Introduction

Fractures of the midface frequently occur after facial trauma. Advances in radiological imaging and rigid fixation have led to improved diagnosis and outcome of these fractures. The classically described LeFort, trimalar, and orbital fractures often occur in conjunction with one another, and rather than a segmental approach to each one, the facial trauma surgeon should think of them as various manifestations of orbitozygomaticomaxillary fractures. The anatomy, pathology, and treatment of these types of fractures will be discussed. Precise anatomic reduction and, at times, fixation, lead to superior functional and cosmetic outcomes. Nasoorbitoethmoid fractures and nasal fractures are covered in a different Grand Rounds.

Epidemiology

Typically facial fractures occur in young males. The male to female incidence of these fractures is 4:1. The most common cause of facial trauma is motor vehicle accidents, followed by altercations and falls. The most common facial fracture is the nasal fracture, followed by zygomatic fractures. Interestingly, in altercations the left zygoma is fractured more often than is the right zygoma, presumably due to the preponderance of right-handedness in assailants. Facial fractures remain somewhat uncommon in the pediatric population, possibly due to the smaller relative dimensions of the midface compared to the cranium, and also perhaps due to the mechanism of injury (2,26).

Anatomy

The midface is composed of the paired maxilla bones which are fused in the midline and which articulate with the frontal bones medially and the zygomas laterally. Posteriorly the maxillary bones articulate with the palatal bones which anatomically act in conjunction with the
maxillae. The bones of the midface are quite thin and surround the air-filled paranasal sinuses. The teleological function of the sinuses has been debated, but in facial trauma they are thought to serve as a "crumple zone" which absorbs anterior trauma and shields the cranium.

The zygoma serves to define the external cheek contour and is an important aesthetic area of the midface. It also serves to shield the orbit. According to Stanley, there are six important articulations (22). Four of these are superficial, and two are deep. The superficial ones are as follows: superiorly at the zygomaticofrontal suture, posteriorly at the zygomaticotemporal junction (which leads into the zygomatic arch), medially at the orbital rim, and inferiorly at the lateral antrum. The two deep articulations are the lateral orbital wall where the zygoma articulates with the orbital process of the sphenoid bone, and across the inferior orbital fissure along the orbital floor where it articulates with the orbital process of the maxilla.

The orbit is composed of seven bones: the lacrimal and ethmoid bones medially (also referred to as the lamina papyracea), the frontal bone superiorly, sphenoid and zygoma posteriorly and laterally, and the maxilla inferiorly with a small process that extends up from the palatal bone. It is a bony socket that has been described as a four-sided pyramid with the apex posteriorly or as a cone. The orbit houses the globe and its associated muscles, nerves, and vessels. The anterior orbital floor is concave, but as it extends posteriorly it becomes convex. There is no clear anatomical separation between the orbital floor and the medial wall. The optic nerve enters superomedially to the apex of the orbital cone.

Functionally, although composed of thin bone, the midface has focal areas of strength referred to as buttresses. The more important buttresses are the vertical buttresses, which serve to withstand the force generated during chewing. These radiate from the maxilla and project up to the skull base. The medial buttress is the nasomaxillary, and it passes along the lateral piriform aperture, up the frontal process of the maxilla, and into the frontal bone. The lateral buttress is the zygomaticomaxillary, and it passes laterally from the maxilla to the zygoma and attaches to the skull base at the zygomaticofrontal suture. There is a third vertical buttress posterior to the other two that connects the maxilla with the sphenoid bone known as the pterygomaxillary buttress. Cosmetically the vertical buttresses serve to establish the height of the midface.

The horizontal buttresses serve to reinforce and support the vertical buttresses. The thick area of the frontal bone which supports both nasomaxillary and zygomaticomaxillary buttresses is known the frontal bar. On the other side of the orbit the inferior orbital rims function as buttresses between the same vertical buttresses. The alveolar ridge is the most inferior of the midface horizontal buttresses. Manson observed that the horizontal buttresses have both a coronal and sagittal component to them (14).

**Fractures**

LeFort in 1901 investigated patterns of midface trauma. His classification, although not perfect, is widely known and serves as a useful descriptor of various midface fractures. He found that fractures tend to occur in consistent patterns because these are the weaker areas of the midface. LeFort fractures tend to result from anterior facial trauma. It should be realized that
there is an infinite number of fracture possibilities and no classification scheme is able to describe them all.

The LeFort I fracture essentially separates the lower maxilla including the alveolar ridge and teeth from the rest of the midface. The fracture classically travels through the inferior portion of the piriform aperture. The LeFort II fracture includes the entire piriform aperture in the distracted midface. The fracture line includes the frontonasal suture, passes through the inferomedial orbit, and between the zygoma and maxilla for a larger area of dissociation. The LeFort III fracture is similar except that the fracture line passes through the lateral orbit superior to the zygoma, which is attached to the maxilla. This also known as craniofacial dissociation as the bones of the midface are essentially completely disarticulated from the cranium.

The zygoma itself is a relatively strong bone, and fractures of the body of the zygoma are rare. Instead the force transmits to the weaker suture lines and fractures them. A variation of this is a blow directly over the zygomatic arch that causes an isolated arch fracture. Zygoma fractures tend to result from lateral trauma, as opposed to LeFort fractures, which tend to result from anterior trauma. Because the zygoma articulates superficially with the maxilla, frontal, and temporal bones, zygomatic fractures in the past have been referred to as tripod or trimalar fractures. Others have noted that its deep articulation with the sphenoid really makes it a quadropod fracture. Another term in the literature is the zygomaticomaxillary complex, or ZMC, fracture. As mentioned previously, Stanley feels that there are six important articulations. The four superficial ones define two arcs – a vertical arc from the zygomaticofrontal suture down to the lateral antrum, and a horizontal arc from the zygomatic arch to the inferior orbital rim. The intersection of these two arcs defines the malar prominence (24).

Orbital fractures may occur in combination with other fractures or may occur in isolation. For example, the zygoma by nature of its articulation with the orbit may cause orbit fractures during a zygoma fracture. However, isolated orbital fractures do occur, usually from an object that avoids the bony protection of the zygoma and orbital rims and transmits force directly to the globe, such as a baseball or a fist. This causes increased orbital pressure and causes a "blow-out" of the thin bones. Usually this involves the orbital floor or medial wall. Less commonly involved are the lateral and superior walls.

**Patient Evaluation**

Evaluating the facial trauma patient can be challenging. First and foremost one must remember the basics of trauma delineated in the Advanced Trauma Life Support courses. With extensive facial trauma and the possibility of skull base injury endotracheal intubation may be relatively contraindicated and one must consider a surgical airway if needed. Also, a patient who has sustained forces adequate for facial injury must be assumed to have a cervical spine injury until proven otherwise. Epistaxis can be troublesome and hemodynamically significant and is addressed in the usual way with the caveat that skull base injury may be present.

Once the patient is stabilized a history and physical is performed. Subjective data the patient may note that might be a clue to facial fractures include pain, malocclusion, numbness in portions of the face, trismus, and diplopia. Malocclusion is a sensitive indicator of injury due to
the high sensitivity of the periodontal ligaments. Numbness often indicates disruption or compression of a peripheral nerve. Trismus may result from mandibular trauma or from an impacted zygoma impinging on the temporalis muscle. Diplopia may result from entrapment of the extraocular muscles or gross globe malposition. Of special note, monocular diplopia indicates an intrinsic globe problem and mandates prompt ophthalmologic evaluation. Unfortunately some of the trauma patients are obtundant or intoxicated and are unable to provide subjective data. In this case the physician must rely on physical examination.

On physical examination the examiner should note presence and location of any lacerations or ecchymoses, any gross asymmetries, and palpate for instability, crepitus, tenderness, bony stepoffs, and check for canthal tendon disruption. The trigeminal nerve should be tested. Ophthalmologic examination deserves special mention.

Ophthalmologically, Stanley feels that it is unreasonable to expect ophthalmologic consultation on every patient (22). He feels that each patient should have documentation of visual acuities (subjective and objective), pupillary function, ocular motility, anterior chamber exam (to look for hyphema), and funduscopic exam. Ophthalmologic consultation should be obtained then as indicated. One may wish to investigate the local standard of care in this regard.

If the patient is unresponsive, looking for an afferent pupillary defect may uncover an occult visual loss. If indicated clinically, tonometry may be used to assess the intraocular pressure. This may serve as a baseline for serial examinations. Also, forced duction testing can be done to check extraocular movements. This is done by grasping the sclera in the fornix and mechanically moving the globe. Typically this would be for the inferior rectus, and the globe would be attempted to be moved superiorly. Inhibition of this motion would be indicative of entrapment and possible need for exploration.

Despite the best exam, radiological imaging remains an important step in the evaluation of facial trauma. For orbitozygomaticomaxillary fractures, CT scanning appears to offer a substantial improvement over plain films that justifies the increased cost. Important areas to evaluate on CT scanning include the vertical buttresses, the orbital walls, the zygomatic arch, the palate, and the mandibular condyles (22). Missing a condylar fracture could be particularly troublesome as one may place the patient in maxillomandibular fixation in an anatomically incorrect fashion and lead to a long-term condylar problem.

**Treatment**

**Zygoma**

When more than one facial area is injured, one must develop a rational treatment plan. Ideally one would work from that which is stable to that which is unstable. In general this means stabilizing the mandible, zygoma, and palate, before the midface, which in turn should be done before the orbit or a concomitant nasoorbitoethmoid fracture. A global treatment plan is unattainable, however, and every patient must be dealt with on an individual basis.
Cosmetically one seeks to reestablish facial height and width. This is accomplished by recreating the patient’s natural anatomy. In order to achieve this goal one must work from stable areas to unstable areas on the facial skeleton. For example, the frontal bar establishes facial width. If the frontal bar is intact, resuspending the vertical buttresses from it serves to establish proper facial width in the midface. Also, if the mandible is intact one may use it as a landmark for proper facial height. On the other hand, in certain cases in which the mandible is not intact, it may be preferable to recreate the midface first and use it as a guide to establish the proper position of the mandible. This will be addressed shortly.

For the zygoma, ideal timing of repair is between five to seven days post-injury. This gives the tissues time for edema and swelling to resolve but is before fibrosis and contraction set in. Pre- or intra-operative steroids may assist in reducing the swelling. After ten days the masseter begins to contract and may make reduction of the zygoma suboptimal. Many recommend prophylactic antibiotics due to concern over the maxillary sinus violation, but this has not been definitively shown to be necessary.

If the zygoma is minimally displaced and there is no comminution, the patient may be a suitable candidate for reduction only. This is commonly done via a Gillies approach, in which an incision is made in the hairline down to and through the superficial layer of the deep temporal fascia. A blunt instrument such as the Rowe elevator is advanced down to beneath the zygoma, and the bone is elevated until a "pop" is heard. If physical exam then verifies a good reduction, the incision is closed and the procedure is complete. The patient should wear a guard over the arch for a period of time to remind and protect the patient from an accidental displacement of the now-reduced zygoma.

If there is moderate displacement or comminution of the lateral antral wall, or if there is not a good "click" or "pop" upon Gillies reduction (suggesting inadequate bony integrity to support reduction), the lateral antral wall may need to be plated. This can readily be accomplished through a sublabial incision. Stanley indicates that two screws on either side of the fracture are adequate (22).

For more advanced fractures, internal fixation may be necessary at the lateral antrum, the inferior orbital rim, the zygomaticofrontal (ZF) suture, and even the zygomatic arch. One pearl is that the ZF suture is uncommonly comminuted, and one can place a wire there for semirigid fixation while exploring and treating the other areas. One can then come back and plate it rigidly. Access to the ZF suture can be readily had through a lateral brow incision. This should be hidden in or near the brow, but the brow should not be shaved, and the incision should parallel the roots to avoid brow hair loss. The lateral antrum and orbital rim can be accessed via a sublabial incision or via an ocular approach, such as the transconjunctival or subciliary approaches. Lateral canthotomy and inferior cantholysis may be necessary to increase exposure. Full access to the arch may require a hemicoronal approach. If a coronal or hemicoronal approach is used, Stanley comments on the level of dissection. Classic teaching is that one should perform the dissection beneath the superficial layer of the deep temporal fascia to protect the frontal branch of the facial nerve. This exposes the temporal fat pad. Stanley feels that this can lead to temporal atrophy, and for the experienced facial trauma surgeon he feels that careful dissection superficial to this layer can protect the nerve and preserve the fat pad, thereby avoiding temporal wasting (22).
Midface

For midface fractures a similar rationale is employed. A minimally displaced, minimally comminuted fracture can either be treated with simply maxillomandibular fixation (MMF) or by open reduction/internal fixation (ORIF) if six weeks of MMF is unacceptable to the patient. If the patient is allowed to return to early function he or she should understand that this will be for soft foods only, as truly rigid fixation in the midface, unlike the mandible, is unattainable due to the thin bones and correspondingly thin plates.

For more comminuted or displaced fractures, one very important piece of data is the status of the mandible. If the mandible is intact, it serves as a guide for placing the upper dentition into occlusion. MMF is placed, and then the midface is treated with appropriate ORIF. If there is no temporomandibular joint (TMJ) injuries and MMF was passively obtained without "pulling" the mandible into occlusion, the MMF can be released after the ORIF of the midface and the patient allowed to function (again, soft diet only). Should there be difficulty obtaining MMF or suspicion of a non-fracture TMJ injury, one should reduce the fractures with wire (which is more forgiving) and then keep the patient in MMF for 4-6 weeks.

If the mandible is fractured, as long as the fracture site is not the condylar head or high condylar neck then one can place the patient in MMF, ORIF the mandible, and then proceed exactly as above. If the mandible fractures are in the above-mentioned locations, one cannot rely on the mandible to establish proper facial height, and one should then first ORIF the midface, then place the patient into MMF, then treat the mandible as indicated.

If the palate is fractured it may be helpful to first wire the posterior aspect of the palate for stability before MMF or any midfacial plating is undertaken. Particularly if the mandible is concomitantly fractured, if one fails to do this first then occlusion could be obtained that actually is splayed out and is not the patient’s true anatomy.

Orbit

The goal in orbital treatment is to prevent limitation of ocular motion by muscle entrapment and limit enophthalmos. With that in mind, then, the indications for orbital exploration are essentially related to current or anticipated fulfillment of those criteria. Shumrick found in patients with concomitant zygomatic or midface fractures that the indications for orbital floor exploration are as follows: persistent diplopia with a positive forced duction test, obvious enophthalmos, comminuted orbital rim by CT, greater than 50% floor disruption by CT, combined floor/medial wall defects by CT, fracture of body of zygoma by CT, and "blow-in" fracture with exophthalmos by physical examination or by CT (21). As with zygoma fractures, Mathog recommends a delayed period (7-10 days) as the optimal time to intervene in order to decrease swelling yet prevent long-term changes (16).

There are some contraindications to orbital surgery of which the surgeon should be aware. If the patient has an injury to his or her only-seeing eye, the concern for binocular diplopia is moot, and risk to the eye should be carefully balance against any intervention. Gross malpositioning of the globe may still need surgery, but one should proceed with caution,
particularly with posterior dissection or forceful globe handling. Also, presence of certain injuries such as hyphema, globe injury, and retinal tear may be exacerbated by surgery, and thus intervention should be delayed. Of course, medical instability (perhaps due to concomitant multi-organ trauma) is also a contraindication to surgery.

Access to the orbital floor or medial orbit is commonly through either a subciliary or transconjunctival incision. The transconjunctival incision has the advantage of no external scarring. The lid is everted and the conjunctiva incised at the level of the lid retractors. Dissection is then carried anterior to the orbital septum down to the orbital rim. One should incise the periosteum slightly below the orbital rim and then dissect up and into the orbit, elevating periorbita away from bone. Lateral canthotomy and inferior cantholysis can be performed to increase exposure.

Once the fracture is exposed one has to decide how to best repair it. For smaller defects of the anterior concave floor, Marlex mesh is a good choice. It requires 360-degree edge support, but it may merely be laid in place. Subsequent fibrosis will integrate the mesh into the periorbita. For larger defects involving the posterior convex floor as well, or for those with only medial and lateral support, Medpor may be placed. One must be vigilant in dissecting back a full four centimeters, lest an inadequately-treated posterior defect lead to posterior herniation of orbital contents and failure of the repair. For larger defects of involving the medial and lateral wall, either outer-table calvarial bone grafts or titanium mesh should be employed.

Orbital roof fractures are uncommon due to the high degree of force needed to fracture this thick bone (15). When they do occur, commonly they occur in conjunction with intracranial injury. One should be careful in their to avoid connecting any grafts to the frontal bar directly, as this will cause diminution of the natural roof concavity and will inferiorly displace the globe. The graft instead should be attached superior to the frontal bar.

**Cutting Edge**

Bioresorbable plates are just coming onto the market. They might have particular utility in the pediatric population, where there is concern that unless removed, rigid fixation may inhibit facial growth. Early reports, however, are that that are difficult with which to work. Some centers currently have intraoperative CT scanning. The advantage of immediate radiographic inspection of reduction at a point when it could be easily changed is obvious, but this is still unavailable at most centers. Some centers employ three-dimensional reconstruction CT, but the advantage over conventional CT has yet to be demonstrated.

**Conclusion**

Precise anatomical reduction of orbitozygomaticomaxillary fractures is necessary for optimal outcomes. A thorough understanding of the anatomy, pathology, and treatment options will give the facial trauma surgeon the optimal tools for achieving a successful result.
Bibliography


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