A Vision Center of Excellence newsletter focused on ocular casualty care and readiness

FRONTLINES OF EYE CARE

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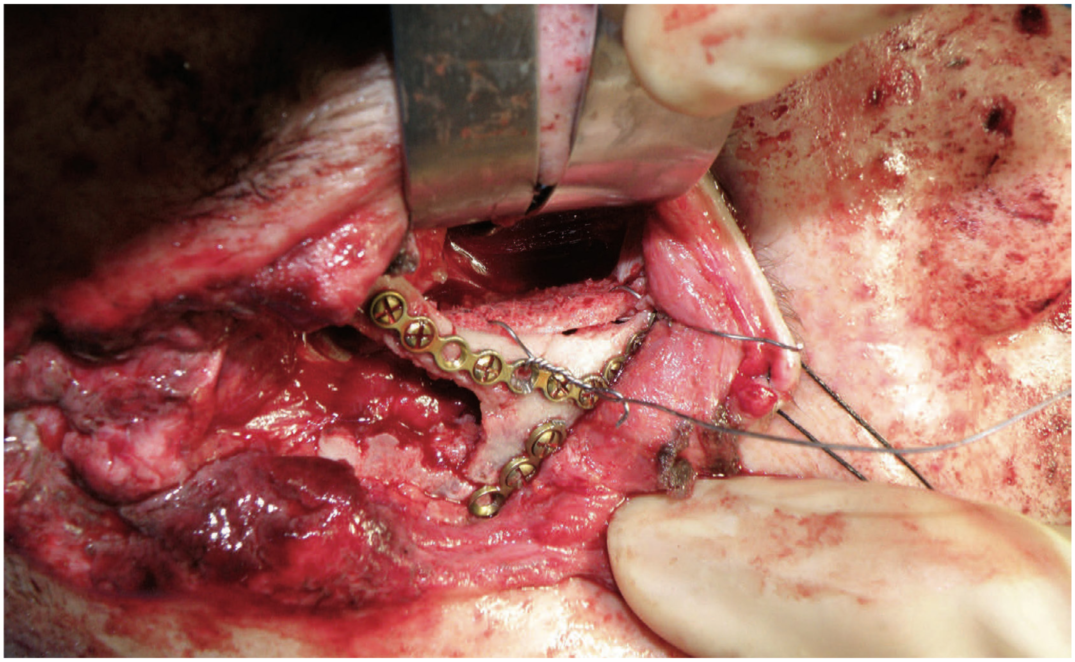

Orbital fracture repair. *(Source: James W. Karesh, MD)*

FEATURE

ORBITAL FRACTURES: ANATOMY, REPAIR, AND SURGICAL CONSIDERATIONS

Facial Fracture Repair and the Facial Buttresses

The facial skeleton can be divided into three anatomic regions: (1) lower face (formed entirely by the mandibular bone); (2) mid-face including the zygomaticomaxillary complex and the naso-orbital-ethmoidal complex; and (3) upper face including the frontal and temporal bones and the frontal sinus. The mid-face bones enclose and protect the nasal cavity, paranasal sinuses, and the orbits. In addition, the bones of the mid-face provide the superior dental occlusal surface for the mandible, provide a base for the facial muscles and muscles of mastication, and maintain the vertical and horizontal dimensions of the face by providing a stable connection between the cranial base and the other facial bones.

In 1901, René Le Fort experimentally used significant amounts of blunt trauma force on cadaver skulls to determine how this force would disrupt the normal relationships between the facial bones.[1] He was able to identify three basic fracture patterns associated with significant

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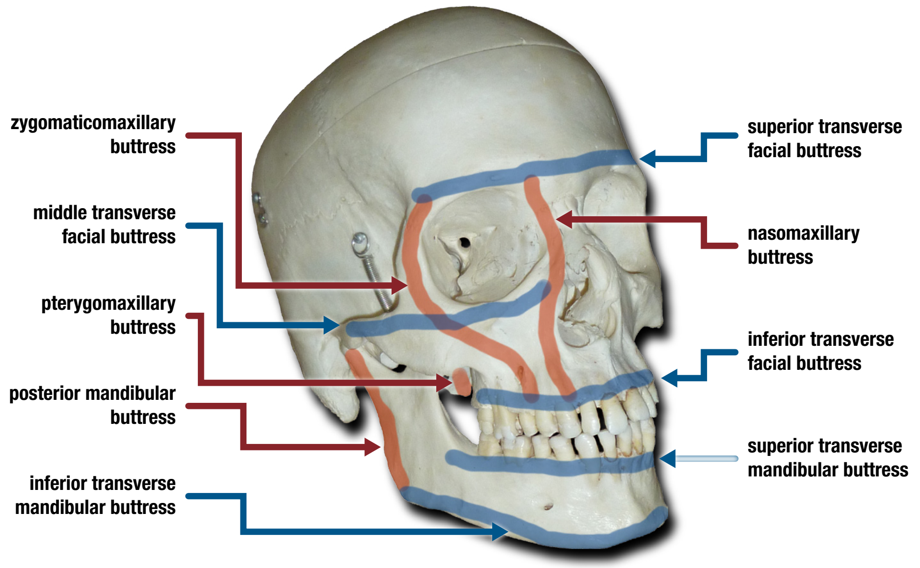
blunt force trauma to the face. Today, these are designated as Le Fort 1, 2, and 3 fractures.[2] Le Fort 1 fractures are horizontal in nature and involve the alveolar portion of the maxilla, below the nose and above the teeth. Le Fort 2 fractures are pyramidal in shape and extend through the nasal bridge at, or below, the naso-frontal suture, the superior medial wall of the maxilla, the lacrimal bones, and the orbital floor. The Le Fort 3 fracture separates the mid-face from the cranial base, extending through the zygomatic arch, frontal-zygomatic suture, the lateral and medial orbital walls, and naso-frontal and frontomaxillary sutures.[2] While Le Fort's descriptions provide a starting point for understanding mid-face fractures and establishing appropriate guidelines for the repair of these fractures, in reality, most mid-face fractures do not conform to these ideal descriptions.

An alternative perspective looks at the facial skeleton as a series of structural beams. A number of groups including Manson et al.,[3] Gruss and Mackinnon,[4] Yamamoto et al.,[5] and DeBrul and Sicher[6] have characterized the mid-face as having a system of horizontal and vertical buttresses that maintain the stability of the overall facial structure and connect the cranial base and the facial bones. These buttresses function much like the internal architectural framework of a skyscraper by providing the necessary rigidity and structural support to ensure building stability. Similar to the facial bones, this framework also gives a building its unique appearance, supports the attachment of an external surface covering for protecting the building's inner spaces from the elements, and provides the necessary support for erecting internal walls that divide spaces into separate functional areas. Moreover, the facial skeleton, with its supporting buttresses, is the basis of our individual appearance. It also provides a framework for attaching skin, preventing mid-face collapse, and stabilizing the normal



Artificial skull with buttresses identified. (Source: James W. Karesh, MD)

anterior and vertical projections of the face.[5] The buttresses compartmentalize the facial skeleton into inner protected "working" spaces or "rooms" with relatively fragile walls surrounding inner areas with important functions, including the orbits, eyes, mouth, and nose.

There are five vertical facial buttresses. The three major vertical buttresses are the medial or nasomaxillary buttress, the lateral or zygomaticomaxillary buttress, and the posterior or pterygomaxillary buttress. The medial or nasomaxillary buttress extends from the anterior maxillary alveolus, along the piriform aperture and the nasal process of the maxilla ending at the frontal bone. The lateral or zygomaticomaxillary buttress extends from the lateral maxillary alveolus to the zygomatic process of the frontal bone and extends laterally along the zygomatic arch. The posterior or pterygomaxillary buttress attaches the posterior portion of the maxilla and to the pterygoid plate and sphenoid bone.[5] In addition to these three major vertical buttresses, there are two other vertical buttresses: the central naso-ethmoidal buttress and the posterior mandibular buttress.[7] The central naso-ethmoidal buttress is formed by the ethmoid and vomer bones. The posterior mandibular buttress is formed by the ascending ramus and condyle of the mandibular bone.[7]

There are also five horizontal facial buttresses that are important for maintaining facial width, anterior facial projection, protecting the cranial cavity and orbit, supporting the muscles of mastication, and maintaining normal dental alignment.[7] The superior transverse facial buttress (frontal bar) consists of the frontal bone and the cribriform plate of the ethmoid bone. The middle transverse facial buttress consists of the temporal bone, zygomatic bone and arch, infraorbital rim, and frontal process of the maxillary bone. The inferior transverse facial buttress includes the hard palate and maxillary alveolus.[7] The superior transverse mandibular buttress consists of the inferior alveolar ridge of the mandible. The inferior transverse mandibular buttress consists of the inferior border of the mandible.[7]

Fractures of the facial skeleton commonly result from blunt-force trauma to the face. For the ophthalmologist, the goals of facial fracture repair include preserving vision, restoring the normal contour, position, volume, and form of the orbit, and reestablishing normal globe motility and position. Additional goals of

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facial fracture repair include restoring facial width, height, and projection; maintaining and/or restoring airways; restoring oral and masticatory function; preventing malocclusion; and providing sufficient support for any necessary dental prosthesis. The keys to repairing facial fractures and reconstructing the facial skeleton are: (1) anatomically accurate open exposure/reduction; (2) stabilization via rigid internal fixation of the facial buttresses; and (3) accurate reconstruction of the orbital wall. This is essential for skeletal stability. It is also important to be able to visualize a three-dimensional image of the skeleton and its compartments as the reconstructive effort proceeds. In the past, surgical wiring was used for facial fracture repair. However, the standard of care today is the use of rigid plates with screw fixation.

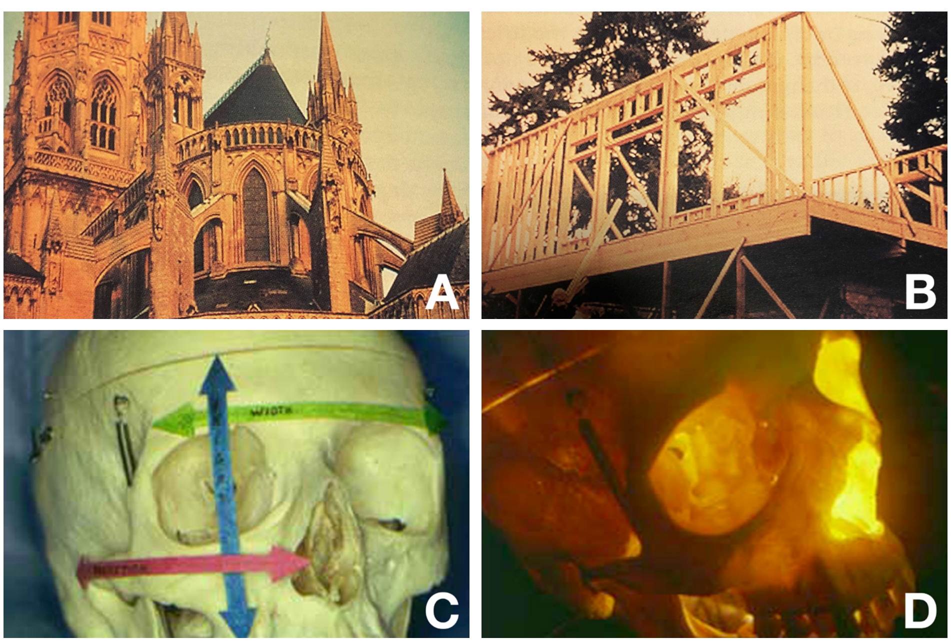
The orbital floor, medial orbital wall, anterior wall of the maxilla, lacrimal bone, and the other relatively thin bones of the face and nose are too fragile to provide a platform for anchoring rigid repair plates and bone screws. On the other hand, the buttresses are an ideal platform for anchoring rigid repair plates with bone screws. Without stable buttresses, any facial fracture repair will ultimately fail due to the forces of gravity and the effects of the facial musculature and the muscles of mastication. The goal of facial buttress repair is to disimpact, rotate into position, and rigidly fixate the displaced bones forming the vertical and horizontal buttresses of the face. Missing bone should be replaced with bone grafts that are also rigidly fixated to the facial skeleton. These grafts are often harvested from the cranium, hip, or rib. It is particularly important to reconstruct and carefully repair the vertical and horizontal buttresses formed by the frontal, zygomatic, and maxillary bones.

The proper reconstruction and rigidity of these bones determines the anterior projection, shape, and position of the orbits relative to the face, as well as the volume within the orbit; the function and three-dimensional position of the globes; and the width, height, projection, and stability of the mid-face. Failure to correctly reconstruct these buttresses will result in significant facial deformity including telecanthus, enophthalmos, and hypoglobus. These deformities will require secondary corrective surgery and may result in compromised globe function, diplopia, and vision loss. It is particularly important to properly rotate and reposition the zygomatic bone, as this bone is an important part of both the horizontal and vertical buttresses of the mid-face. An inadequately repositioned zygomatic bone will prevent reformation of the normal orbital contour and volume, limit anterior cheek projection, and reduce the normal horizontal width of the face. In addition, an inadequately reconstructed zygomatic arch can interfere with mastication and jaw opening if it impinges upon the condyle of the mandible or interferes with normal masseter function.

Orbital Fracture Repair

The orbital cavities and bones comprise the superior portion of the mid-face, while the alveolar and palatine (hard palate) processes of the maxillary bone and the palatine bone comprise the inferior portion of the mid-face. In contrast to the bones of the inferior mid-face, which are part of the horizontal buttress structure of the facial skeleton, the bones of the orbit are components of both the vertical and horizontal buttress support for the facial skeleton. While the orbital bones involve only a subset of the buttress support for the facial skeleton, fractures of the orbital bones may have a significant effect on the stability of the facial skeleton and eyes that can result in significant functional disability. To emphasize the importance of the eyes, it should be noted that 50% or more of the human brain's processing power is dedicated to vision. The optic nerve and retina are externalized brain tissue consisting of both white (optic nerve) and grey (retina) matter, respectively.

The opening into the orbit is formed by the major vertical and horizontal facial buttresses of the mid-face, creating something akin to a reinforced protective door frame around the anterior opening of the orbit. Bony plates extend posteriorly



Architectural buttresses (A,B) provide the three-dimensional structural stability for infrastructure similar to how accurate alignment of the facial buttresses (C,D) maintain the face's three-dimensional framework. *(Source: Textbooks of Military Medicine - Ophthalmic Care of the Combat Casualty)*

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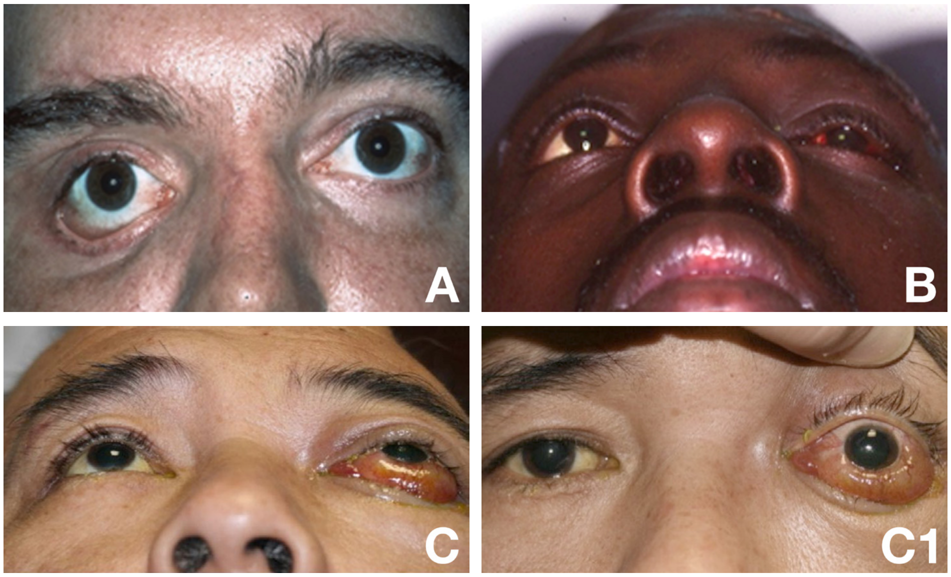
from these buttress bones (frontal, maxillary, zygomatic) to form the roof, floor, and lateral walls of the orbit. Nasally, the medial wall consists almost entirely of the very thin ethmoid bone and the much smaller lacrimal bone, which are separate bones and not part of the facial buttress structure.[8] The most posterior portion of the orbit is formed by the greater and lesser wings of the sphenoid bone and a small portion of the palatine bone.[8]

Orbital fractures can be arbitrarily divided into those involving the orbital walls and those involving the orbital entryway (also known as rim fractures). In reality, while fractures involving the orbital walls can occur in isolation without any involvement of the bones forming the orbital rim, fractures of the orbital rim almost always involve the orbital walls.

In all instances of facial trauma, whether or not a facial or orbital fracture is known to be present, it is necessary to perform an eye examination to determine if either a closed or open globe injury is present and to measure visual acuity and ocular motility prior to any surgical intervention. Trauma that is significant enough to cause an orbital fracture can also cause significant injury to the eye, optic nerve, orbit, and brain.[8] In addition to globe rupture, some of the injuries associated with orbital fractures include corneal laceration, hyphema, iris tears, glaucoma, lens dislocation, vitreous hemorrhage, retinal detachment, traumatic optic neuropathy and loss of vision, extraocular muscle damage and diplopia, orbital compartment syndrome, pneumocephalus, and brain contusion and hemorrhage.[8,9]

There are some basic examination techniques that are helpful in evaluating orbital fractures. Palpating the orbital bones for rim "step-off" defects will help to define the extent of zygomatic fractures and orbital rim fractures. Note that rim fractures, including those producing step-off defects, are usually painful on palpation. Similarly, comparing the uninjured side to the injured side can help to expose asymmetries caused by a fracture, such as enophthalmos, exophthalmos, hypoglobus, and hyperglobus. Numbness of the cheek usually indicates a fracture of the inferior orbital rim with involvement of the infraorbital canal and infraorbital nerve (V2). A widening of the face or a downward displacement of the cheekbone indicates a zygomatic bone fracture. If an exophthalmometer is not available to assess globe position, a "worm's eye" view (looking up at the face from below) or a "bird's eye" view (looking down over the forehead) will help to reveal enophthalmos or exophthalmos. Looking straight at the face will reveal the presence of hypoglobus due to a floor fracture. In unusual cases, the entire globe may appear to be absent when it has fallen into the maxillary sinus as the result of extremely large floor fractures.



Patients (A,B) experiencing an orbital fracture while a patient (C, C1) experiences conjunctiva chemosis due to facial trauma from an orbital fracture. (Source: James W. Karesh, MD)

Naso-orbital-ethmoidal (NOE) fractures are complex fractures involving the frontal sinus, ethmoid sinuses, anterior cranial fossa, orbits, frontal bone, and nasal bones. These fractures result in a significant disruption to the three-dimensional anatomy of the mid-face and are associated with blindness, telecanthus, enophthalmos, posterior displacement of the midface, cerebral spinal fluid leaks, anosmia, epiphora, sinusitis, nasal deformities, and nasal bleeding. One way to evaluate a suspected NOE fracture is to assess the intercanthal distance. In NOE fractures, the intercanthal distance is abnormally widened (telecanthus). The normal intercanthal distance (as well as the normal horizontal width of a palpebral fissure, from lateral to medial canthus) is approximately 30 mm.[10] An intercanthal distance greater than approximately 32 mm is consistent with telecanthus and a possible NOE fracture.

Initially, the reduction in ocular motility associated with orbital fractures is usually caused by orbital edema and inflammation. However, it may also indicate muscle or soft tissue entrapment. There is one particularly worrisome fracture-related ocular motility abnormality that requires urgent surgical intervention. The "white-eyed" blowout fracture (a variant of any trapdoor fracture) is a fracture of the orbital floor occurring in younger individuals with more elastic orbital bones.[10] The white-eyed blowout fracture can elicit the oculocardiac reflex, a condition requiring urgent care. Following blunt trauma to the orbit, the flexible bone of the orbital floor will split open and then snap close, incarcerating the inferior rectus muscle or its muscle sheath. These fractures are

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associated with profound restriction of upgaze and vertical diplopia, a quiet and white-eye, and, often, activation of the oculocardiac reflex characterized by nausea, vomiting, dizziness, light headedness, hypotension, pallor, headache, gait instability, bradycardia, and, rarely, asystole. The oculocardiac reflex can occur in conditions other than white-eyed blowout fractures (i.e., fractures productive of bleeding and ecchymosis). The most important element is the presence of the oculocardiac reflex, which demands urgent surgical correction. It is important to check the pulse of anyone who has sustained a blowout fracture before they are dismissed from the hospital. This reflex can occur in adults but is considerably more common in children. It is mediated by connections between the ophthalmic branch of the trigeminal cranial nerve via the ciliary ganglion and the vagus nerve of the parasympathetic nervous system. Similar effects can occur with surgical manipulation of the extraocular muscles, manipulation of or direct pressure on the globe, and ocular pain. Regardless of the patient's age, muscle entrapment within a fracture and the associated motility restriction and diplopia are separate, but concurrent, fracture-related problems. Urgent surgery is necessary to release the entrapped muscle to relieve diplopia and prevent muscle atrophy, fibrosis (Volkmann's ischemic contracture), and permanent diplopia, while simultaneously resolving bradycardia, nausea, and vomiting.

Other than orbital wall and floor fractures eliciting an oculocardiac reflex, significant persistent functional visual disturbance, other functional deficits (e.g., diplopia interfering with activities of daily living or trismus interfering with eating or speaking), or a severe facial deformity, there is no universal consensus regarding the timing of or criteria for repairing fractures involving the orbital walls. Some of the criteria used to justify fracture repair include fracture size and the amount of enophthalmos and/or hypoglobus.[11] In addition to non-resolving diplopia and trismus, fracture repair is indicated for enophthalmos or hypoglobus greater than 2 mm, fractures involving more than half of the orbital floor, evidence of significant herniation of orbital soft tissue into the maxillary sinus, and evidence of entrapment of orbital soft tissue or one of the extraocular muscles.[11-13]

In general, it is helpful to wait 1–2 weeks before repairing orbital fractures to allow for resolution of post-injury swelling, edema, and inflammation, which may obscure the presence of enophthalmos and motility defects and may increase intraoperative hemorrhage. A short course of oral steroids may help to reduce swelling. It is necessary to obtain thin cut (1.5–2 mm) computed tomography imaging of the orbit in the axial plane with reconstructed coronal and sagittal views prior to performing surgery to correct any orbital or facial fracture.[8,9] Three-dimensional reconstruction of these CT images is quite helpful for visualizing the position of the fracture fragments, but is not required. The use of pre-operative antibiotics will depend on whether wound contamination is present and the protocol at a particular medical facility.

An extensive and comprehensive discussion of the various methods and approaches for repairing orbital fracture is not possible in the space allotted. However, some basic principles are worth mentioning. Successful repair of orbital fractures requires a stable base upon which the various fracture fragments can be rebuilt and rejoined into their original pre-injury configuration. This means that facial buttresses must be repaired before the orbital walls. Without repair of these buttresses, it will be extremely difficult to properly reposition the orbital walls and reform the orbit into its normal shape, volume, and position. It is particularly important to correctly reposition the zygomatic bone, as this bone not only forms the lateral orbital wall but also establishes facial width and the anterior projection of the cheek. When fractured, the zygomatic bone is frequently torqued inward and downward. Repositioning and fixating this bone into its normal position requires direct open reduction with rigid miniplate fixation. The bone should be fixated minimally at two or, preferably, three or four of its original buttress connections. Prior to permanent fixation, it is important to check the bone’s position by directly visualizing the inner contour of the lateral orbital or obtaining an intraoperative CT to ensure proper restoration of orbital contour and volume. An incorrectly positioned zygomatic bone will result in facial asymmetry, including flattening of the cheek, an abnormal facial width, enophthalmos secondary to orbital

Exposure, reduction, and fixation of infraorbital rim and frontozygomatic suture. *(Source: Annals of Maxillofacial Surgery)*

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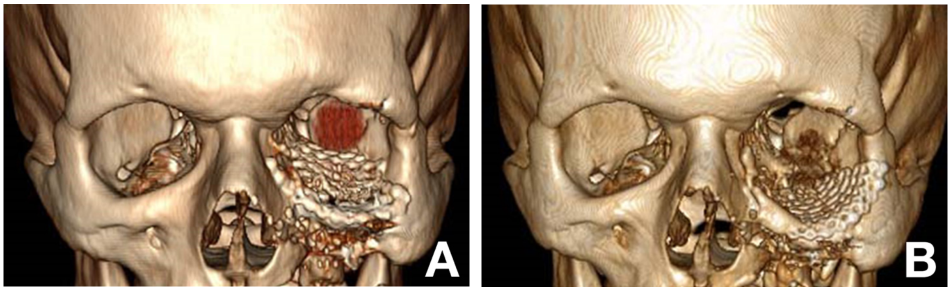
volume enlargement, and significant trismus from inward bone rotation and interference with jaw movement.

The most important locations for rigid fixation of the zygoma are across the frontozygomatic suture (lateral orbital wall), across the superior aspect of the zygomaticomaxillary suture (horizontal buttress forming the inferior orbital rim), and across the inferior aspect of the zygomaticomaxillary suture (inferior portion of the vertical zygomaticomaxillary buttress). The first two of these fixation points help to elevate the zygoma, and the third fixation point prevents inward or outward rotation of the zygoma. Surgical exposure for rigid fixation of the zygoma can be achieved through existing facial lacerations or various surgical incisions. Exposure of the inferior aspect of the zygomaticomaxillary suture is achieved via a maxillary buccal vestibular incision. A lateral lid crease or canthotomy incision can be used to expose the zygomaticofrontal suture and lateral orbital wall. A transconjunctival incision can expose the inferior orbital rim and floor, and an extension medially through the caruncle will expose the medial orbital wall. The plates used for rigid fixation of fracture fragments should be long enough to span the fracture and allow placement of two fixation screws on either side of the fracture.

The management of orbital fractures involving the alveolar portion of the maxillary bone and lower mid-face, as seen with Le Fort-type fractures, requires stabilization of this horizontal buttress before addressing any co-existing orbital rim and zygomatic bone fractures. The stabilized maxillary bone forms the base for upper mid-face and orbital fracture repair. This is often termed the “bottom-up” approach to fracture repair.[8] In general, stabilization of the alveolar portion of the maxilla requires the placement of arch bars across the teeth of both the mandible and the maxilla connecting the arch bars with interdental wiring while maintaining proper dental occlusion. It is helpful to work with oral and maxillofacial surgeons when placing arch bars and stabilizing dental occlusion. Dental occlusion forms the template for accurate alignment and bone reduction. Setting the template first by mandibulomaxillary fixation (MMF) creates a "known" from which the "unknown" can be reconstructed. MMF is to the lower half of the face what internal orbital contour is to the upper half. After the maxillary bone has been stabilized, the inferior orbital rim and zygomatic bone can be repositioned and rigidly fixated.



Before: Patient (A) with an incorrectly repaired orbital fracture. After: Same patient (B) with the orbital fracture correctly repaired. (Source: James W. Karesh, MD)

Both zygomatic bone and maxillary bone fractures are associated with enophthalmos as a result of orbital enlargement.[8,14] The horizontal plate of the maxillary bone forms the majority of the orbital floor. Fractures involving the orbital floor allow orbital soft tissue to expand into the maxillary sinus. Currently, a variety of plates are used to reconstruct the orbital floor when it is fractured. These plates are designed to be cut and bent to properly cover medial wall and floor defects. Generally, plates need to rest upon stable bone to support the orbital soft tissue and prevent rotation or slippage of the plate into the maxillary sinus. In order to prevent plate movement or extrusion, screws are used for plate fixation to the inferior orbital rim.[14] Before final plate positioning and fixation, as much orbital soft tissue as possible should be elevated from the maxillary sinus. Orbital soft tissue remaining in the maxillary sinus can result in enophthalmos or motility deficits. Improper positioning of floor fracture plates is not uncommon. Sometimes, the posterior and lateral aspects of the plates are inadequately supported by remaining orbital bone, and the weight of the orbital contents pushes them into the maxillary sinus. Some plates may lack sufficient rigidity, length, or width to support the orbital contents. On occasion, plates may simply fail to sufficiently cover a fracture. Enophthalmos can also occur when the zygomatic bone is not properly positioned and the lateral orbital wall is expanded or the floor of the orbit is depressed laterally. Enophthalmos can also occur when surgeons fail to reposit prolapsed orbital soft tissue due to concerns about optic nerve damage during posterior orbit dissection. Plating the medial orbital wall may be necessary for medial wall fractures with muscle entrapment or large fractures with extensive orbital fat prolapse.

The superior orbital rim or frontal bar horizontal buttress and the medial vertical buttress formed by the maxillary and frontal bones are less commonly fractured than either the inferior or lateral orbital rims. Rigid fixation of the medial buttress can often be performed through lacerations associated with the fracture. Alternatively, a medial incision can be made over the area of the fracture, and the plating of the medial buttress can be performed through that incision. Carrying this incision too far superiorly and laterally in the area of the supraorbital rim notch can risk damage to the supraorbital nerve and artery. Carrying the incision too far inferiorly towards the medial canthal angle and tendon can risk damage to the lacrimal drainage apparatus. When plating fractures involving the medial buttress in the vicinity of the medial canthal tendon,

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care must be taken to prevent the placement of screws into the lacrimal sac or duct and severing the lacrimal canaliculi. Damage to these structures is associated with chronic tearing and nasolacrimal duct obstruction.

Fractures involving the frontal bar often also involve the front sinus, frontal cranium, and orbital roof. These are usually best managed in conjunction with neurosurgery and/or otolaryngology, as they can be associated with cerebrospinal fluid leaks, frontal lobe damage, intracranial bleeding, and damage to sinus drainage. Management of these fractures is beyond the scope of this article.

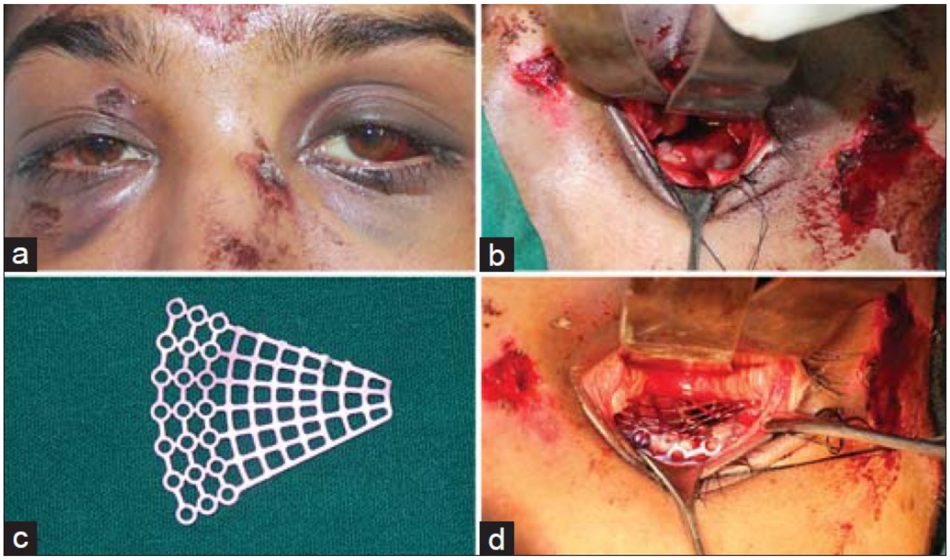
Considerations for Choice of Implants and Hardware for Orbital and Mid-Face Fracture Repair

A variety of materials are available for repairing orbital wall and floor fractures.[15] Important criteria for these materials include non-reactivity and sufficient strength to support and maintain the position of the orbital contents.[16] They should elicit no inflammatory response, foreign body reaction, or significant fibrosis and they should have few or no short- or long-term side effects, which may include implant migration, extrusion, orbital or hematic cyst formation, or the formation of excessive scar tissue. Availability, cost, and ease of use are other considerations. The surgeon should choose the implant appropriate for the type of fracture present.

In the past, x-ray film, nylon foil, silicone and silastic sheets, and autologous bone have been used for orbital and mid-face fracture repair.[17] These materials have been supplanted by more effective implants. The sheets and foils, used extensively during the 20th century, were occasionally associated with extrusion and hematic cyst formation, but may still be of value in certain clinical circumstances. They were often fixated in place by fashioning a tab anteriorly and fitting the tab behind the anterior lip of the fracture as small fixation screws were often not available. They were also held in position with sutures or wire placed through drill holes in bone. Autologous bone was well-tolerated, but required a second surgical site for harvesting graft material and some finesse and experience to shape the implant appropriately. Autologous bone is also still used for fracture repair, particularly when there are large areas of missing bone. However, bone is more difficult to shape and cut than titanium and porous polyethylene coated titanium implants.[13] Bone implants were also fixated with wires that passed through drill holes or with screws when these became available for use in the face and orbit.[13]

Today, titanium plates of different shapes (often covered with high density porous polyethylene) as well as high density porous polyethylene sheets are commonly used.[17,18] In addition, it is possible, through the use of three-dimensional CT imaging, to have custom-made implants of high density porous polyethylene or other material created to specifically fit any orbital wall or floor defect. These custom-made implants will not be available in theater and can likely be made only in CONUS. Titanium implants, both uncovered and covered with high density porous polyethylene, require shaping and cutting to fit over an orbital floor or medial wall defects. To support the globe and soft tissue contents of the orbit, these implants, in turn, must be supported by remaining orbital bone. These implants are usually fixated with one or two small screws drilled into the bone of the orbital rim. When drilling holes and placing screws, it is important to avoid damage to the infraorbital neurovascular bundle and ensure that the screws are placed in stable bone.

As mentioned previously, mid-face fractures destabilize the facial buttress structure, frequently damage the orbit, paranasal sinuses and nasal cavities, and cause significant facial deformity. It is necessary to repair facial buttress fractures before repairing orbital wall fractures, since orbital wall stability is dependent on facial buttress stability. The repair of facial buttresses generally requires the use of rigid metallic plates spanning fracture fragments and fixated in place with screws. One long, rigid multi-holed plate can be used to fixate more than two fracture fragments. Plate size and thickness, as well as screw



(a) Preoperative view showing left eye hypoglobus, pseudoptosis with supratarsal hooding indicative of enophthalmos, (b) Intraoperative view: Exposure of orbital floor disruption via transconjunctival approach, (c) Prefabricated titanium mesh, (d) Orbital floor reconstruction using titanium mesh. (Source: Annals of Maxillofacial Surgery)

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Large left orbital floor fracture greater than 50% of orbital floor. *(Source: Middle East African Journal of Ophthalmology)*

length, are limited by the size and thickness of the involved bones as well as the thickness of the skin covering the face. In the past it was necessary to make drill holes in the bone for screw placement. Today, many plating sets contain self-drilling screws so that drill holes may not be necessary. When rigidly fixating bone fragments, intervening soft tissue must be removed as bone to bone contact is necessary for primary bone healing. Misalignment of fracture fragments, damage to sensory nerves, tooth roots, lacrimal drainage, stripped screw holes, and screw breakage are some of the complications that can occur when insufficient attention is paid to plate fixation. While most rigid plates and screws used in fracture repair are non-magnetic, consultation with radiology is necessary if an MRI is planned for patients who have had these devices implanted.

Bioabsorbable plates made from various polymers of polylactide, polyglycolide, and polydioxanone are alternatives to metal screws and plates.[19,20] These polymers have also been combined to form copolymers such as Vicryl™ (polylactic and polyglycolic acids) and Maxon™ (glycolic acid and trimethylcarbonate). They elicit minimal tissue reaction and have been shown to have sufficient longevity and strength for successful stable facial fracture repair.

Bioabsorbable plates and screws have been successfully used to repair both pediatric and adult facial buttress fractures. More frequently, they are used to repair pediatric fractures due to concerns that metal plates may impede facial growth. Bioabsorbable plates tend to be more expensive than metal plates, are typically not available in theater, and have some variability in their resorption rate, which may negatively affect the stability of the repaired fracture. The resorption of these polymers is mainly by hydrolysis. They seem to work well, but there is not sufficient data to determine how they compare against titanium and porous polyethylene coated titanium implants.

There may be instances in which plates and screws are not available to repair facial fractures. In such cases, surgical stainless-steel wire can be used for fracture fixation.[17] Surgical wire is used for attaching arch bars and interdental wiring in the repair and stabilizing of mandibular and maxillary fractures. Twisting the wire ends together is used to reapproximate and tighten the connection between wired fragments. When surgical wire is unavailable, a heavy permanent suture such as 0 or 2-0 braided polyester or nylon can be used.[21] One or more drill holes on either side of the fracture line are usually used for wire or suture fixation. Bone fragments fixated with wire or suture material are usually not as stable as those fixated with plates and screws.

Post-operative Complications

As already mentioned, persistent enophthalmos following orbital floor fracture repair is often the result of inadequate extraction of incarcerated orbital tissue. Implants incorrectly contoured, sized, or positioned to cover medial wall fractures also result in enophthalmos. It can also occur if there is necrosis of the orbital fat or a failure to restore the orbit to its pre-injury volume and size. Adequate elevation of the orbital floor and medial wall periosteum is essential for elevating all orbital soft tissues that have herniated into the maxillary or ethmoidal sinuses. Forced ductions during elevation of herniated orbital tissue will help demonstrate continued entrapment of an extraocular muscle and therefore the need for additional tissue repositioning.[11] Forced ductions are also helpful for determining if an orbital implant requires repositioning because it is restricting normal globe movement.[11] Another cause of undercorrection is inadequate posterior implant support. If posterior support is not possible, lateral support for the posterior portion of the implant will usually be adequate. During placement of orbital floor implants, it is important to remember that the medial orbital strut covers the infraorbital neurovascular bundle and helps to provide support for the orbital tissues. Damage to the infraorbital neurovascular bundle during fracture repair can cause significant bleeding and the loss of cheek and tooth sensation.

It is important to properly shape implants to conform to the normal contour of the orbital walls. Both uncoated and

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porous polyethylene coated titanium implants have medial extensions designed to account for medial wall fracture and the upward angle of the orbital floor. While it is not always necessary to repair relatively small medial wall fractures, those medial wall fractures associated with muscle entrapment or an oculocardiac reflex must be repaired.

While both titanium and high density porous polyethylene coated floor implants are generally well-tolerated, titanium implants tend to elicit more rapid soft tissue and bone incorporation, making them difficult to remove and may lead to interference with globe motility. The porous polyethylene coated implants have a barrier surface to prevent tissue incorporation.

Some other complications associated with orbital fractures and the implants used for their repair include orbital compartment syndrome; implant migration and extrusion with fistula formation; extrusion of screws used to fixate implants; infections of the orbit, periorbital soft tissues, and sinus; silent sinus syndrome; chronic orbital inflammation; hematic cyst formation; persistent cerebrospinal fluid leakage; dacryocystitis; nasolacrimal duct obstruction; persistent diplopia; visual field loss; and blindness.

There are many implants available for successfully repairing orbital wall and floor fractures as well as fractures of the orbital buttresses. The most significant factors for successful repair of these fractures are complete exposure of the fracture and any bone fragments, extraction of all incarcerated orbital tissue, checking for restricted ocular motility, releasing any entrapped tissue interfering with motility, correct repositioning of fracture fragments followed by rigid fixation of the fragments, and repair of defects in the orbital floor and wall with a fixated implant properly sized and positioned to support the orbital contents.

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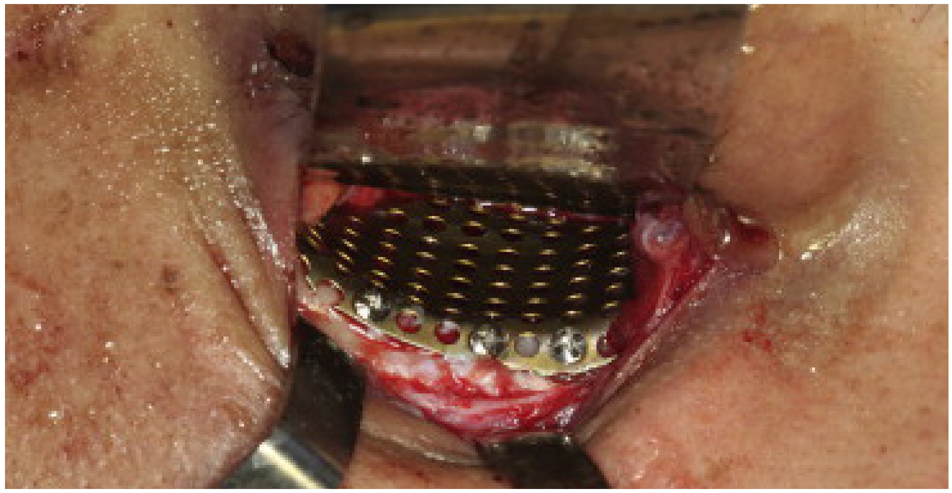
VISION CENTER OF EXCELLENCE FOCUS ON EMERGENCY OCULAR CARE:
MANAGEMENT OF ORBITAL FRACTURES



Reconstruction of orbital floor using titanium mesh. (Source: ScienceDirect)

Emergency management of ocular trauma is necessary for both the ophthalmic and non-ophthalmic communities. To this end, VCE is sharing quarterly emergency management tips for non-ophthalmic providers as well as Damage Control Ophthalmology (DCO) principles specifically for ophthalmologists. **In this issue of Frontlines, we share principles for the management of orbital fractures.**

Orbital fractures are a common occurrence in combat trauma and are typically caused by direct, blunt impacts to the face and often occur with injuries to the eye, brain, and other facial structures, including the nose, cheek, and jaw. The most common facial fractures sustained during the Afghanistan and Iraq wars were of the orbit (26.3%) and maxilla/zygoma (25.1%).[1] The primary mechanisms that cause these types of injuries are penetrating or blunt trauma from improvised explosive devices, gunshot wounds, motor vehicle accidents, and rocket-propelled grenades. Orbital fractures can also be caused by non-battle injuries, including trips and falls, assaults, sports, motor vehicle accidents, and other activities involving blunt facial trauma. Computed tomography (CT) of the orbit and face is the best imaging method for evaluating the presence of orbital fractures and determining the extent of injury. In general, orbital fractures do not need to be addressed immediately or in theater and their repair can usually be delayed for up to two weeks. However, orbital fractures eliciting an oculocardiac reflex must be repaired urgently. Delaying orbital repair has its own consequences (e.g., scarring, which can limit the effectiveness of surgery). Therefore, diagnosis, referral, and appropriate treatment are critical to maximizing functional outcomes.

It is important to rule out an open globe injury if orbital fractures are present. Open globe injuries should be repaired immediately and must be prioritized over repair of orbital fractures. Orbital compartment syndrome (OCS) is also another ocular emergency that can occur as a result of orbital fractures.[2] Contrary to common perception, orbital fracture is not protective of OCS. Immediate decompression of the orbital compartment is necessary and best achieved by performing a lateral canthotomy and inferior cantholysis within 60-90 minutes of onset of OCS (See Winter Frontlines 2018).

Further principles regarding combat-related ocular trauma need to be developed and formalized. VCE is currently developing DCO principles, which will encompass the following: *Necessity, Urgency, Adequacy, and Avoidance*. V

Necessity - Addresses aspects of care that must be applied at a particular point of care prior to transfer to the next level of care. The need for immediate intervention largely depends on severity of injury.

Urgency - Addresses the time frame in which any necessary treatment or intervention must be performed. Severity of injury will dictate urgency with which the eye must be treated.

Adequacy - Addresses how meticulous or definitive repairs must be. Repairs for severe injuries must be meticulous, where the first repair is typically the final one. However, general practitioners and ophthalmologists must also identify injuries for which repairs can be ignored or temporized and revised later.

Avoidance - Addresses interventions that should not be performed in order to effectively manage the eye injury.

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Emergency Management of Orbital Fractures: For Non-Ophthalmic Providers

PRINCIPLE 1: Perform the ABCs of Eye Trauma to determine extent of structural damage and injury to the eye resulting from or associated with orbital fractures.

- Every patient with trauma involving the eye, orbits, and periocular areas must receive a complete eye exam. A screening eye exam for a patient with a suspected orbital fracture should consist of the patient's history, including the cause of the injury, the time-course of events, and any treatments received
- **A:** Check visual **Acuity**; decreased vision may indicate the presence of a serious eye injury
- **B:** Perform **Best** possible examination of **Both** eyes. Open globe injuries occur with orbital fractures and are **ocular emergencies**. If possible, evaluate every patient with blunt or penetrating trauma to the orbit for an open globe injury. Examine ocular movement; note any decreased motility, especially in upward and lateral gaze; and test for diplopia. Observe for bradycardia, nausea, vomiting, oculocardiac reflex, and syncope. Check pupils for any deformities and reactivity; a unilaterally dilated pupil or an afferent pupillary defect may indicate an optic nerve injury
- **C:** Examine **Contiguous** structures adjacent to the eye. Check for development of an orbital compartment syndrome. Palpate the orbital rims and periorbital areas for step-off fractures and crepitus. Note if patient has numbness in upper teeth and cheek. Perform a "bird's eye" or "worm's eye" view of the patient (i.e., look over the patient's forehead from above or look up at the patient from below to see if the eyes are protruding an equal amount). Facial fractures associated with clear nasal fluid drainage suggest a cerebrospinal fluid leak most likely from a cribriform plate fracture. Similarly, facial fractures associated with globe pulsations suggest a direct connection between the cranial cavity and brain with the eye
- **D: Drugs:** Medications for patients with suspected or known orbital fractures should consist of pain control as outlined in the Joint Trauma System clinical practice guideline for the management of ocular injuries. Patients should also receive medication to control nausea and vomiting as well as agitation. If lacerations are present, antibiotic treatment should also be initiated. **Don'ts:** DO NOT perform an ultrasound on the eye; it may worsen the eye injury. DO NOT put pressure of any type on an injured eye. Applying pressure may extrude intraocular contents and convert a repairable eye to a non-repairable eye. DO NOT attempt to measure intraocular pressure. DO NOT patch the eye **Diagnostics:** Obtain face and orbit CT imaging (1.5-2 mm thin cut axial slices with coronal and sagittal reconstructions). A "head" protocol is not sufficient for determining the extent of orbital fractures. If CT is unavailable, obtain plain film (posterior-anterior, lateral, and Waters views) radiographs
- **E:** Place **Eye Shield** over an injured eye and **Evacuate** the patient to the nearest ophthalmologist. Eye protection can be used as a temporary eye shield **(See Principle 4)**

PRINCIPLE 2: An orbital compartment syndrome (OCS) is an ocular emergency associated with orbital fractures and requires immediate in-the-field lateral canthotomy and cantholysis to prevent vision loss (See Winter Frontlines 2018).

- Orbital fracture is not protective of OCS
- Decreased visual acuity, restricted ocular motility, proptosis, a tense orbit, and ocular/orbital pain indicate an OCS
- The diagnosis of an OCS is entirely clinical and does not require confirmatory imaging studies, which only delay the emergency surgery
- Use **blunt-tipped** scissors to avoid injuring the globe
- Treatment is a lateral canthotomy and cantholysis of the inferior limb of the lateral canthal tendon. Following surgery, shield the eye and evacuate the patient to the nearest ophthalmologist
- Table 1 lists interventions for preventing an OCS in a patient with facial fractures. These measures are particularly important during patient transport. None are a substitute for an emergency canthotomy and cantholysis

Table 1. Interventions for preventing an OCS in a patient with orbital fractures.

Preventive measures/ interventions	Reason
Anti-emetics, nausea control	Hemorrhage risk reduction
Caution against nose blowing, sneezing	Reduce risk of intraorbital air
Blood pressure control	Hemorrhage risk reduction
Avoid using anticoagulants/ aspirin	Hemorrhage risk reduction
Pain medication/ sedation	Patient comfort/ hemorrhage risk reduction
Consider cabin pressure during flight	Prevent expansion of intraorbital air
Oral or IV steroids	Reduce trauma related inflammation and edema involving the orbital tissues and extraocular muscles
Tape a rigid eye shield over injured eye	Reduce risk of external pressure on eye

PRINCIPLE 3: Certain orbital fractures are associated with the oculocardiac reflex and require urgent surgery.

- The oculocardiac reflex is characterized by nausea, vomiting, dizziness, light headedness, hypotension, pallor, headache, gait instability, bradycardia, and, rarely, asystole
- Bradycardia (abnormally slow pulse rate) can be caused by entrapment of the extraocular muscles and is sometimes profound
- Surgical intervention for these types of fractures must be performed as soon as possible to prevent the aforementioned abnormalities and muscle ischemia with permanent muscle damage and diplopia
- Intravenous atropine can be used to reverse the parasympathetic response

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Navy Cmdr. Kevin McGowan models the correct placement of the rigid eye shield. (Source: Graham Snodgrass, U.S. Army Public Health Command)

PRINCIPLE 4: SHIELD and SHIP.

Place a rigid eye shield over the injured eye and evacuate patient to the nearest ophthalmologist.

- **SHIELD:** Place a rigid metal or plastic shield over the injured eye in a way that it does not touch the eye. Hold the shield in place with tape. Eye protection, goggles, glasses, or the bottom of a Styrofoam or paper cup can be used as temporary shields
- **SHIP:** Evacuate casualty expeditiously to nearest ophthalmologist. Note that patients with orbital and concomitant facial fractures may have associated cranial, midfacial, and mandibular-neck (airway) involvement and therefore may need to be evaluated by other surgical specialties as well (e.g., neurosurgery, maxillofacial surgery, plastic surgery, and otolaryngology)

Damage Control Ophthalmology: For Ophthalmologists

DCO PRINCIPLE 1: Rule out open globe injury or orbital compartment syndrome associated with orbital fractures.

- All open globe injuries must be repaired within 12-24 hours. Open globe repair must precede orbital fracture repair
- Presence of an orbital compartment syndrome requires immediate lateral canthotomy and inferior cantholysis within 60-90 minutes

+ **Necessity** – Critical
+ **Urgency** – Repair open globe injury within 12-24 hours. Perform canthotomy and cantholysis within 60-90 minutes of OCS
+ **Adequacy** – Meticulous
+ **Avoidance** – Do not repair orbital fracture before repairing an open globe injury or in the face of an open globe injury

DCO PRINCIPLE 2: Orbital fractures do not need urgent repair and can usually be delayed up to two weeks, except in the case of oculocardiac reflex (urgent).

- A trapdoor fracture, particularly if associated with an oculocardiac reflex, requires urgent fracture repair with release of entrapped tissue as soon as possible
- If surgery is deferred, consider use of systemic steroids to decrease scarring. A short course of oral or IV steroids (about 1 mg/kg) with a rapid taper over 7-10 days will rapidly reduce muscle and soft tissue swelling and inflammation

+ **Necessity** – Optional
+ **Urgency** – Not urgent, unless an oculocardiac reflex is present. Must be repaired within 2 weeks
+ **Adequacy** – N/A
+ **Avoidance** – Does not require in-theater repair, particularly in contaminated orbits

DCO PRINCIPLE 3: In all cases of blunt trauma to the head, determine if an orbital fracture is present.

- Obtain face and orbit CT imaging
- Determine if the globe is enophthalmic or proptotic
- Evaluate ductions and versions
- Palpate the orbital rims for "step-offs" and periorbital tissues for crepitus
- Evaluate "black eyes" for zygomaticomaxillary complex fractures; check for trismus, distortion, and canthal dystopia

+ **Necessity** – Critical
+ **Urgency** – As soon as possible
+ **Adequacy** – Obtain 1.5-2 mm thin cut axial slices with coronal and sagittal reconstructions of the face and orbit. A "head" protocol is not sufficient for determining the extent of orbital fractures
+ **Avoidance** – N/A

DCO PRINCIPLE 4: If deciding to repair an orbital fracture, open reduction with internal fixation is indicated.

- Set the template (e.g., dental occlusion, intermaxillary fixation, mandibulomaxillary fixation)
- Work from the known to the unknown, stable to unstable
- Expose the fracture completely and ensure that adequate lighting is available
- Use rigid fixation with plates and screws for facial buttress repair, specifically the superior and inferior orbital rims comprising the horizontal buttresses and the lateral orbital rim, which forms a vertical buttress. The buttresses must be repaired before the orbital walls or floor
- Choose the floor and wall implant appropriate for the type of fracture present
- After repairing the facial buttresses and the orbital rims, repair the orbital walls.
- Difficult and complicated fracture repairs and repairs requiring multiple surgical subspecialties must be performed at facilities where all required equipment and specialists/subspecialties are present

+ **Necessity** – Optimal
+ **Urgency** – As soon as possible if oculocardiac reflex is present, otherwise can be delayed up to two weeks. Clinically re-evaluate patients frequently
+ **Adequacy** – Use internal orbital contour as guide to accurate orbital reduction, then plate rims based on that
+ **Avoidance** – Do not rely exclusively on external cues for reduction and alignment. Do not suture the septum. Do not use porous implants in contaminated orbits. Do not repair orbital fracture before repairing an open globe injury or in the face of an open globe injury

Conference Presentations and Publications

The following presentations and publications highlight contributions from VCE staff and collaborators.

Recent Conferences

The Association for Research in Vision and Ophthalmology (ARVO)

29 April–3 May 2018, Hawaii Convention Center, Honolulu, HI | https://www.arvo.org/

Presentations

Special Session: Santullo O, et al. Military Relevant Priorities and Strategies for Injury Diagnostics and Treatments.

Special Interest Group, Ocular Trauma: Rex T, Blanch R, Coats B, Purdue M, Thomas CM. Animal Models of Ocular Trauma.

Poster Presentations

Mazzoli RA, Snider M, Lewin-Smith M, Merezhinskaya N, et al. **The DoD Joint Pathology Center (JPC)/ Vision Center of Excellence (VCE) Ocular Foreign Body Compositional Analysis Program.**

American Optometric Association

20–24 June 2018, Colorado Convention Center, Denver, CO | https://www.aoa.org

Upcoming Conferences

Blinded Veterans Association

13–17 August 2018, Reno, NV | https://www.bva.org

Military Health System Research Symposium

20–23 August 2018, Gaylord Palms Resort & Convention Center, Kissimmee, FL | https://mhsrs.amedd.army.mil/

MHSRS Track Sessions

Vision - Ocular Trauma Casualty Management Grand Rounds

Oral Presentations

Hadley S, Gaska JP, Winterbottom M. **The New USAF Cone Contrast Color Test (CCT-HD): A Paradigm Shift in the Ability to Accurately Test Human Color Vision.**

Mazzoli RA, Reynolds M, Frazier TC. **Establishing an Ocular Casualty Care System: A Capabilities-Based Model for Life, Limb, and Sight.**

Snider M, Lewin-Smith M, Strasburger SL, et al. **The DoD Joint Pathology Center (JPC)/Vision Center of Excellence (VCE) Ocular Foreign Body Compositional Analysis Program.**

Poster Presentations

Bailey J, Mazzoli RA, Reynolds M, et al. **The Spectrum of Military Ocular Combat Casualty Care (MOC3): Damage Control Ophthalmology (DCO), Ophthalmic Prolonged Theater Care (OPTC), and Definitive Ophthalmic Theater Care (DOTC).**

Bramblett GT, Holt A, Por E, et al. **Optimization of a Surgical Approach to the Porcine Optic Nerve.**

Cornell LE, McDaniel JS, Bunegin L, et al. **Targeted Particle Tracking in an Aqueous Chamber Fluid Flow Model.**

Gensheimer WG, Townley R. **Military Refractive Surgery Practice Patterns Questionnaire.**

Harris J, Sandoval M, Bramblett GT, et al. **Technique for Obtaining Flash Visual Evoked Potentials (SVEP) in the Yucatan Mini-Pig Using a Hand-Held Device.**

Holt A, Por E, Gorantla V, et al. **Characterization of a Porcine Optic Nerve Injury Model.**

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McDaniel JS, Johnson AJ, Zamora DO. **Antibiotic Loading of $SCCO_2$ Sterilized and Lyophilized Human Amniotic Membrane.**	Rios D, Johnson P, Bice L, et al. **Specialized Pro-Resolving Lipid Mediators, Maresin 1 (MaR1) and Neuroprotect in D1 (NPD1) Reduce Gliosis in Retina and Optic Nerve Injury Induced by Blast Wave Exposure.**
Rivers BA, Ryan DS, Sia RK, et al. **Identifying the Incidence of Data Entry Errors on Nomograms in Refractive Surgery.**	Roberts R, Ryan D, Sia R, et al. **Elimination of Transcription Errors in Refractive Surgery.**
Wang HC, Burketa, Bramblett GT, Greene WA. **A Rabbit Model of Penetrating Eye Injury Leading to Intraocular Fibrosis in the Posterior Segment.**	Wang HC, Rettinger CL. **Quantitative Assessment of Retina Explant Viability in a Porcine Ex-vivo Neuroretina Model.**

Panel Discussion

Mazzoli RA, Tourtillot B, Shoge R, Egan JA. **Ocular Trauma Casualty Management Grand Rounds: Case Presentations and Panel Discussion.**

American Academy of Ophthalmology - Annual Scientific Symposium

27–30 October 2018, McCormick Place, Chicago, IL | https://www.aao.org/annual-meeting

Didactic

Miller KE, LeGault GL, Ellos JE. et al. **Ocular Trauma: Translating Lessons Learned from the Battlefield into Everyday Practice.**

Skills Session/Laboratory

Miller KE, LeGault GL, Ellos JE. et al. **Ocular Trauma: Translating Lessons Learned from the Battlefield into Everyday Practice.**

Presentation

VA-DoD Special Symposium: **Ocular Trauma Care: The Challenges and Successes in the Continuum of Care for Eye Injured Service Members and Veterans.**

Recent Publications

Godbole NJ, Seefeldt ES, Raymond WR, et al. **Simplified Method for Rapid Field Assessment of Visual Acuity by First Responders After Ocular Injury.** *Mil Med.* 2018;183(suppl_1):219-223

Karesh JW, Mazzoli RA, Heintz SK. **Ocular Manifestations of Mosquito-Transmitted Diseases.** *Mil Med.* 2018;183(suppl_1):450-458.

Sykes S, Chou E, Mazzoli RA, et al. **Comparison of Simulation-Based versus Live Tissue–Based Ocular Trauma Training on Novice Ophthalmologists: Repair of Marginal Eyelid Laceration Model.** *J Acad Ophthalmol.* 2018;10(01):e61-e68.

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CELEBRATING 28 YEARS OF SERVICE OF VCE EXECUTIVE DIRECTOR, CAPT PENNY E. WALTER

CAPT Penny E. Walter, VCE director since May 2014, has retired from the U.S. Navy. Commissioned as a Lieutenant, CAPT Walter served her first tour as a staff optometrist at the U.S. Naval Academy from 1989 to 1992. Since then, she has served in many capacities, including as Optometry Department Head at Arlington Annex and the U.S. Naval Hospital, Guantanamo Bay, Cuba. Prior to her role at VCE, CAPT Walter reported as the Commanding Officer, Naval Ophthalmic Support and Training Activity and later to Walter Reed National Military Medical Center as the Navy Optometry Specialty Advisor. She has previously been selected as both the Navy Senior Optometrist and the Armed Forces Optometrist of the Year and was selected by Vision Monday as one of the 50 most influential women in the optical industry. In addition, she has received the Navy Legion of Merit, Navy Meritorious Service Medal, Navy Commendation Medal, and the Navy Achievement Medal.

Dr. David Eliason, MD, will serve as the Acting VCE Executive Director.

VCE TO TRANSITION UNDER THE DEFENSE HEALTH AGENCY (DHA)

This summer, we will transition from the Department of the Navy (BUMED) as our lead component to DHA J-9.