as NOE, frontal sinus, and ZMC fractures frequently occur in association with Le Fort fracture patterns, and should be noted.

3. Fractures of the hard palate, maxillary dentoalveolar units, and mandible will affect occlusion and thus affect the repair; these injuries should be specifically sought.

References


