Chapter 20

ORBITAL TRAUMA

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INTRODUCTION

Because of the number of structures present in a relatively small space, the management of orbital trauma demands exacting evaluation. Appropriate management requires in-depth knowledge of anatomical structures and their surgical relations. Additionally, because the energies causing orbital trauma are often much greater than those that cause purely ocular trauma, adjacent nonocular structures (eg, nose, paranasal sinuses, midface and jaw, brain) are commonly injured as well (Figures 20-1 and 20-2). Because of this, extensive orbital trauma is often best managed by a multidisciplinary team, on which ophthalmology must be represented. Typical head-and-neck trauma teams include representatives from neurosurgery, otorhinolaryngology (ear, nose, and throat [ENT]), plastic surgery, and oromaxillofacial surgery (OMFS).

In most wartime scenarios—and certainly in many peacetime situations—the general ophthalmologist may be called on to assist or direct the management of orbital trauma, either as a member of a head-and-neck trauma team in the event of complex injury, or as the primary physician in the event of isolated globe or adnexal injury. Extended

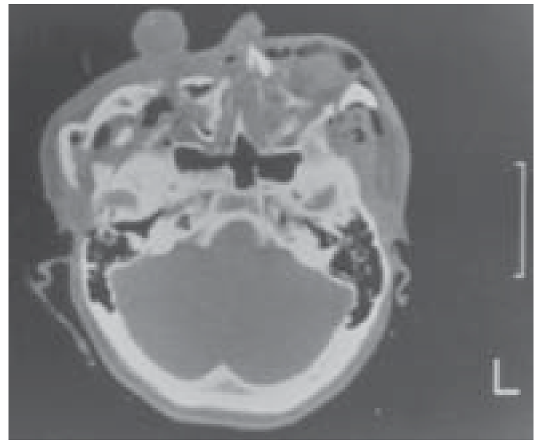

Fig. 20-1. An unrestrained passenger in a motor vehicle accident hit the dashboard and windshield with his face and head. The urgent computed tomography scan demonstrates traumatic enucleation / avulsion of the right eye and massive disruption of the naso-orbital-ethmoid region, as well as bilateral fractures of the zygomaticomaxillary complex. Such high-energy injuries almost always involve multiple anatomical areas and demand multidisciplinary team management. With emergent intervention, the patient survived this dramatic injury.

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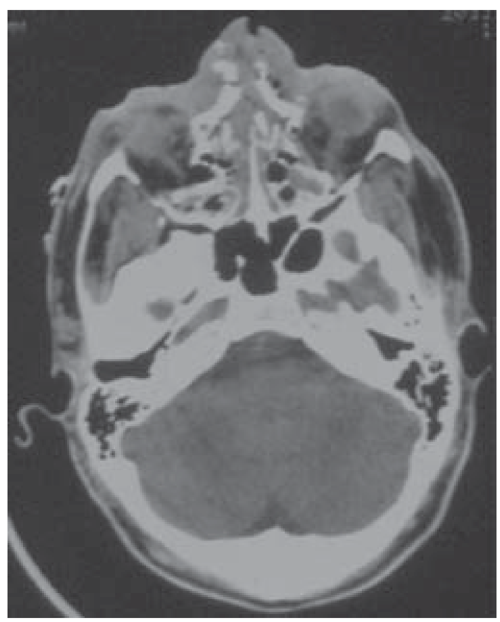

Fig. 20-2. (**a**) A 24-year-old man was attempting to secure a shipping pallet with a tie-down chain when the chain broke and recoiled into his midface. He arrived in the emergency department, and an ophthalmologist was called to evaluate his eyes and orbits. The patient was alert and oriented, and his airway was not compromised. Fortunately, his eyes were not involved. (**b**) The computed tomography scan shows massive naso-orbital-ethmoid disruption, which required open reduction and internal fixation. Such injuries require multispecialty cooperation in evaluation, management, and surgical planning to ensure the maximal functional and surgical outcome. In these cases, early surgery generally leads to the best result.

training in ophthalmic plastic and reconstructive surgery may be an unavailable luxury; nevertheless, the ophthalmologist must take an active role in the evaluation and management of all orbital injuries. Although many other specialists can offer experience in the repair of bony orbital injuries, no other physician can evaluate the globe and its adnexa as expertly as an ophthalmologist can.

ORBITAL ANATOMY AND MIDFACIAL BUTTRESSES

Orbital Soft Tissues

An extended discussion of orbital soft-tissue anatomy is beyond the scope of this chapter. Suffice it to say that the orbit contains fat, muscles, nerves, blood vessels, and above all, the globe (Figure 20-3). The single most important structure within the orbit is the eye. Beyond all else, the ophthalmologist's primary concern—the raison d'être—must be the evaluation, restoration, and preservation of the globe's integrity. Orbital concerns must *always* be secondary to the eye and vision. In current practice, whether in peacetime or combat, it is inexcusable and indefensible to overlook or forego evaluation of the eye of a patient who has suffered orbital trauma. For this reason, it is incumbent on any physician—regardless of specialty—who is evaluating an orbital injury to seek the expertise, advice, and assistance of an ophthalmologist (Figure 20-4).

The orbit has a rich vascular supply, with arterial contributions from both the internal and the external carotid circulations. The venous circulation, as part of the valveless head-and-neck system, is particularly fragile and susceptible to both direct and indirect trauma, such as remote pressure changes as may be caused by sudden decompression, Valsalva pressure, strangulation, or chest compression (Figure 20-5). Consequently, hemorrhage within the orbit is a near-constant companion to

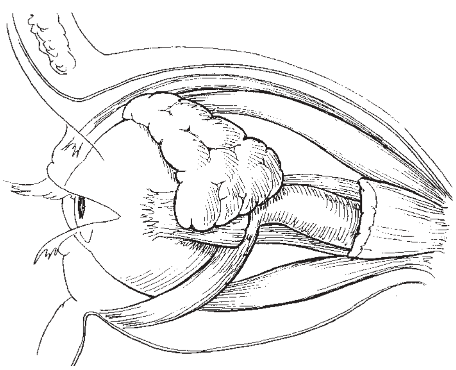

Fig. 20-3. Of all the structures in the orbit, the globe is the most important. Evaluation of vision is required in all orbital traumas. The intramuscular septum, which connects the extraocular muscles, subdivides the orbital compartments into the intraconal and extraconal spaces. Drawing prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

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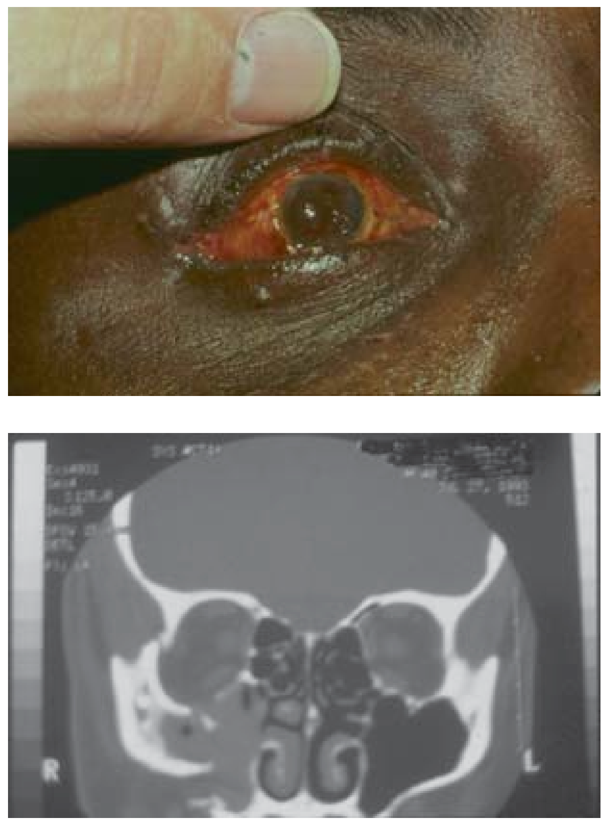

Fig. 20-4. Primary and emergency medical personnel must be acutely aware that facial injuries often affect both the eye and orbit. Likewise, the ophthalmologist evaluating an ocular injury must keep in mind the possibility of concomitant orbital injury. While evaluation and repair of the eye must always take priority over orbital and adnexal injuries, these injuries may require attention nonetheless. (**a**) This 40-year-old man was struck over the right cheek with a glass bottle, which shattered, resulting in the large corneoscleral and lid lacerations. The globe and lid were repaired before the patient was transferred for further treatment, but unfortunately, the eye remained blind. (**b**) A computed tomography scan demonstrates a concomitant right zygomaticomaxillary complex fracture, which was repaired by open reduction and internal fixation before enucleation.

Fig. 20-5. Orbital hemorrhage after chest compression. Increased central venous pressure impedes venous return from the head and neck, often resulting in orbital hemorrhage. (**a**) This patient, an infantry soldier, was engaged in night training maneuvers when an armored personnel carrier rolled through his unit's area and directly over him. Because it had been raining heavily and the ground was especially soft, he survived the accident, suffering intracerebral hemorrhage, other internal injuries, a fractured pelvis, and avulsion of the right brachial plexus nerve roots. Amazingly, the only ocular damage was the bilateral subconjunctival hemorrhages, which are evident in this clinical photograph. (**b**) The thoracic contusion sustained by the patient.

orbital trauma, especially penetrating trauma.

Because the orbit is confined by a dense periorbita (periosteum) surrounded by four bony walls, the orbital contents can decompress in only one direction—anteriorly—and even that is limited by the fibrous orbital septum and canthal structures. Bleeding into this confined space can quickly lead to devastating ocular and orbital consequences. Hemorrhage may occur either within the orbit proper or in the subperiosteal space and can result from either blunt or penetrating trauma, or from remote barotrauma. It may also mask the presence of an orbital foreign body

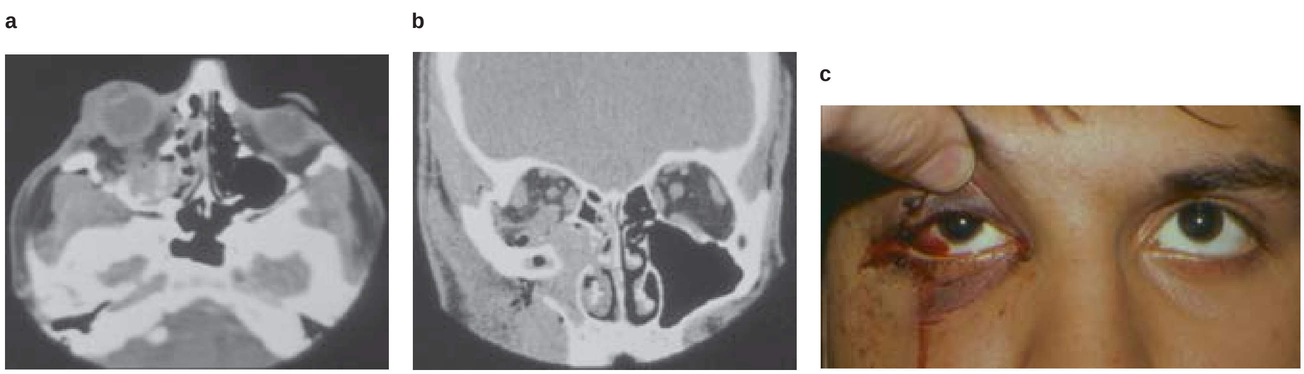

Fig. 20-6. Late orbital hemorrhage and vision loss. When this 20-year-old man first presented to the emergency department after a fistfight, his visual acuity and motility were "normal." However, over the ensuing 20 minutes, the patient complained of decreased vision in the right eye, increased proptosis, limited motility, and pain. (**a**) An emergent computed tomography (CT) scan revealed a large right zygomaticomaxillary complex fracture with sinus opacification secondary to marked hemorrhage. Significant proptosis is evident, as are adnexal soft-tissue swelling and orbital emphysema. Ophthalmologic examination revealed vision of 20/100 with an afferent pupillary defect, tense proptosis, and an intraocular pressure of 44. Immediate canthotomy and cantholysis resulted in return of 20/70 vision, resolution of proptosis, and reduction of intraocular pressure to 26. (**b**) A follow-up CT scan made 2 hours later shows the hemorrhage extending into the inferior orbital soft tissues, although it does not appear to significantly involve the remainder of the intraorbital soft tissues. The amount of sinus clot was sufficient to prevent further drainage of hemorrhage, resulting in increased orbital pressure. (**c**) The same patient 2 days after presentation. The canthotomy and cantholysis are easily seen. Vision was 20/20. He subsequently underwent open reduction and internal fixation and did well.

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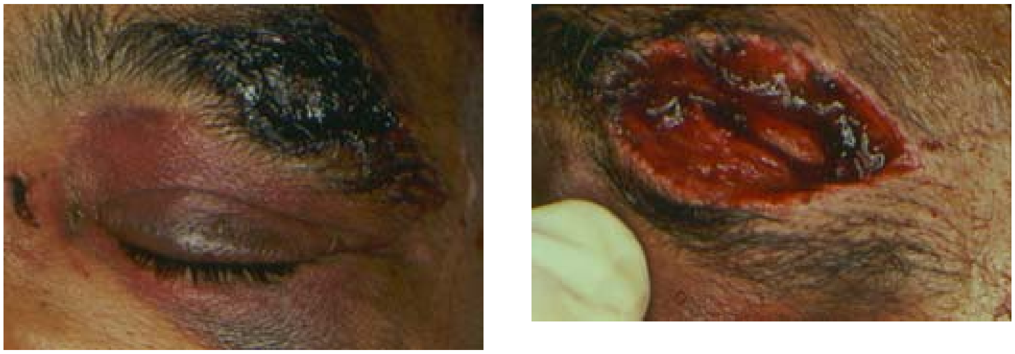

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Fig. 20-7. (**a**) This patient was involved in a motor vehicle accident and suffered a brow laceration. At initial evaluation in the emergency department, the laceration was believed to be minor, having self-sealed with coagulum. It was not explored or sutured, but was patched and the patient was referred for routine evaluation the next day. (**b**) After debridement, the true depth of the wound was revealed, which extended to the periosteum, with underlying bony fracture.

(FB). Therefore, orbital hemorrhage always requires prompt evaluation. Additionally, because active bleeding can continue long after the initial injury, vision must be followed vigilantly, even after the initial presentation (Figure 20-6). More will be said about the evaluation and management of orbital hemorrhage later in this chapter.

Ophthalmologists should always maintain a high index of suspicion for occult penetrating trauma. By the time the patient presents for evaluation, many apparently minor lacerations will have reapproximated and sealed with serum, coagulum, and clot. Often, however, these lacerations disguise retained FBs (such as slivers of windshield glass) or deep injury and may be much more significant than they first appeared (Figures 20-7 and 20-8).[1] Lid and facial lacerations should, therefore, be meticulously cleaned, explored, and debrided of FBs, and lid lacerations, especially, should be thoroughly inspected to rule out full-thickness involvement and

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Fig. 20-8. Unexplored brow laceration. This left brow laceration resulted from a rock thrown during a bar fight. When the patient presented to the emergency department, the wound was felt to be of limited depth and therefore was irrigated and sutured. (**a**) Over the ensuing week, increasing brow pain and lid swelling that were unresponsive to oral antibiotics prompted referral to the ophthalmology clinic, where a tender, fluctuant pocket was palpated at the brow. (**b**) The wound was reopened and explored, revealing approximately 20 retained brow hairs. Only sterile reactive fluid was drained. Full exploration, however, revealed that the wound extended to the periosteum. The wound was debrided, irrigated, and reclosed over a drain. The patient subsequently did well. (**c**) The same patient 7 months later.

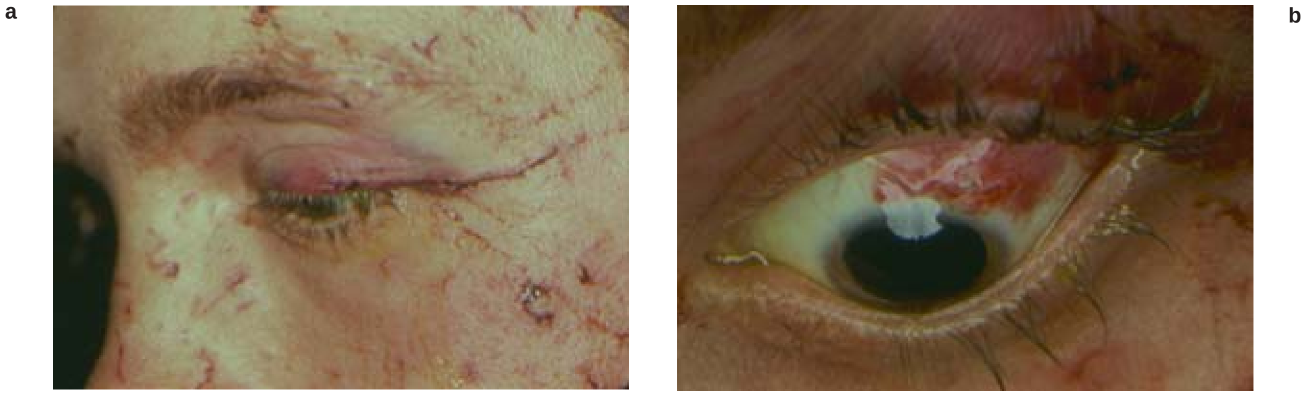

Fig. 20-9. Unsuspected globe trauma. (**a**) This patient was involved in a motor vehicle accident with multiple, apparently superficial, facial lacerations from windshield glass slivers. The lacerations were primarily debrided and sutured in the emergency department, and the patient was referred to the eye clinic the following day for routine evaluation of the lid lacerations. Visual acuity was noted to be 20/50. Many lacerations still harbored glass slivers. (**b**) Thorough examination disclosed an undetected scleral laceration and vitreous hemorrhage. Lid puncture wounds can be seen laterally. No intraocular foreign body was found on surgical exploration. The globe was repaired and the patient's vision returned to 20/20.

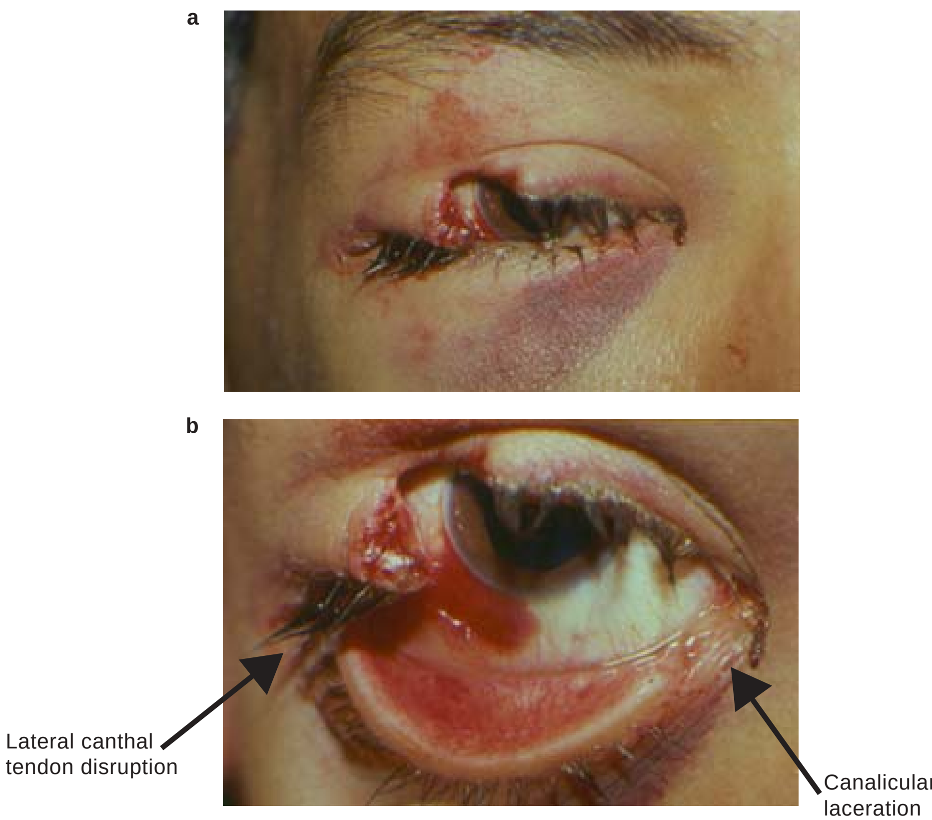

Fig. 20-10. Unrecognized adjacent injury. Canalicular trauma should always be suspected in lid trauma. (**a**) This man was struck with brass knuckles and was referred for treatment of the upper lid laceration. Close inspection of the medial canthus shows the lid to be misleadingly well apposed, with only a small hemorrhagic coagulum implying any injury to the structure. (**b**) A complete examination revealed concomitant—and previously unrecognized—complete disruptions of the lower canaliculus and lateral canthal tendon.

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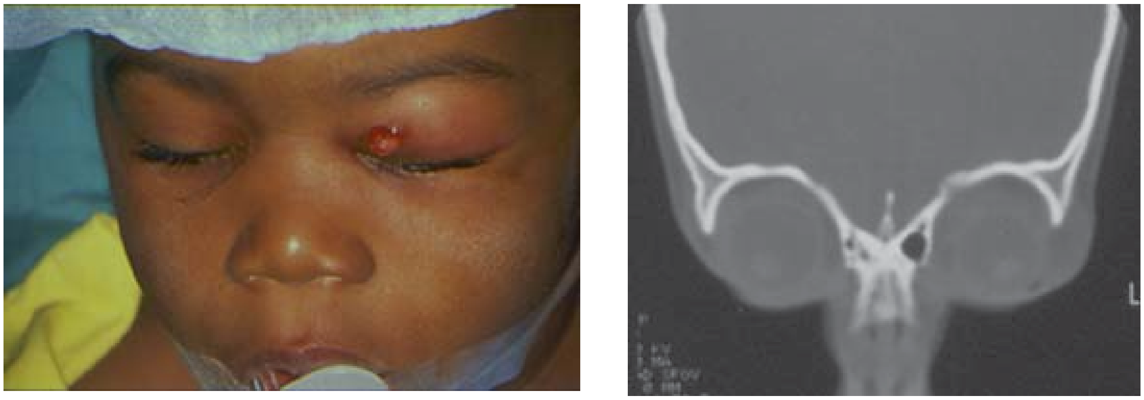

Fig. 20-11. Unsuspected orbital injury. Herniated or visible orbital fat is prima facie evidence of orbital injury, the extent of which is never known on presentation. (**a**) This 2-year-old boy fell on a pencil while running. The patient was alert, oriented, and normally playful during the examination, the only abnormality discovered being the lid laceration and herniating orbital fat. (**b**) A computed tomography scan demonstrated intracranial puncture of the orbital roof. Fortunately, no treatment was needed other than debridement and closure of the lid wound. Similar injuries can also harbor retained foreign bodies.

unsuspected globe injury or canalicular damage (Figures 20-9 and 20-10). Because the orbital fat lies behind the orbital septum, visible orbital fat is an ominous sign, by definition disclosing an orbital injury, and should provoke extended examination with computed tomography (CT), magnetic resonance imaging (MRI), or both (Figure 20-11).

Orbital Bony Anatomy

Seven bones come together to make up the four walls of the bony orbital socket, which takes the shape of a quadrangular pyramid. The orbit is lined with periosteum (the periorbita), which is densely adherent at the orbital rim, the optic canal, and orbital fissures. The periorbita is relatively loosely adherent along the plates of the bony walls, creating a potential space for the accumulation of subperiosteal fluid and blood. None of the bony plates are especially thick, and all can easily be fractured. The orbital floor and medial wall, being adjacent to sinus air spaces, are especially vulnerable to hydrostatic and mechanical buckling forces. Although the bone of the medial wall (the lamina papyracea) is physically thinner than that of the orbital floor, the honeycombed arrangement of the underlying ethmoid air cells gives the medial wall a significant structural advantage over the floor, which is obliged to sit over the cavernously empty maxillary sinus (Figure 20-12). Consequently, the most frequently fractured wall is the floor, not the medial wall. The roof and the lateral wall, on the other hand, being veritably sandwiched between soft tissues (brain and orbit on the roof, temporalis muscle and orbit on the lateral wall), are more substantially cushioned against fractures. Therefore, fracture of either of these walls is indicative of significant traumatic energy.[1–4]

Midfacial Buttresses

The orbital rim, which is arranged as a quadrilateral spiral and is significantly thicker than the remainder of the bony walls (see Figure 20-12), is an essential component of the midfacial buttress system. Unfortunately, the concept of midfacial buttresses is one that is not widely addressed in the general ophthalmic literature. Nonetheless, it is the vernacular among the other services that may be consulting ophthalmology in cases of extensive trauma (ie, ENT, plastic and craniofacial surgery, OMFS, or neurosurgery).[5] Because the orbital rim is integral to the buttresses, the evaluation and repair of rim fractures necessitates that ophthalmologists have at least a cursory knowledge of this concept.[5,6]

The buttresses are to the face what I-beams, girders, studs, and joists are to buildings: they provide the major structural support on which all the other walls, floors, roofs, and ceilings are hung. They maintain the facial skeleton in three dimensions: vertical height, horizontal width, and anteroposterior projection (Table 20-1).

Some areas of the orbital and facial bones are substantially thicker than the bony plates that extend from them (eg, the superior rim vs the orbital roof, or the inferior rim vs the anterior maxillary face and the orbital floor; see Figure 20-12). With-

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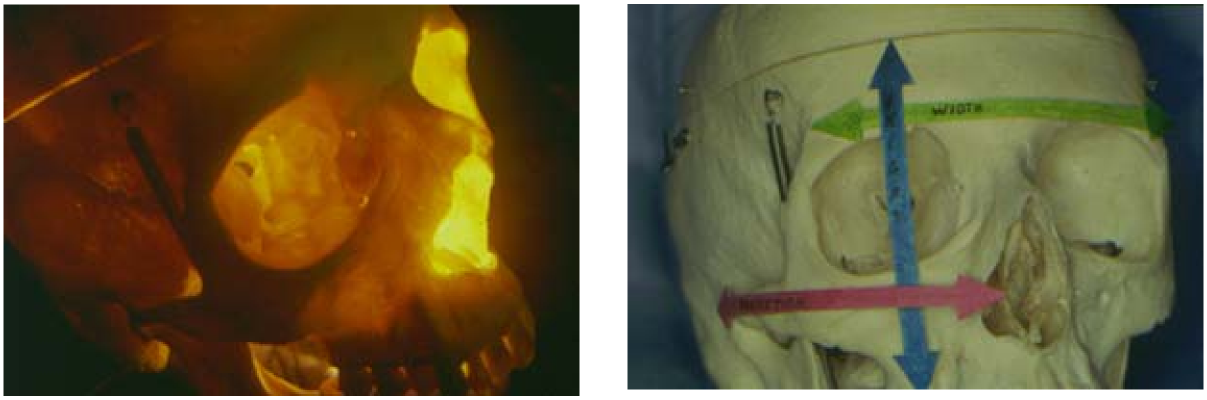

Fig. 20-12. (**a**) The bones of the orbital walls are all very thin, as this transilluminated skull demonstrates. The corrugated ethmoid air cells are clearly visible. These give the medial wall substantially increased strength, compared with the floor, which physically is thicker. The roof and lateral orbital walls are thin, as well. The midfacial buttresses are seen as noticeably thicker areas of bone, much thicker than the orbital plates. The buttresses provide a stable, rigid framework for the face and skull, and they maintain facial width, height, and projection. The areas of the orbital rim, the zygomaticomaxillary complex buttress, and the nasomaxillary buttress are clearly identifiable. (**b**) The integrity of these buttresses is essential in maintaining the three-dimensional facial framework.

out these areas of bony reinforcement, the thinner facial plates alone would not be strong enough to counter the muscular forces of the facial muscles—let alone the dynamic contractile forces of posttraumatic cicatricial changes—and the face would collapse in a large, unstable heap. For example, imagine a house of cards; it might be able to stand up weakly on its own, but it cannot handle much stress (Figure 20-13). In fact, if the buttresses are intact, loss of all the adjacent walls would not significantly alter the three-dimensional size of the face, just as a house or building remains stable and identifiable with only its frame intact even if all the plasterboard and plywood walls have been removed. The reverse, as stated before, is not true: if all the plasterboard and plywood are intact but the studs and weight-bearing walls (ie, the buttresses) are buckled, the building will not be stable (Figure 20-14).

This is not to say that the loss of the thinner bony plates is inconsequential. On the contrary, loss of an orbital wall may have significant functional and cosmetic sequelae, even if the rim is completely intact. Loss of the orbital floor causes, for example, hypo-ophthalmia, enophthalmos, and diplopia and requires surgical repair (just as a hole in the floor of a third-floor office has to be repaired lest the furniture fall through it into the second-floor office below). The point is that if the girders of the building are buckled, repairing only the hole in the floor does little for the ultimate stability of the building; the buttresses must be stabilized first.

Because the buttresses are two-dimensional plates instead of simple bars, they actually have some structural strength in two directions (eg, the ethmoid plate of the medial wall supports not only height but also projection). Consequently, aligning the horizontal and vertical buttresses ensures projection. Some authors believe that the most important determinant in ensuring projection is reestablishment of accurate facial width, the key structure being the zygomatic arch.[4]

TABLE 20-1

MIDFACIAL BUTTRESSES

Dimension	Buttress
Vertical (height)	Zygomaticomaxillary complex (key element)
	Nasomaxillary
	Pterygomaxillary
	Fronto-ethmoid-vomer
Horizontal (width)	Superior rim
	Inferior rim
	Zygomatic arch (key element)
	Maxillary alveolus and palate
Anteroposterior (projection)	Zygomatic arch
	Maxillary alveolus
	Fronto-ethmoid-vomer

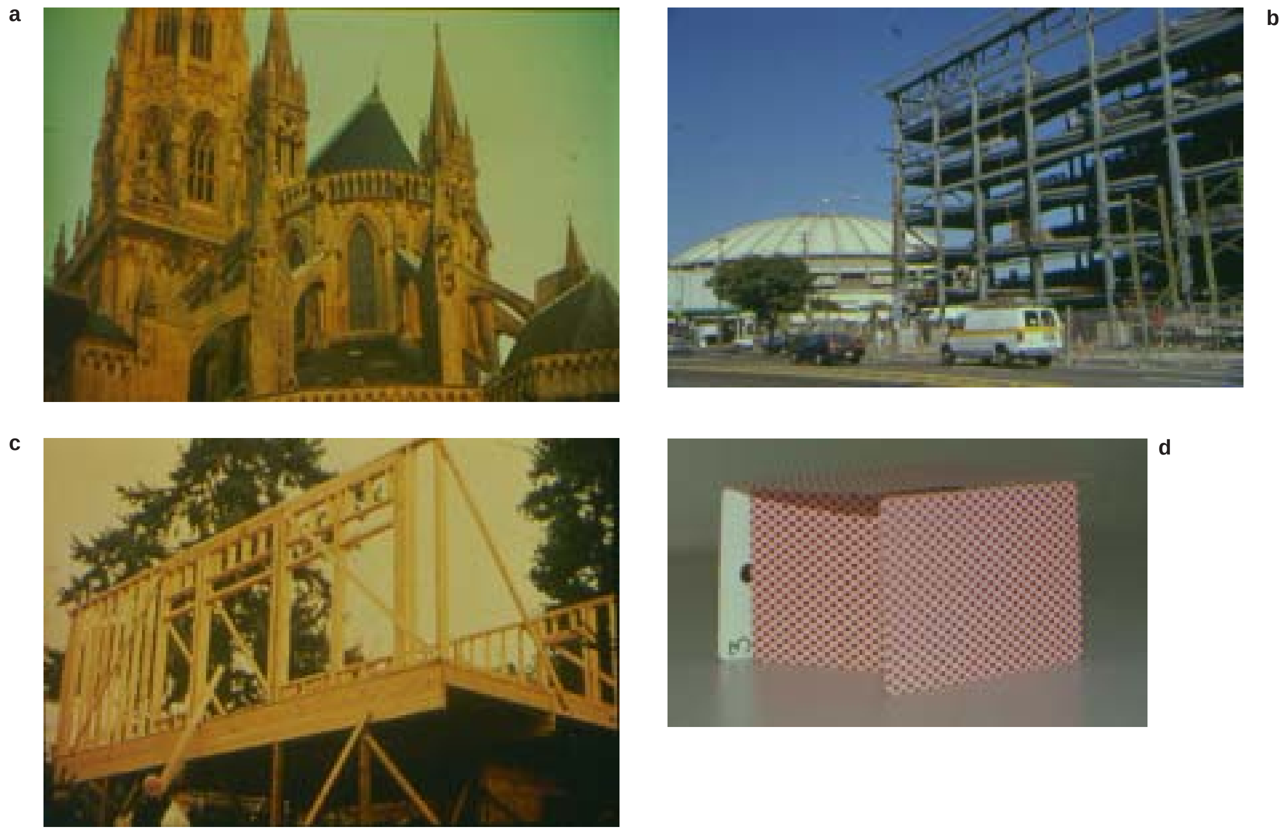

Fig. 20-13. Architectural buttresses help maintain three-dimensional structural stability. Without architectural buttresses—such as (**a**) the external flying buttresses of the Cathedral of Notre Dame, Bayeau, France, or (**b**) the internal buttresses of such modern structures as Seattle's Safeco Field and Kingdome, or (**c**) the studs and joists of modern housing—structures would have little strength against three-dimensional forces and would have the stability of (**d**) a house of cards.

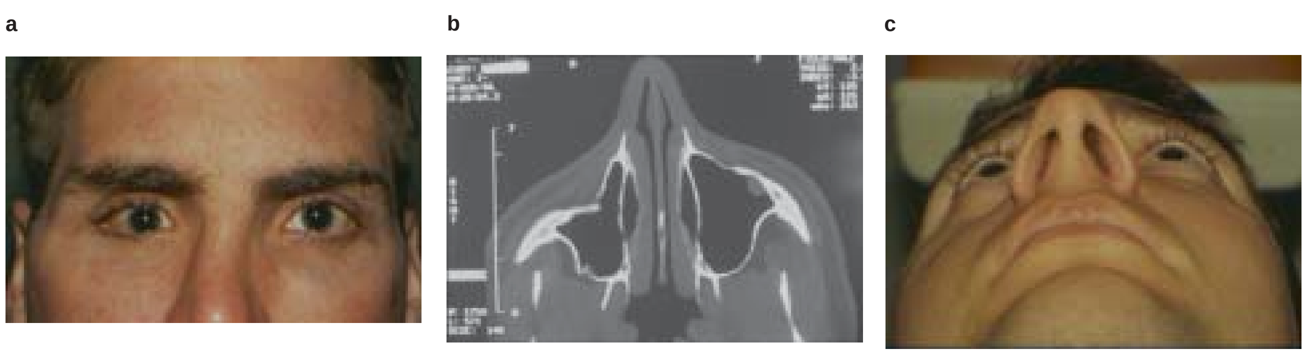

Fig. 20-14. Reconstitution of the midfacial buttresses after trauma is essential for maintaining proper facial projection. (**a**) A patient who suffered multiple midfacial fractures, including a zygomaticomaxillary complex fracture, after a parachute fall. Failure to reestablish proper articulation of the midfacial buttresses resulted in long-term orbital enlargement, increased facial width, malar flattening, and significant facial distortion. Despite frank right hypoglobus, the patient did not complain of symptomatic diplopia. (**b**) This computed tomography scan is of a different patient, who suffered a zygomaticomaxillary complex fracture in a car accident. (**c**) Three years later, this patient exhibits persistent malar flattening and significant enophthalmos as a result of insufficient reduction and poor alignment of the midfacial buttresses. Late repair of such deformities is difficult, because secondary soft-tissue contracture and fibrosis resist bony repositioning.

IMAGING

Although imaging for trauma is the subject of Chapter 4, Imaging of Ocular and Adnexal Trauma, some thoughts on orbital applications are nonetheless appropriate here. Imaging is always indicated in orbital trauma, and whether the ophthalmologist is looking for intraorbital foreign bodies (IOFBs), soft-tissue integrity, or bony fractures, the various imaging modalities—CT, MRI, and even plain film radiography—can provide significant information.

Computed Tomography

Currently, the most useful information for evaluating and managing orbital trauma is gained with CT. It provides the best visualization of bony integrity, gives reasonably good soft-tissue detail, and discloses many FBs, especially metallic ones. Many other FBs, however, such as those composed of glass, vegetable material, wood, and plastic, are poorly detected. Although CT scanners are currently deployed with many field hospitals, they are not universally available at all operational medical units. Nevertheless, CT is currently the imaging modality of choice for most orbital trauma.[7,8]

In general, a noncontrast protocol of 3-mm slices in both axial and true coronal planes gives sufficient information to manage most traumas. Certain conditions or circumstances warrant modification of this protocol. If true coronal views are not possible (eg, if the patient has a cervical spine injury), thin-slice (1.0–2.0 mm) axial studies give enough

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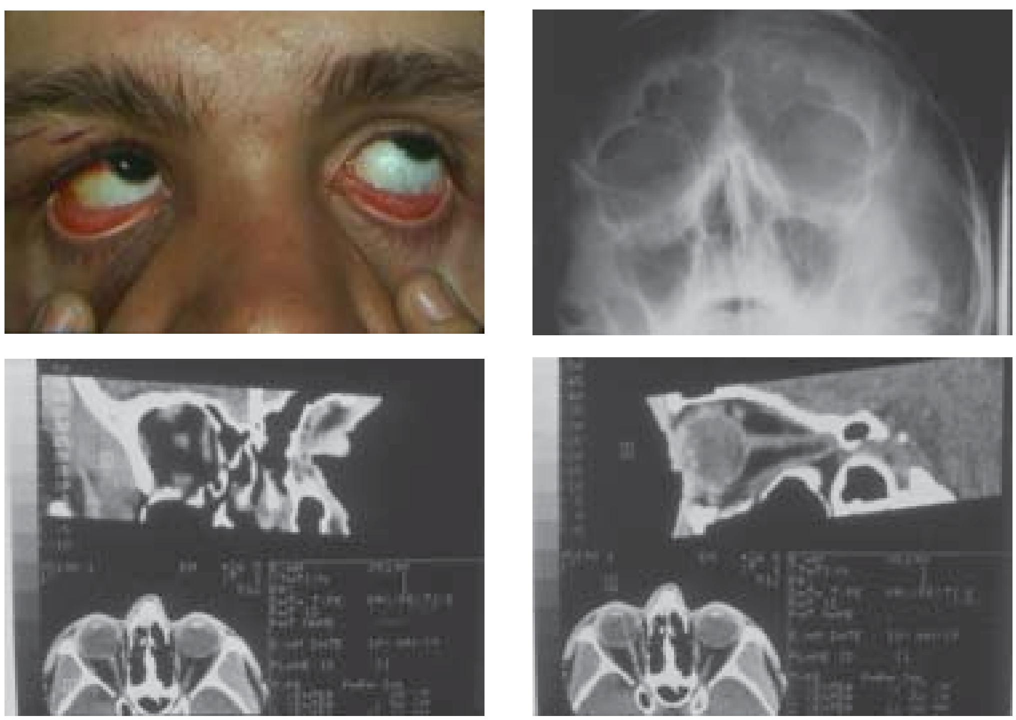


Fig. 20-15. Imaging: blowout fracture. (**a**) This 19-year-old man was the victim of an assault. The visual acuity was 20/20 in both eyes, but he complained of symptomatic diplopia in all fields of gaze, worst in upward left gaze. (**b**) A plain film radiograph (Waters's view) shows depression of the right orbital floor, but no gross herniation of orbital tissues into the maxillary sinus (the "tear drop" sign) is seen. (**c**) A coronal computed tomography (CT) scan, however, clearly demonstrates a large fracture of the medial orbital floor, with suggestion of perimuscular soft tissue entrapment. (**d**) Sagittal reconstruction localizes the fracture to the antero-middle floor and again shows soft-tissue entrapment. Note: Views c and d are reformatted views, as evidenced by the step artifacts of reconstruction and lack of metal scatter artifact from dental fillings. However, better detail is usually attained by direct coronal views. If reconstructed views are needed, initially obtaining the thinnest slices (1.5–2.0 mm) maximizes the quality of the reconstruction. Helical CT techniques produce excellent multiplanar reconstructions.

detail to allow reformatting into acceptable coronal views (Figure 20-15). If the ophthalmologist is looking specifically for optic canal trauma, 1.0–1.5-mm axial views give the best information (Figure 20-16). Thicker slices (eg, 3.0-mm) give adequate information for managing most facial traumas, but they are more prone to volume-averaging-induced artifacts that can mask subtle but significant detail and are, therefore, inadequate for complete evaluation of the canal. Because head or brain CTs are oriented differently from orbital views, slices of 5-mm thickness are unreliable when evaluating the orbital apex and should not be used. The patient is better served by the ophthalmologist's ordering the appropriate study at the outset than by his or her trying to "interpolate" a substandard study. If optic canal trauma or traumatic optic neuropathy is suspected, it behooves the ophthalmologist (or the emergency department physician) to convey the need for thin-slice orbital scans to the radiologist as soon as possible, so that the patient will not have to make multiple and unnecessary trips to the scanner.

Remembering that the skull does not reach adult size until about age 16 years, acquiring 3-mm slices on a child's orbit is akin to getting 5-mm slices on an adult. Volume-averaging makes discrimination of fine detail very difficult in such thick slices. Therefore, in children younger than 12 to 13 years of age, 1.0- to 2.0-mm slices generally yield the most useful information (helical, or spiral, scanners now make this easy).

When planning reformatted views, obtaining the thinnest scans possible maximizes the quality of the reconstructed views. Remember, however, that the quality of any reformatted view is degraded by metal artifacts and signal-averaging (Figure 20-17). On the other hand, when the patient has extensive dental fillings or prior metal facial plating, then reformatted coronal views from thin-slice axial views often eliminate the metal-scatter artifact of direct coronal views. Nevertheless, direct coronal views generally give more reliable information than reformatted views (see Figures 20-15 and 20-16).

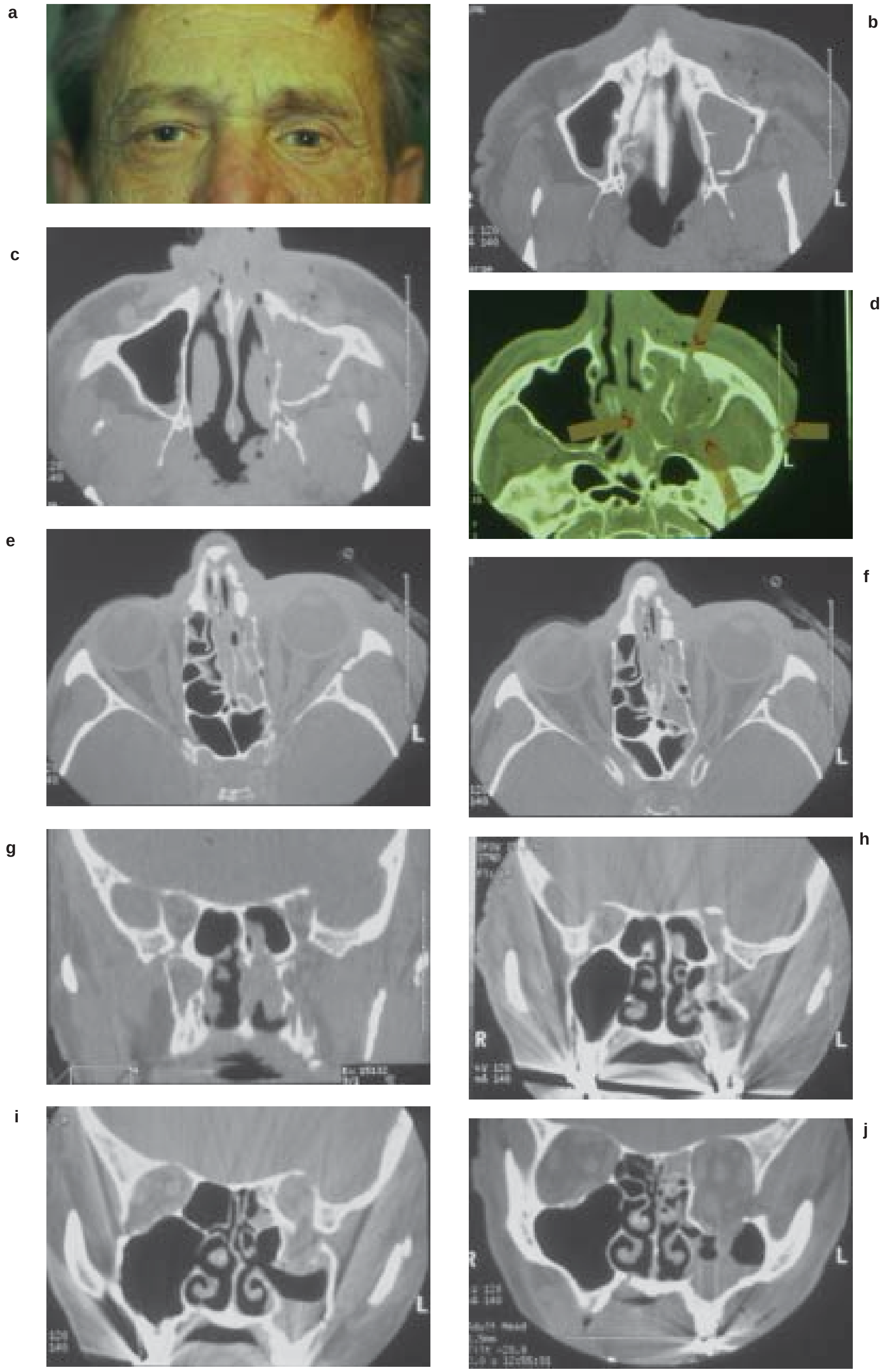
Although three-dimensional images of orbital and facial trauma make impressive lecture slides, such reconstruction is associated with unacceptable levels of signal degradation and artifact, which limits its usefulness in acute trauma management. Currently (2002), three-dimensional reconstruction adds little relevant information and is of little use in acute orbital trauma, although it is useful in many peacetime situations (eg, management of craniofacial and synostotic syndromes). But because spiral scan techniques now allow the rapid acquisition of thin, seamless slices, three-dimensional formatting may become more applicable in acute trauma management (Figure 20-18).[7,8] Occasionally, sagittal reconstruction is worthwhile (see Figures 20-15 and 20-17).

Recent advances in CT technology have decreased both the amount of radiation delivered and the time required for scanning. Spiral scanning allows rapid studies and therefore is useful in many situations (eg, acute chest and head trauma, vascular imaging, and when scanning children). Spiral techniques permit reconstructed views of exceptional quality. Such refinements in image quality will likely continue as software and hardware improve.[7]

Unfortunately, CT is not without its drawbacks. What it contributes in bony detail is often lost in soft-tissue resolution. Many FBs are isodense with bone, hemorrhage, fat, and inflammation and are therefore very difficult to detect. Metal artifacts—from dental fillings, metal plates, wires, or other FBs—can induce such destructive interference that a high-quality scan may not be obtainable (Figure 20-19). Although the patient and the CT gantry can be repositioned so that most of the X-ray beams avoid the metal, the resulting orientations and cross-sections are often so atypical or unusual that they are difficult to interpret—even by physicians accustomed to unusual scans (Figure 20-20).

Spiral scans, while dramatically decreasing the scan time, may do so at the expense of decreasing the life of the X-ray tube. Because the beam is turned on from the beginning of the spiral to the end, it can get much hotter than it does during a conventional scan, during which the tube cools between slices. Of course, spiral scanning is merely a CT technique; it can be performed as needed and then the machine can be returned to its conventional usage. Nonetheless, helical techniques can dramatically increase X-ray tube maintenance and decrease the expected tube life. Consequently, spiral scans should be ordered only if conventional scans are unacceptable.

Many of these drawbacks are compounded in the field environment. Although mobile, the equipment is heavy, bulky, and expensive. Replacement parts can be difficult to obtain during combat operations, when the scanner is most needed. In addition, the scanner might be located in a separate trailer or van within the field hospital, which can lead to difficulties in patient transportation and flow (Figure 20-21). Despite significant advances in decreasing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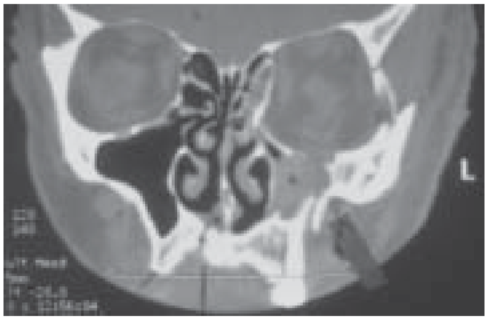

Fig. 20-16. Multilevel facial trauma and traumatic optic neuropathy. (**a**) A spooked horse trampled the chest and face of this 63-year-old patient, who is shown here 4 months postoperatively. Amazingly, he did not lose consciousness and was able to make his own way to the emergency department, where he reported decreased vision in the left eye. Visual acuity was 20/30 in the right eye and 20/70 in the left eye, with subjective red color desaturation and an afferent pupillary defect. He also had restrictive diplopia in 10° upgaze. There was significant point tenderness over the zygomaticomaxillary (ZM) suture, the zygomaticofrontal (ZF) suture, the zygomaticomaxillary complex (ZMC) buttress, and the zygomatic arch (ZA) suture. Trismus, malocclusion, and clinically evident enophthalmos were noted. The optic nerves were flat and without pallor. (**b**) A thin-slice (1.5-mm) axial computed tomography (CT) scan showed multilevel facial fractures, including fracture of the right hard palate and maxillary plate and (**c**) left ZMC. Disruption of the left pterygoid plate classifies this as a "unilateral" Le Fort I fracture. (**d**) A higher slice demonstrates displaced fractures of the inferior rim, the medial and posterior maxillary walls, and the ZA (arrows). Coupled with the fractures of the anterior and medial maxillary walls and pterygoid, involvement of the nasal rim in the area of the nasolacrimal duct constitutes a Le Fort II fracture.

(**e**) A midorbital view shows comminuted nasal and left medial wall fractures, as well as minimally displaced fractures of the left lateral wall. This constitutes a Le Fort III fracture as well as a naso-orbital-ethmoid (NOE) fracture. Because of the complexity of many modern facial fractures, the Le Fort classification often inadequately describes the true extent of the injury. Consequently, many trauma surgeons forego attempting to categorize fractures under this system and opt instead for a simple description of the structures involved. Also evident is a small fracture of the posterior ethmoid-sphenoid plate at the left orbital apex, in the region of the superior orbital fissure and optic canal. This image—just below the optic canal—shows a small bony fragment that displaces the medial rectus but does not appear to directly encroach into the canal. (**f**) This adjoining image shows the optic canal well, almost in its entirety. The bony canal does not appear fractured or physically compromised but may, nonetheless, harbor an invisible, nondisplaced hairline fracture. When evaluating a patient with potential traumatic optic neuropathy, thin-slice images, such as these 1.5-mm views, give the best detail of the optic canal. Similarly, direct, true coronal films are more discriminating than reconstructed views. (**g**) A coronal view at approximately the same level of the orbital apex, reconstructed from the 1.5-mm axial study, shows the step artifact characteristic of reconstructions but no metal scatter artifact from prior dental work. No fracture is convincingly demonstrated in this image. (**h**) On the other hand, this image of the area of the optic canal taken 5 days later is a true coronal view, as evidenced by the smoother bone and tissue contours and dental artifact. A nondisplaced fracture of the posterior ethmoid is clearly seen here. (**i**) This coronal CT scan also shows the extent of the floor fracture, extending posteriorly to the area of the inferior orbital fissure. Complete reduction of all herniating orbital tissues in this region is extremely difficult, and puts the optic nerve at risk from surgical compression and manipulation.

(**j**) More anterior views show the marked disruption of the left floor, with herniation of the orbital tissues into the maxillary sinus below. Rounding of the inferior rectus muscle indicates disruption of the periorbital septae, which keeps the muscle in its naturally elliptical shape (compare with the right eye). Such large fractures require a substantial and rigid plate that can be cantilevered over the maxillary sinus to support the orbital tissues. Many times, the floor plate will have to be secured to the orbital rim. Current options for the plate material include calvarial bone, iliac bone, channeled and unchanneled porous polyethylene sheets, and titanium mesh plates.

(**k**) This image clearly shows the disruption of the left ZMC buttress (arrow) and separation of the ZF suture. It also shows the degree of collapse of the medial orbital wall, floor, and nasolacrimal duct, in the area of the maxillary osteomeatal complex. Disruption of the right maxillary alveolus (grease pencil marks) and dislocation of the base of the nasal septum are also evident. The patient was treated for traumatic optic neuropathy with "megadose" corticosteroids (methylprednisolone 30 mg/kg intravenous loading dose, followed by 15 mg/kg every 6 h for 48 h), with rapid visual improvement to 20/25. Five months later, a trace afferent pupillary defect was still present in the patient's left eye, red desaturation remained slightly diminished, and visual fields showed a slight enlargement of the blind spot. Facial fractures were surgically reduced within 1 week of injury, requiring use of multiple titanium fixation plates. The floor was reconstructed with a porous polyethylene sheet. Residual enophthalmos is evident (see view "a"), but the patient has full ocular motility. Despite a significant amount of left hypoophthalmia, because the hypoglobus is purely vertical with retention of parallel visual axes, the patient does not suffer diplopia. In general, surgical repair of facial fractures can be postponed for 7 to 10 days. However, large fractures such as these should be repaired as soon as is feasible, taking into account such factors as acute swelling and patient stability.

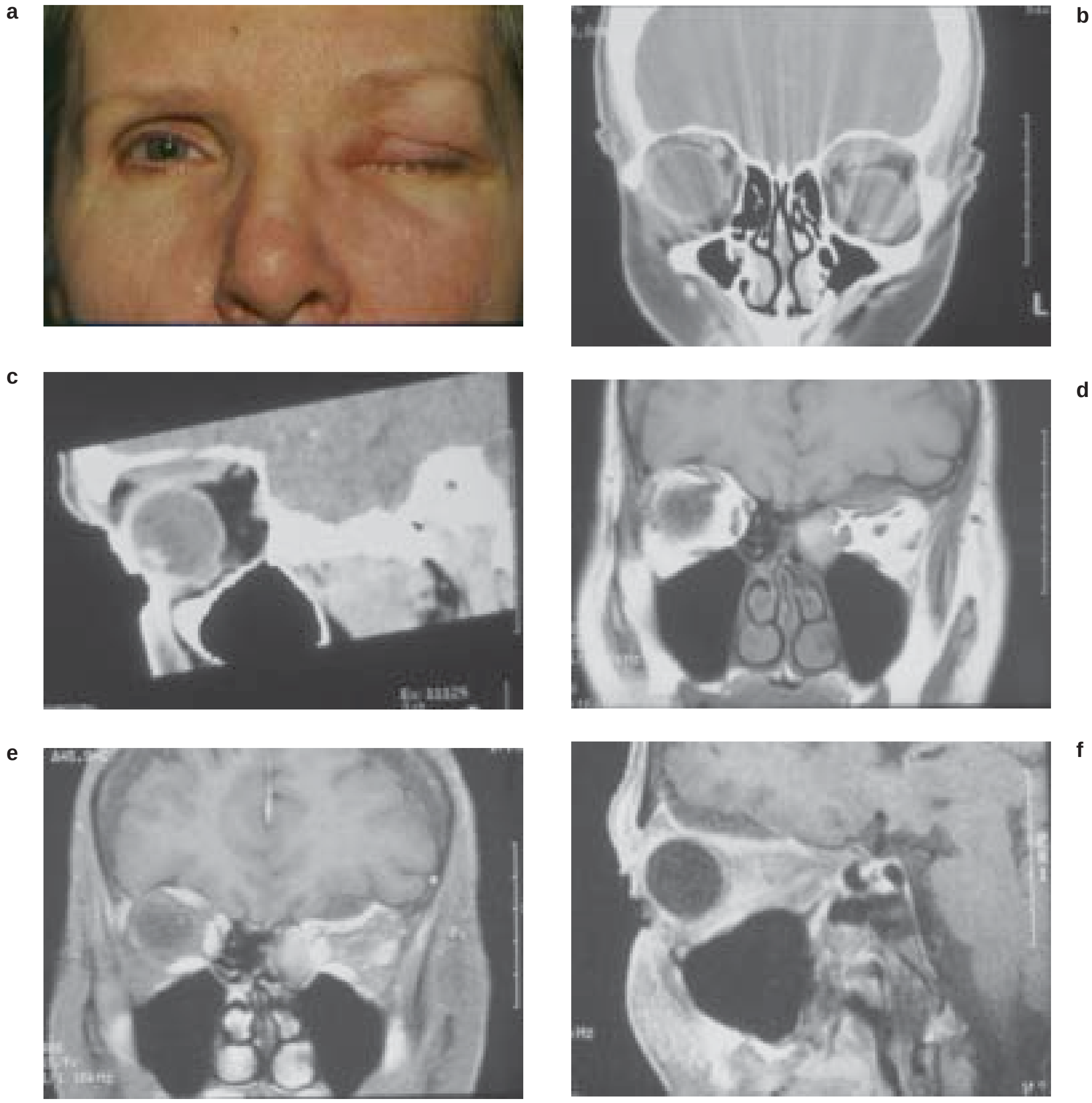

Fig. 20-17. Subperiosteal hemorrhage. (**a**) This patient, a 54-year-old woman, complained of spontaneous orbital fullness and pressure in the left eye. She denied trauma, Valsalva pressure, or metabolic disorder. Examination revealed ptosis, proptosis, hypoglobus, and mild limitation of supraduction. (**b**) This coronal computed tomography (CT) scan demonstrates a homogeneous, biconvex mass along the roof. A thin separation between the levator/superior rectus complex and the mass is suggested but is not conclusive. Notice the dental artifact, which indicates a true (not a reformatted) coronal scan. (**c**) This sagittal CT reformation shows the lenticular mass limited by the periosteum. Notice the lack of dental metal scatter and the step artifact, which is characteristic of reconstructions. A lytic bony defect is seen just above the mass. Despite being reconstructed from thin-slice primary studies, whether this defect is real or merely a reconstruction artifact is difficult to tell here. Such dilemmas are inherent limitations of reformatted views. (**d**) This coronal T1 magnetic resonance imaging (MRI) scan shows a bright, fat–tissue separation between the darker signals of the superior muscle complex and the periosteum, localizing this process to the subperiosteal space. (**e**) Coronal T2 MRI and (**f**) sagittal fat-suppressed T1 MRI images demonstrate a mildly heterogeneous signal from the mass, which is consistent with subperiosteal hemorrhage (SPH). No bony defect of the roof is seen on the sagittal MRI, but the periosteal attachments are once more clearly evident. The patient underwent superior orbitotomy, with evacuation of a liquefied SPH, and did well subsequently.

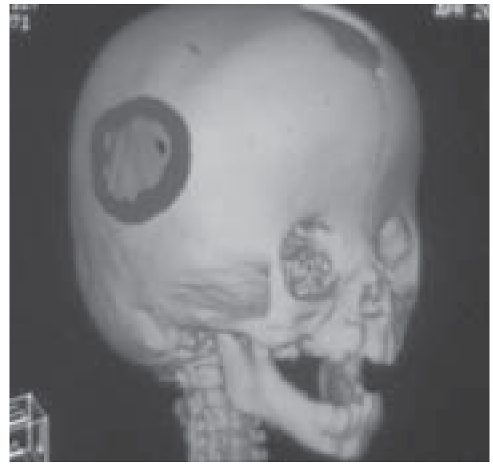

Fig. 20-18. Three-dimensional (3-D) reconstruction is rarely useful in acute trauma because of unacceptable signal dropout and artifact. Nonetheless, it is quite useful in craniofacial evaluation and surgical planning. This 3-D computed tomography (CT) scan clearly shows complete bicoronal craniosynostosis and significant metopic suture narrowing. The anterior fontanel is large. The lateral bony defect laterally is artifactual. Notice the amount of signal void and dropout in the interior orbit. Such artifact makes 3-D reconstructions unreliable in acute trauma.

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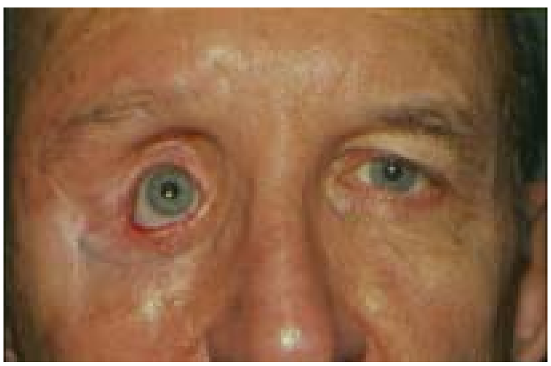

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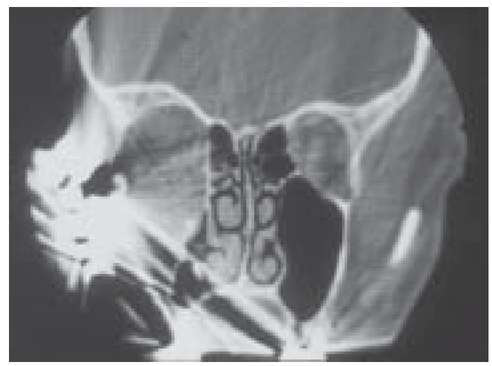

c

Fig. 20-19. Chronic changes after massive facial trauma, with metal orbital implant. Metallic implants can significantly degrade standard computed tomography (CT) scan images, especially if the metal contains a significant amount of iron or steel. This effect is sometimes avoided by conventional radiographs. (**a**) This patient suffered massive facial injuries as a result of a bomber engine explosion on his flight home at the end of World War II. The right eye was enucleated, and the zygoma and orbital rim were reconstructed with a Vitallium plate, but the orbital floor was not reconstructed. Fifty years later, despite several subsequent reconstructive efforts, the patient is left with massive socket contraction, lid dystopia, and thin skin overlying the metal plate. He can barely retain a prosthesis and prefers not to wear one.

(**b**) The CT scan shows the extent of the orbital disruption, with massively enlarged orbital volume and missing lateral orbital wall. Unfortunately, the Vitallium plate and dental work artifact degrade the signal so significantly that other details are obscured. Trying to mentally reconstruct an image of the metal plate from the fragmented images of the CT scan is exceedingly difficult. (**c**) On the other hand, a plain film radiograph, posteroanterior view, clearly demonstrates the shape, contour, detail, and position of the plate and the dental work. It does not, of course, adequately demonstrate the orbital soft tissues. Orbital reconstruction of such cases is frustrating for both the patient and the surgeon, as the contracted tissues resist advancement, and poor tissue vascularity leads to surgical failure.

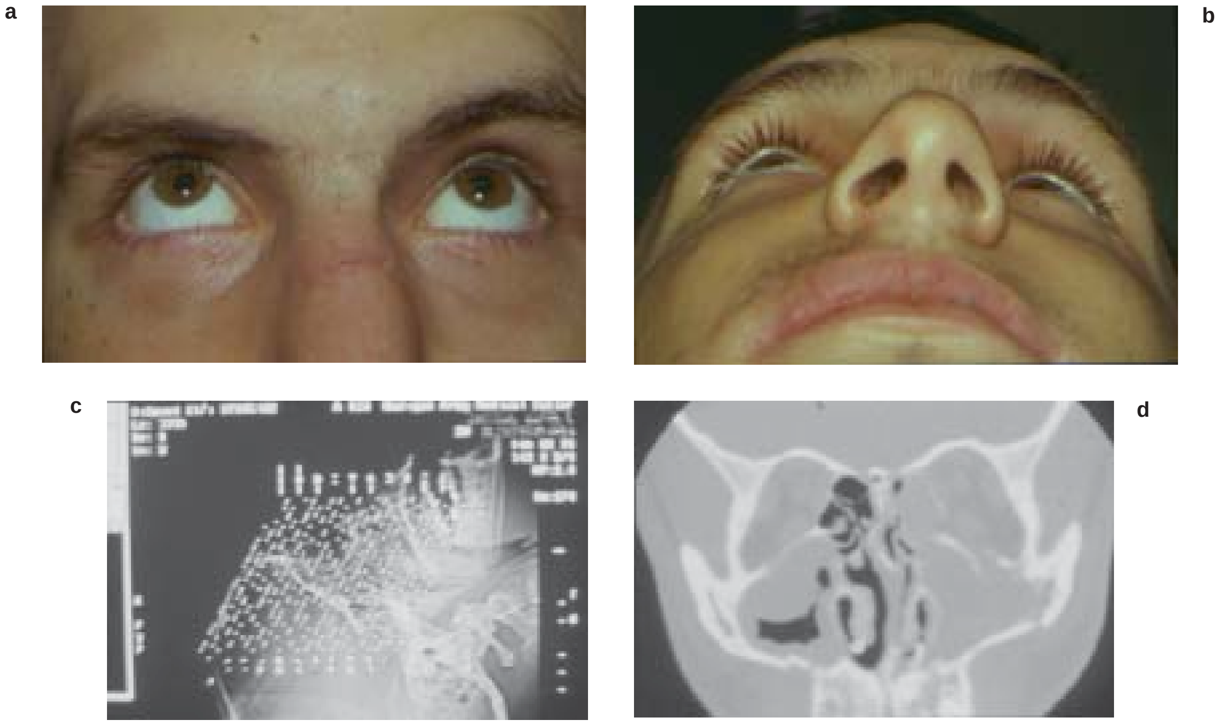

Fig. 20-20. (**a**) During night training maneuvers, this 20-year-old Army Ranger prematurely exited a helicopter 40 feet off the ground and suffered significant head, facial, back, and extremity trauma. After being stabilized at a local hospital, he was evacuated for further evaluation and treatment. On presentation at the medical treatment facility, the patient's ocular examination was surprisingly unremarkable. Large fractures are often nearly asymptomatic, as the bony fragments are either too comminuted or too displaced to cause entrapment. In such cases, the ophthalmologist must have a high index of suspicion, based on associated symptoms. The patient denied diplopia in any field of gaze, including up-gaze, and demonstrated full, unrestricted ocular motility. On close questioning, however, he admitted to sensory dysesthesia over cranial nerve V_2 bilaterally as well as mild trismus. He denied malocclusion. He had significant point tenderness over the zygomaticomaxillary and the zygomaticofrontal sutures as well as over the zygomaticomaxillary complex (ZMC) buttress. (**b**) The left maxilla was significantly depressed.

(**c**) Because of the cervical spine injury, the patient could not be properly positioned, nor could the CT gantry be fully tilted for true coronal scan. This figure shows the image plane. (**d**) The off-axis orbital scan resulted in this atypical image. The angulation is such that the midposterior orbit is seen in the same frame as the maxillary alveolus, the midmaxillary sinus, the zygomatic body, and the ZMC buttress. Compare the orbital contour in these images with those seen in Figures 20-31, 20-40, 20-43, and 20-44. Images such as these are often difficult to interpret. Nevertheless, the image reveals bilateral ZMC fractures and a large, left-floor blowout fracture. Note the rounding of the left inferior rectus, denoting disruption of the periorbita. Also noted are fractures of the maxillary alveolus and nasal septum. The patient underwent an open reduction and internal fixation of his panfacial fractures and did well.

the time required to obtain a scan, CT can nonetheless be slower than conventional radiography. The inability to properly position a casualty with multiple wounds may limit or degrade the study, either in peacetime or in wartime. When considering a mass casualty environment, CT assets may require prioritization, especially when theater evacuation policies are taken into account. Because it is computer dependent, any failure of the support software has an immediate and profound impact on the quality of care delivered, and remedying such problems in the field or under combat conditions is not as easy as during peacetime.

Like any other highly technical equipment, CT requires a skilled operating technician to ensure its proper function and maintenance as well as to provide acceptable studies. CT technicians can often double as general radiology technicians, but the reverse is not necessarily true. Continued operation in the dusty, dirty, hectic environment of the combat zone can be expected to take a toll not only on the physical equipment but also on the CT personnel.

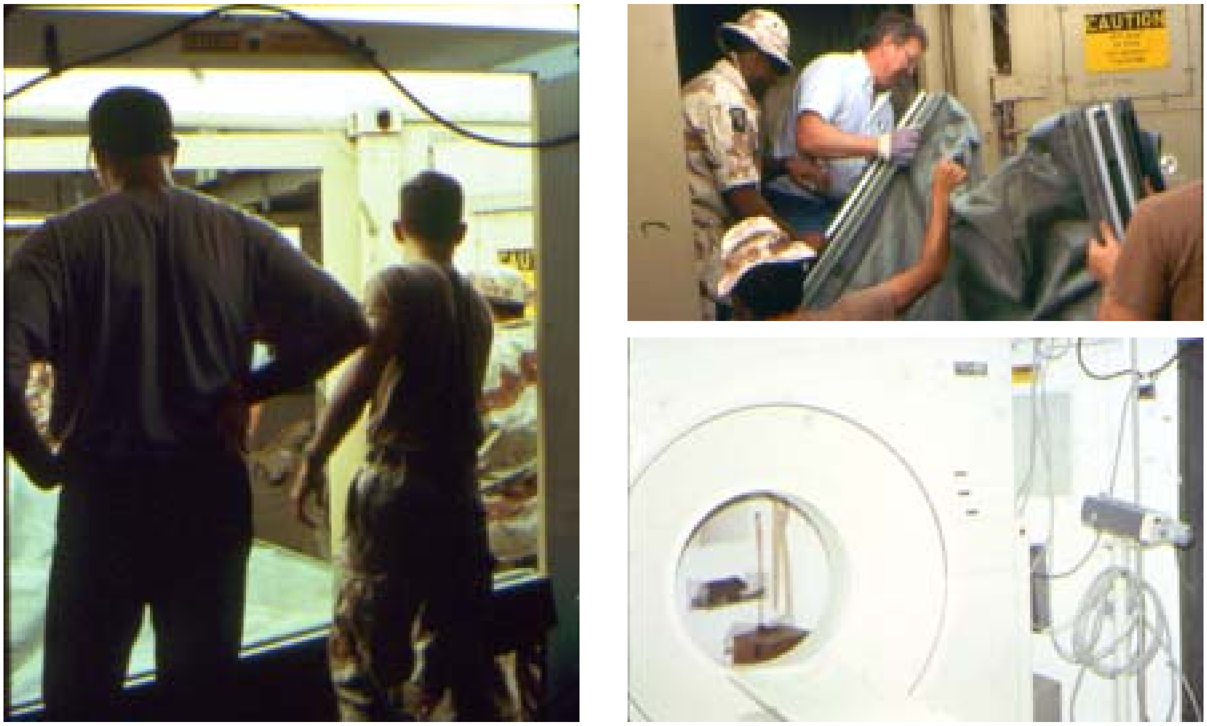

Fig. 20-21. Field computed tomography (CT) scanner. Typically, military ophthalmologists will be deployed to medical units with field CT capability. Physical constraints such as (**a, b**) narrow doorways may impede rapid patient movement and CT evaluation of all traumas in the combat zone. (**c**) Field scanners such as this one, which was deployed to Somalia during Operation Restore Hope (1992–1993), provide fully functional, sophisticated imaging capability.

Magnetic Resonance Imaging

MRI gives excellent soft-tissue detail but suffers in bony resolution. Consequently, its application in orbital trauma is as an adjunctive study rather than the primary imaging modality. It is excellent for revealing many orbital FBs, especially dry wood (green or wet wood may be invisible) and materials that contain little water (few free protons).[9,10] MRI offers the significant advantage of direct multiplanar image formatting (ie, axial, coronal, and sagittal views are generated by one pass through the scanner without the patient's having to be repositioned). However, because of its inherent reliance on strong magnetic fields, MRI cannot be used without first excluding the possibility of metallic FBs via either CT or plain film radiography. Because of the high likelihood of wounds caused by metallic fragments, this consideration applies regardless of which body part is the focus of the study: abdominal wounds cannot be imaged by MRI if there is the possibility of head-and-neck metallic fragments; likewise, a head/orbital injury cannot be imaged if there are other, more peripheral, metallic fragments. MRI is very useful in identifying blood and its breakdown products, and it can help differentiate structures that are homogeneously dense on CT. It is also extremely useful in delineating whether a process is occurring in the subperiosteal space or within the orbit proper (Figure 20-22; also see Figure 20-17).

The advent of MRI brought the anticipation that it would soon supplant CT as the principal imaging modality for all orbital applications, but to date (2002) such has not been the case. MRI is still significantly limited in its ability to identify foreign materials such as glass, plastic, and wet wood. Spatial resolution also remains a limitation, as the thickness of MRI slices still cannot equal the resolution of thin-slice CT. Additionally, because of the way MRI information is obtained, MRI "slices" cannot be overlapped as they are in CT images (eg, spiral-scan slices are seamless, or continuously overlapped), and as a result, some gaps between MRI images always exist. Orbital surface-coil techniques significantly enhance signal detail, but the equip-

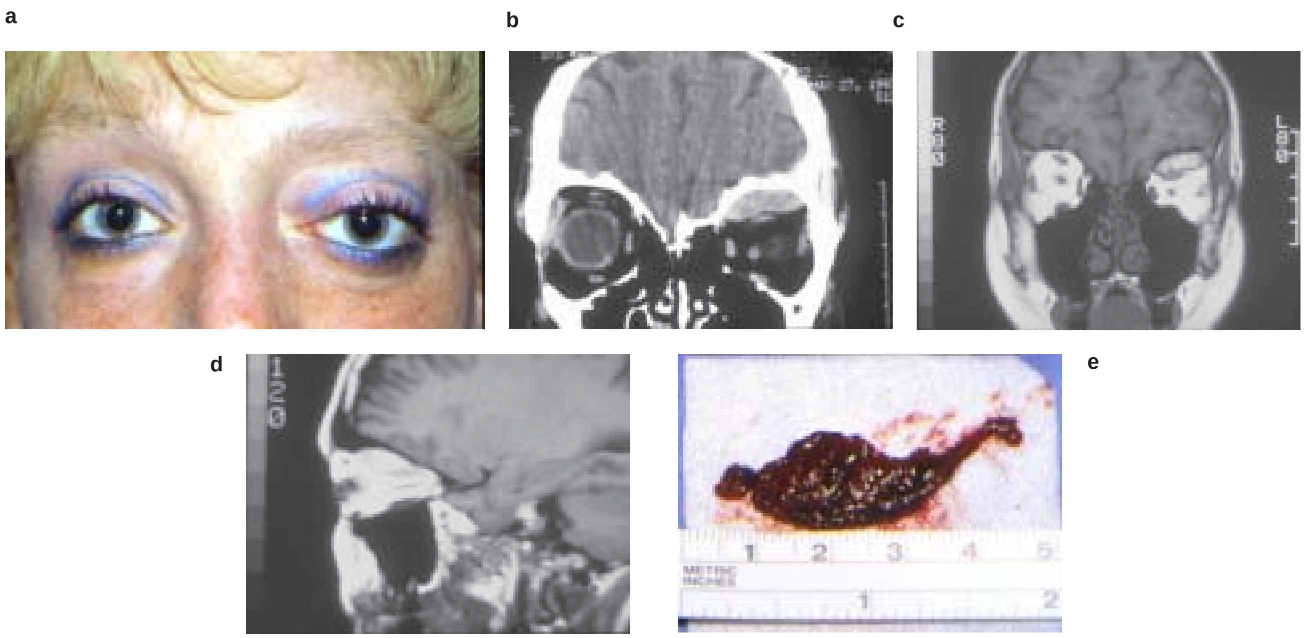

Fig. 20-22. (**a**) This 24-year-old woman complained of acute proptosis in the left eye and diplopia after vomiting. (**b**) Inferior globe displacement implies a superior orbital process, which is confirmed by a coronal computed tomography (CT) scan. Close inspection reveals a fat-density stripe separating the biconvex mass from the levator/superior rectus complex. This finding is virtually pathognomonic for a subperiosteal process. (**c**) A coronal T1 magnetic resonance imaging (MRI) scan verifies the subperiosteal location. A bright fat stripe is interposed between the superior muscle complex and the dark periosteal signal. The mass is noted to be of heterogeneously mixed intensity. (**d**) A sagittal T1 MRI scan demonstrates the subperiosteal nature of the mass. The periosteal attachments—at the internal orbital rim anteriorly and frontosphenoidal suture posteriorly—limit the mass size. This lenticular appearance is characteristic of subperiosteal hemorrhage (SPH). The patient was initially observed conservatively, as many SPHs will resolve spontaneously. However, the proptosis increased approximately 2 weeks after presentation, and repeat CT demonstrated near doubling of the mass size. (**e**) The patient underwent superior orbitotomy and evacuation of the mass, which was found to be an organized hematoma. Such a well-organized SPH can become chronic and precipitate rebleeding, bone destruction, and conversion to a cholesterol granuloma.

ment needed is not universally available. Consequently, most orbital MRI scans are performed with head coils only.

Although MRI has certainly earned its place alongside CT in peacetime orbital trauma management, one of the greatest current limitations to the use of MRI for orbital trauma in the combat theater is the physical size of the magnet and the strength of the magnetic field generated. Magnets of 0.5 tesla (T) may be sufficient for general-purpose imaging, but orbital imaging demands magnet strengths of 1.5 T. The stronger the field strength, the better the resolution and detail. Most magnets of this strength are located in fixed facilities; mobile scanners use weaker magnets. As the magnet field strength increases, so too does the requirement for cooling the magnet. Again, the physical demands of space and technology—the magnet cannot simply be turned off and on—may limit the ready mobility of the larger scanners that are needed for orbital application.

Many considerations compound the impracticality of urgent MRI, especially in a combat environment. Metal objects cannot be brought into the immediate area of the magnet; consequently, the scanner may have to be located away from the rest of the field hospital and away from other metal objects (eg, motor pool, weapons room). Combat and medical personnel must remove any metallic personal items, such as load-bearing-equipment, weapons, identification tags, and the like. If the patient is intubated and reliant on ventilator support, the ventilator must be nonmagnetic. Positioning an intubated patient inside the scanner poses its own difficulties. Additionally, all of the technical and personnel concerns mentioned for CT are applicable for MRI.

MRI has other drawbacks as well. In contrast to the X-ray images obtained by CT, the images created by MRI are derived from radio signals emitted by the relaxation of radio-excited atoms (usually hydrogen). The inherent weakness of these signals dictates that the receiving antennas be placed very close to the "transmitter" (ie, the patient). This requirement explains the claustrophobic environment of the MRI scanner and the surface coils. In such close confines, physical motion easily creates radio-signal artifact and degradation. To counter the claustrophobia, "open" scanners that do not completely enclose the patient have been developed. Unfortunately, the larger opening decreases the field strength of the magnet below that needed for acceptable orbital scans.

Perhaps the single most formidable impediment to MRI in the acute trauma setting is the time required for scans. CT scan times have been dramatically reduced (especially with the advent of helical scanners), but despite improvements in software, MRI techniques still dictate long periods of immobility inside a claustrophobic enclosure. Although imaging protocols have advanced materially beyond the traditional T1 and T2 images, the length of scan times still depends on excitation times, repetition times, echo times, and the number of images needed. This generally means that trauma patients are reasonable candidates for MRI only if they are—or after they have become—medically stable. When considered in the setting of trying to deliver trauma care urgently, MRI is still relegated to the role of an adjunct study. Improved software and scanning techniques may be able to decrease scan times, but until then, MRI will continue to have a limited role in acute trauma management.

Conventional (Plain Film) Radiography

Plain film radiography may be the Model T of imaging: it is not fancy or glamorous, it is cheap and somewhat clunky, but in a pinch, it is better than nothing. It shows bones adequately but is poor for visualizing soft tissues. It shows metallic FBs well and quickly, but most other types of FBs are missed or lost in overlying shadows. Given the increased reliance on CT and MRI, the fine art of reading plain films for orbital trauma is being lost. However, plain film radiography is still the cheapest of all the modalities, and the equipment is technologically unsophisticated, ubiquitous, has known performance characteristics, and is easy to set up, move, and maintain.

Occasionally, plain film radiography actually gives a better image of an FB than CT does (see Figure 20-19), especially in the presence of large metal FBs, which induce considerable metallic scatter on CT (Figures 20-23 through 20-25). In this setting, plain films are often a valuable adjunct to CT. Bone-free dental films or hypocycloidal tomograms can also be used when looking for small, metallic FBs. The biggest drawbacks of plain film are its very poor demonstration of tissue relationships and detail, the small number of images, and the inability

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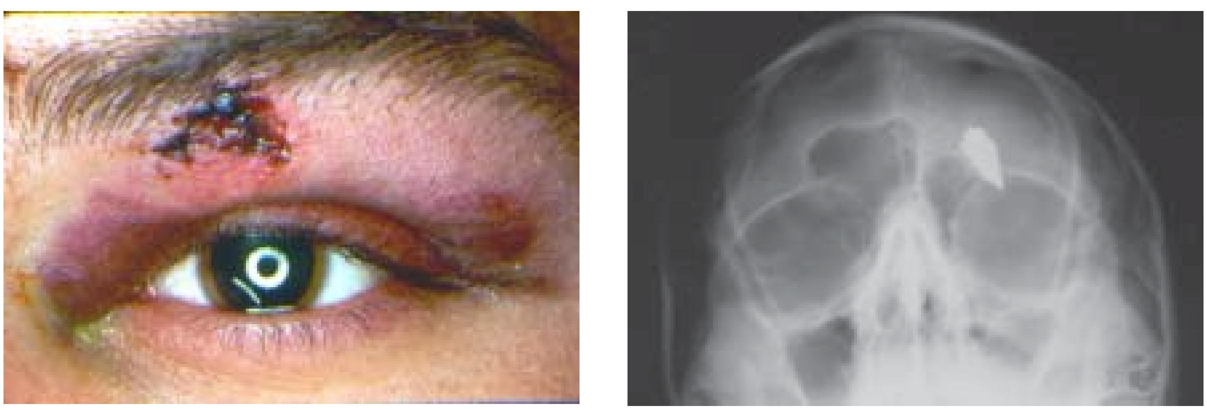

b

Fig. 20-23. Many orbital foreign bodies (FBs) are the result of easily identified events. (**a**) This 21-year-old soldier was standing next to a campfire during a field exercise. Other soldiers had thrown unexpended M-16 blank ammunition into the fire. After one explosion, the patient felt an object strike his left brow (see Figure 20-24). In addition to the obvious lid laceration, examination showed corneal contusion and edema but no other globe trauma. (**b**) A plain film radiograph (Waters's view) showed a large metal orbital FB in the anterior orbit. Plain film is useful for demonstrating the number, shape, and size of such foreign bodies but is insufficient for determining ocular penetration. Because of its anterior location, this FB was removed without complication. In general, however, metallic FBs—especially those in the deep orbit—should be left alone.

Fig. 20-24. Most metallic orbital foreign bodies (FBs) should be left alone. (**a**) This infantry soldier was standing around a campfire during a training exercise when another soldier threw an empty meal container into the fire. Unbeknownst to the patient, the container contained an unexpended M-16 blank round, which exploded and drove fragments into this patient's lower lid (see Figure 20-23). The eye was uninjured. (**b, c**) Plain film radiographs show a single FB just below the anterior orbit. (**d**) Because of its anterior and readily accessible location, this FB was removed without sequelae.

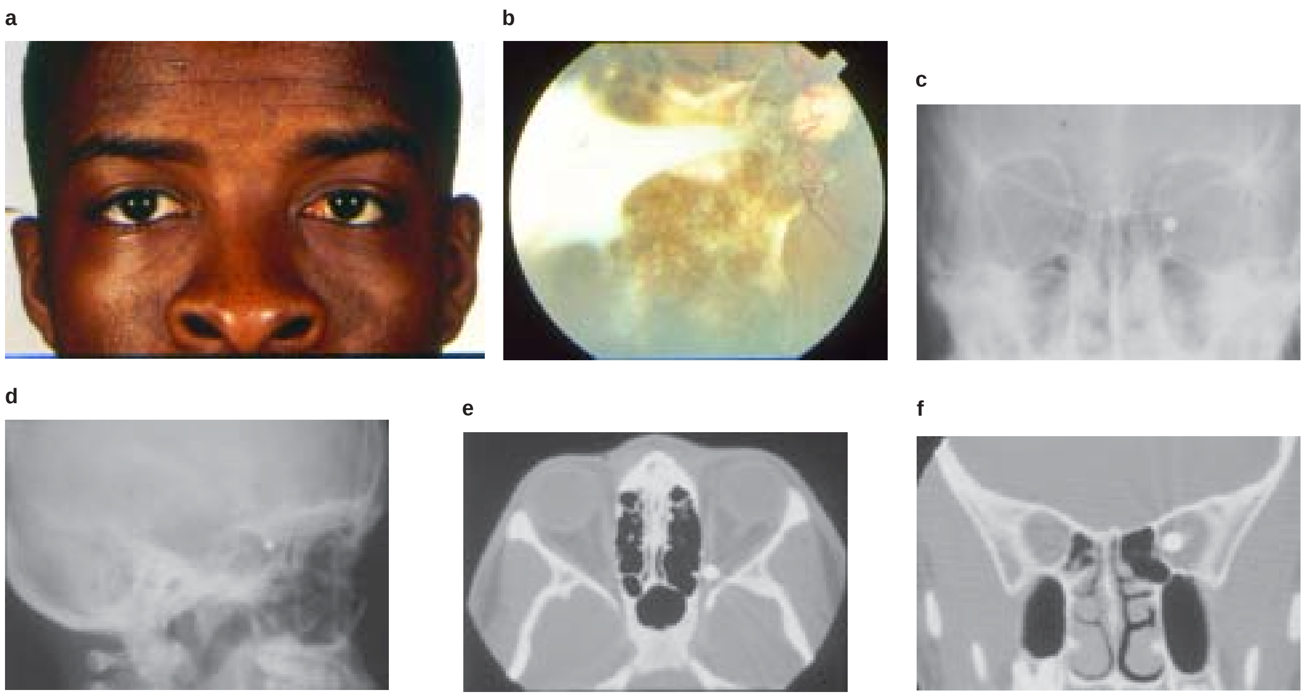

Fig. 20-25. Forgotten orbital foreign body (FB). Most injuries that produce orbital FBs could have been prevented had any kind of spectacle lens been worn. BB guns and air rifles, in particular, are common causes of orbital FBs. Ocular damage and loss of vision in these cases is usually severe but occasionally is surprisingly minimal. (**a**) This 23-year-old soldier presented with diplopia and 20/20 vision in both eyes but with (**b**) intraocular evidence of chronic retinitis sclopetaria and optic nerve pallor in the left eye, although he denied previous ocular trauma. (**c, d**) Plain film radiographs show a spherical, metallic FB—a BB—at the orbital apex. When shown the radiographs, the patient vaguely recalled having been struck by a BB as a child but denied receiving any medical treatment. Notice how well the plain film radiographs show the shape and character of the FB but how poorly they demonstrate tissue relationships. Before the advent of computed tomography (CT), localization of this FB would have been performed via Sweet or Comberg techniques. (**e, f**) The CT scans show the BB lodged at the orbital apex between the left medial rectus and optic nerve, in the region of the superior orbital fissure. In contrast to the plain film radiographs, the CTs show significant metal scatter artifact but excellent tissue relationships. FBs such as these are best managed by simple observation. This patient eventually developed progressive visual field loss and gaze-evoked amaurosis, prompting craniotomy and removal of the BB. Fortunately, he retained 20/20 vision and the visual field loss reversed. Photographs d and e: Reproduced from Otto DS, Nixon KL, Mazzoli RA, et al. Chorioretinitis sclopetaria from BB ex memoria. *Ophthalmic Surg Lasers*. 2001;32:152–155.

for computer manipulation. Therefore, its uses in the planning and management of significant orbital trauma are severely limited. Nonetheless, some cursory knowledge of plain film techniques (such as Comberg's or Sweet's localization of IOFBs) and of which plain film views give the most information (Waters's and Caldwell's views for the orbital floor, medial wall, and rims) can serve more than historical interest—especially during combat, when both the CT and MRI scanners are no longer functioning.[11]

ORBITAL HEMORRHAGE

As stated previously, hemorrhage almost constantly accompanies orbital trauma. Hemorrhage can occur in three locations: the intraconal space, the extraconal space, and the subperiosteal space (Figure 20-26). Retrobulbar hemorrhage can be a devastating occurrence, leading to blindness quickly after the trauma if not addressed promptly and completely. Consequently, vision *must* be checked as soon as possible after the injury. But because bleeding can continue or resume long after the initial injury, vision must be vigilantly followed, even after the initial evaluation. Although orbital fracture (especially floor or medial wall fracture) might be assumed to allow automatic decompression of orbital hemorrhage into the adjacent sinus, in fact, clotting of the blood within the sinus can effectively prevent drainage of recurrent bleeding and therefore lead to renewed visual danger.

Treatment requires prompt evacuation and decompression of the space in which the hemorrhage has occurred. Medical treatments, such as large doses of intravenous corticosteroids or osmotics (such as mannitol), can aid in the management of hemorrhage, but immediate surgical decompression of the orbit remains the mainstay of treatment. Immediate canthotomy and cantholysis can be sight-saving and can be performed without anesthesia if urgently needed. This releases the soft-tissue tether of the lids, which restricts passive anterior decompression and allows the globe to proptose as needed. On sufficient release, the surgeon feels the lower lid swing away freely, the orbit should become less tense, and blood should escape freely. Occasionally, however, no fluid escapes, even after the lid has been well detached. This can occur if the hemorrhage is sequestered in the intraconal space or if the hemorrhage is subperiosteal. If no blood escapes and the orbit remains tense, then the deep intraconal orbit should be opened so that the hemorrhagic pocket is decompressed. This procedure is best performed with blunt tenotomy scissors positioned in the inferolateral quadrant (between the lateral and the inferior rectus muscles) and directed posteriorly. With blunt dissection, the scissors are opened widely until the intermuscular septum is opened, orbital fat prolapses, and blood drains. If no relief of orbital tension ensues, the hemorrhage may be located in the subperiosteal space.

Subperiosteal hemorrhage (SPH) occurs most commonly on the orbital roof, but it can occur along any bony wall (see Figures 20-17 and 20-22). It can be caused by direct blunt trauma to the orbit (eg, fist strike) or other head traumas (eg, extension of subgaleal hematomas of the forehead and skull). SPH has also been reported as a consequence of metabolic diseases such as sickle cell anemia and

a

b

Fig. 20-26. Orbital hemorrhage can occur in (**a**) the intraconal space (central surgical space), the extraconal space (peripheral surgical space), or (**b**) the subperiosteal space. Hemorrhage into any orbital space can cause optic nerve compression and loss of vision. Patients with orbital hemorrhage must be evacuated promptly if vision is threatened. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

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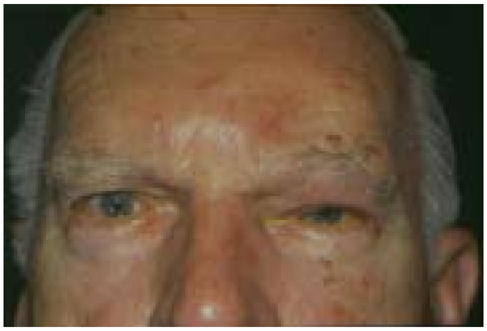

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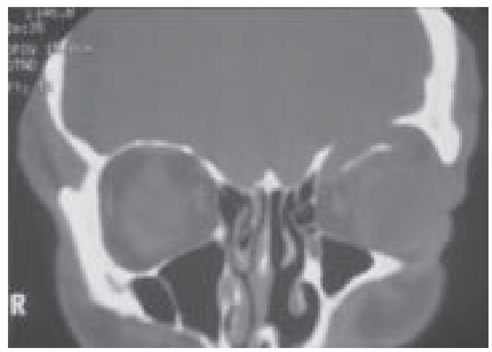


Fig. 20-27. Roof fractures with subperiosteal hemorrhage. Fractures of the orbital roof are rare in adults, and are indicative of high-energy injury. Surprisingly, not all patients are neurosurgically unstable, and many will present to the ophthalmologist for initial evaluation. (**a**) This 65-year-old man presented to the ophthalmology clinic complaining of diplopia after falling from a ladder. He was neurologically intact, despite the obvious depressed frontal fracture. The patient had restricted motility in up-gaze and dysesthesia over cranial nerve V_1. A computed tomography (CT) scan revealed a displaced roof and frontal sinus fracture. He was referred to a neurosurgeon for evaluation and treatment.

(**b**) This 45-year-old soldier struck his left brow and forehead in a motor vehicle accident. He never lost consciousness. On presentation, he complained of vertical diplopia, ptosis, and proptosis in the left eye. He was numb over left V_1 and had pulsatile proptosis. (**c**) A CT scan demonstrated an isolated fracture of the orbital roof with an associated subperiosteal hemorrhage. Such fractures are usually associated with significant intracranial or sinus injury and require neurosurgical and otorhinolaryngological evaluation.

scurvy; barotrauma from activities like strenuous Valsalva pressure (from weightlifting, childbirth, and vomiting), or rapid decompression (from underwater diving and explosive aeronautical decompression); and remote chest compression.[12–15] SPH is commonly associated with orbital fractures (Figure 20-27) and is best verified by CT and MRI. Classically, the mass assumes a lenticular shape, conforming to the bony orbital plate on one side and the displaced periosteum on the other. Its extension is limited by the periosteal attachments to the bony sutures. Orbital structures are displaced centrally. A clean fat stripe that separates the rectus muscles from the mass is often seen, distinguishing SPH from infectious subperiosteal abscess, in which the tissues adjacent to the muscles and mass are inflamed (see Figures 20-17 and 20-22). MRI characteristics will otherwise vary with the age of the hemorrhage and the strength of the magnet used. While some authors have recommended percutaneous needle aspiration of the hematoma, we caution against this practice—especially if the roof is involved—because of the inability to ensure against accidental perforation of the roof and subsequent neurological injury. Rather, we prefer orbitotomy and evacuation under direct visualization (after confirmation by CT).

Like other orbital hemorrhages, most subperiosteal hematomas will resolve on their own over time. However, like subdural hematomas of the central nervous system, they can become chronic processes, with episodic expansion from rebleeding. Chronic subperiosteal hematomas can transform into cholesterol granulomas (phantom tumors of the orbit), which are capable of large-scale bony destruction. Consequently, although acute hematomas can be managed conservatively, they must be (1) observed for expansion and (2) evacuated if (*a*) vision is threatened or (*b*) resolution does not occur within 3 to 6 weeks.[16]

ORBITAL FOREIGN BODIES

The diagnosis and treatment of IOFBs is covered in Chapter 14, Management of Penetrating Injuries with a Retained Intraocular Foreign Body. This section briefly covers the diagnosis and management of orbital FBs that do not involve the eye itself.

FBs are a frequent cause of orbital trauma. Small objects and missiles, which would be harmless were they to impact anywhere else on the body, are capable of creating devastating injury around the eye and orbit. Had the victims been wearing *any* kind of eye protection, the great majority of ocular and orbital FB injuries would have been prevented.[10,17,18] Slivers of glass, plastic, metal, or vegetable matter—whether by-products of motor vehicle or other accidents, on-the-job hazards, metal-on-metal impacts, or the result of intentional harm via combat or other assault—are all capable of inflicting serious orbital injury (see Figures 20-23, 20-24, and 20-25). Most orbital FBs themselves are inert—with the notable exception of vegetable FBs—and cause few long-term problems solely by their presence, but the damage they cause in the acute setting can be impressive and intimidating to the ophthalmologist who is charged with the initial evaluation and management of the injuries (Figure 20-28).

It is not difficult to maintain a high index of suspicion for an orbital FB when the history is highly suggestive. Well-recounted histories of metal-on-metal contact, the sensation that "something flew into my eye," "I got hit by a branch," "I stepped on a landmine," and so forth are not to be disbelieved, and they should quickly prompt the search for a retained orbital FB in addition to the treatment of any obvious injury (Figures 20-29 and 20-30). A much higher index of suspicion must be maintained when the history is vague or the casualty has combined traumas (eg, blunt trauma and multiple superficial lacerations from a motor vehicle accident,

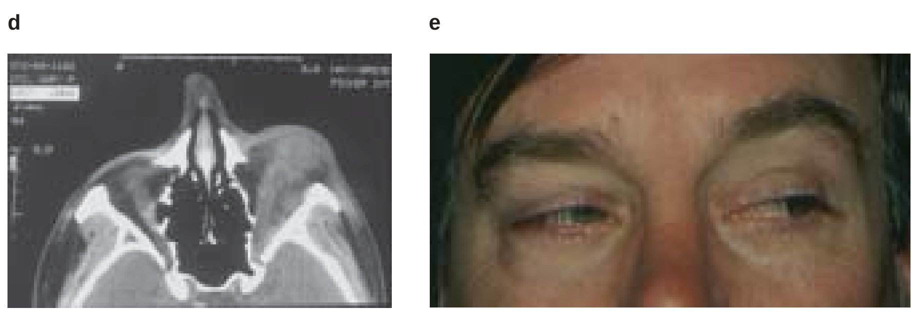
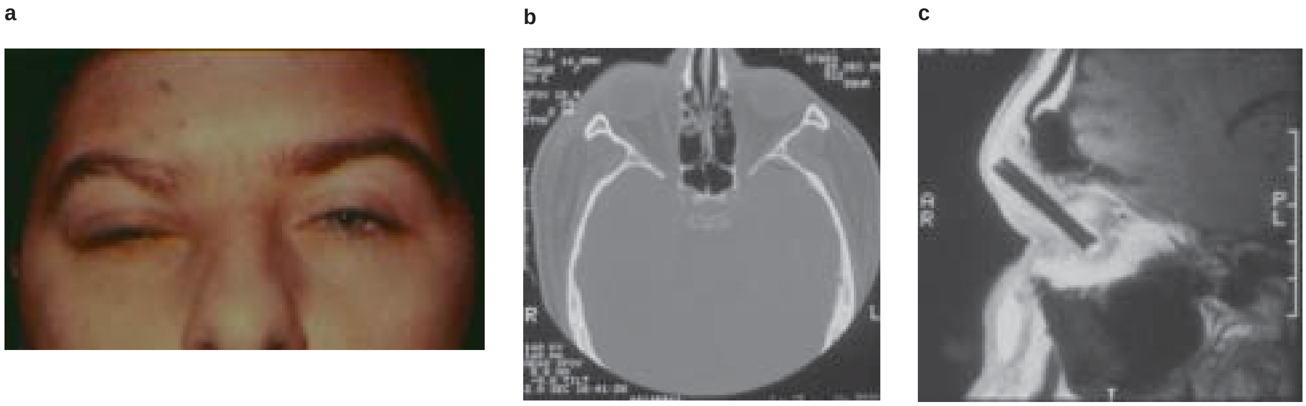


Fig. 20-28. Vegetable foreign body (FB) with orbital inflammation and traumatic optic neuropathy. Unlike most nonorganic FBs, vegetable orbital FBs may cause dramatic orbital inflammation and may require orbital exploration. (**a**) This 42-year-old Navy air traffic controller (shown in left gaze) had been clearing land when he removed his safety goggles to hand-cut a vine-maple tree branch. The branch recoiled, striking him in the left eye and orbit. He presented for care 1 week later with increasing orbital pain, decreased vision (20/50), a subtle afferent pupillary defect, a tense proptotic orbit, and decreased motility. (**b**) A suppurative pustule was explored, revealing (**c**) a small vegetable FB, which was later identified as moss. Serial computed tomography (CT) and magnetic resonance imaging (MRI) scans failed to demonstrate any other frank FBs. (**d**) This CT image shows dramatic inflammatory "dirty fat" and proptosis. The patient was treated with systemic megadose corticosteroids (see Figure 20-16) and antibiotics and underwent exploratory orbitotomy, which yielded more small moss fragments. After 1 year, motility and vision were essentially normal. (**e**) Although slight optic atrophy, mild color desaturation, and a subtle afferent pupillary defect persisted, he retained 20/25 vision.



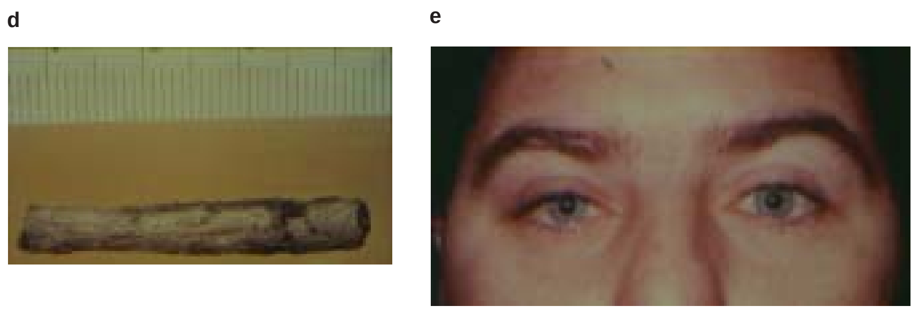


Fig. 20-29. (**a**) This patient was standing while driving his boat one evening in the Louisiana bayous when his head struck "something." The resulting lid laceration was repaired at a local hospital but "just wouldn't heal right." On initial presentation to an ophthalmologist, he had significant ptosis and restriction of elevation in the right eye but only mild inflammatory signs and erythema. An entrance wound is seen in the region of the right brow. (**b**) A noncontrast computed tomography (CT) scan shows a lucency along the medial wall just posterior to the nasolacrimal sac, with a zone of surrounding inflammation. (**c**) A magnetic resonance imaging (MRI) T1 image clearly demonstrates a large, retained, orbital foreign body (FB). (**d**) At orbitotomy, a large wooden FB was removed. Dry wood is often visible on T1 MRI scans, owing to the lack of hydrogen protons. (**e**) The same patient, 6 months postoperatively.

or massive blunt injury and hemorrhage/ecchymosis from unknown mechanism) (see Figures 20-4, 20-9). Even penetration by a known implement can create retained FBs, such as the broken-off tip of a knife (see Figure 20-11). A typically misleading history is that of "I was poked in the eye with this pencil (or stick, nail), but I pulled it right out, all in one piece. See? Here it is."

Because the orbit is so vascular, hemorrhage is always a sensitive indicator of deep orbital injury. Medial penetration is especially noted for brisk hemorrhage because of the location of the anterior and posterior ethmoidal arteries at the frontoethmoidal junction. Certainly, hemorrhagic chemosis should bring to mind not only the possibility of globe rupture but also of orbital hemorrhage secondary to one or more FBs. On the other hand, many small, sharp missiles (such as shards of metal, glass, and plastic) can penetrate deep into the orbit without notable outward signs. Many patients who are struck by FBs but have few outward signs acutely will forget the incident and may never seek medical care unless other symptoms arise later (see Figure 20-25). Vegetable FBs may incite inflammatory reactions long after the entrance wound has healed. In these cases, it is incumbent on the ophthalmologist to *always* suspect a retained FB.

Unfortunately, even if the suspicion for an FB is high, detecting it is still difficult. As sophisticated as imaging modalities are, many FBs still escape detection by even the most sensitive instruments. Detection is highly variable and depends on the density of the material, its CT number (Hounsfield units), the amount of air and water it contains, its ferromagnetic character, and its size. Some FBs with high CT numbers, such as some glass (eg, windshield glass), metal, and bone, may be readily visible on plain film radiographs, especially on hypocycloidal views. Other types of glass and most plastics—including that from which plastic landmines are made—may be invisible to plain film, CT, and MRI. Some FBs that would otherwise be visible can be camouflaged by accompanying hemorrhage and inflammation. In general, CT is the best first choice for imaging, with MRI a strong adjunct.

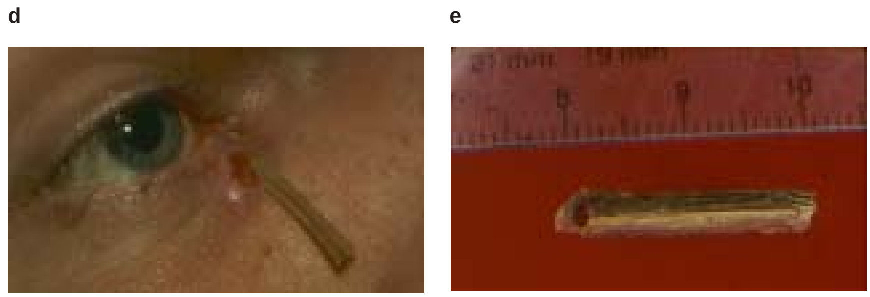


Fig. 20-30. Vegetable orbital foreign body (FB). Organic FBs can lead to significant orbital complications. (**a**) This 19-year-old Army Ranger student was on night patrol in Florida when he tripped and fell, feeling something strike him below the right eye. He experienced immediate pain and total loss of vision. On return to his home station after a week at a local hospital, vision was no light perception with an amaurotic pupil and total paralysis of motility. Although a healing laceration was noted in the nasojugal area, surprisingly few signs of orbital inflammation were found. Serial, fine-cut computed tomography (CT) scans searching for a retained FB were negative. (This injury predated the wide availability of magnetic resonance imaging.) (**b, c**) Three weeks later, the lid laceration dehisced and several small wooden splinters extruded spontaneously. (**d, e**) Further exploration of the wound produced the wooden FB seen in these photographs. The wound healed permanently, but the patient was left with a blind, immobile eye.

As stated earlier, MRI cannot be the first mode of imaging without first ruling out a metallic FB, and plain film studies are of little help for all but metallic FBs. Ultrasound is of proven value in the diagnosis of intraocular FBs but is of little benefit in orbital diagnosis, having limited penetration beyond the anterior third of the orbit.[7,8,10,18,19]

Imaging of FBs is subject to several important limitations. Plastic and vegetable FBs are notoriously difficult to detect either on CT or MRI. In particular, dry wood—because it lacks the water content of fresh or green wood—can initially manifest as an air density on CT. However, the density is not as dark as the free air seen in orbital emphysema (or compared with the sinus air); rather, it is typically a "partial air density"—a mid-density lucency between the densities of free air and water (see Figure 20-29). Wood and other vegetable matter is often surrounded by focal inflammation, and many scans have incorrectly been interpreted as "intraorbital air with surrounding inflammation," even though *air within the orbit* NEVER *causes "surrounding inflammation."* Another common indicator of vegetable matter is a finding of a linear intraorbital density on CT; however, *there are no linear structures in the orbit.* The ophthalmologist must personally review these films.

Modern digital CT displays that do not rely on conventional film processing allow active computer manipulation of the window/contrast levels at the desktop, but this must be done with caution. Such manipulation may allow the FB to be seen more clearly when the levels are changed, but when actively "playing with the contrast" it is possible to overcall or undercall any abnormality: nonexistent lesions can be "created," and existing lesions can be erased. Because the low water content of dry wood means few free protons for radioexcitation, on MRI, dry wood can often easily be identified as a dark mass against the bright fat of T1 images (see Figure 20-29).[9,10] Similar properties can help identify some plastics as well, but every material has its own, unique MRI characteristics. Fresh vegetable FBs, such as green wood, are much more difficult to detect, as the higher water content allows the material to blend in much more readily into the water densities of fat and orbital hemorrhage on CT images. Likewise, the high proton content of fresh wood will diminish the contrast on T1 MR images. With time, dry wood may hydrate, and the CT and MR characteristics will become more like wet wood. Such chronicity is usually accompanied by chronic orbital findings clinically, such as chronic redness or pain, or chronic drainage and fistula formation. Some chronic vegetable FBs will extrude spontaneously (see Figure 20-30).[8–10,18,19]

ORBITAL FRACTURES

Le Fort Midfacial Fractures

The well-known traditional classification scheme for midfacial fractures was developed by the 19th-century French surgeon and gynecologist Léon C. Le Fort, after he observed the patterns of injuries created by experimentally battering the heads of corpses. Since Le Fort's time, with the development of the motorcycle and other high-speed conveyances, and with the increased availability of handguns and semiautomatic, military-style weapons, the energies associated with facial traumas have increased dramatically. Because of the complexity of modern fractures and the recent progress in diagnostic and management techniques, Le Fort's traditional classification is neither very useful nor universally applicable in acute orbital trauma management. Frankly, most modern facial fractures do not fall neatly into one of Le Fort's three categories. Nevertheless, it is worthwhile for ophthalmologists to be familiar with the classification, as it conveys a common and easily understood description about the complexity and areas involved in a fracture, even if the fracture does not fit a "pure" Le Fort category. Currently, the classification scheme is more useful in the field of reconstructive craniofacial and maxillofacial surgery, as it accurately describes the various *planned* osteotomies performed in facial reconfiguration.

Common to all three Le Fort classes—and integral to the diagnosis of a true Le Fort fracture—is involvement of the pterygoid plates: all Le Fort fractures extend internally to involve the pterygoids. If the pterygoids are intact, then the fracture is *not* a true Le Fort fracture but can be considered an incomplete Le Fort. Extensive trauma can involve multiple Le Fort levels, usually asymmetrically.[2,4]

For additional information on the categories of Le Fort fractures, see Chapter 18, Injuries to the Face and Neck, in *Anesthesia and Perioperative Care of the Combat Casualty,* another volume in the Textbooks of Military Medicine series.[20]

Le Fort I: Low Transverse Maxillary Fractures

A horizontal fracture across the maxillary ridge and alveolus at the base of the nasal (pyriform) aperture is a classic Le Fort I fracture. This creates a free-floating maxilla. These fractures are the only ones that do not involve the orbit. Le Fort I fractures are created intentionally during orthognathic maxillary surgery (see Figure 20-16).

Le Fort II: Pyramidal Fractures

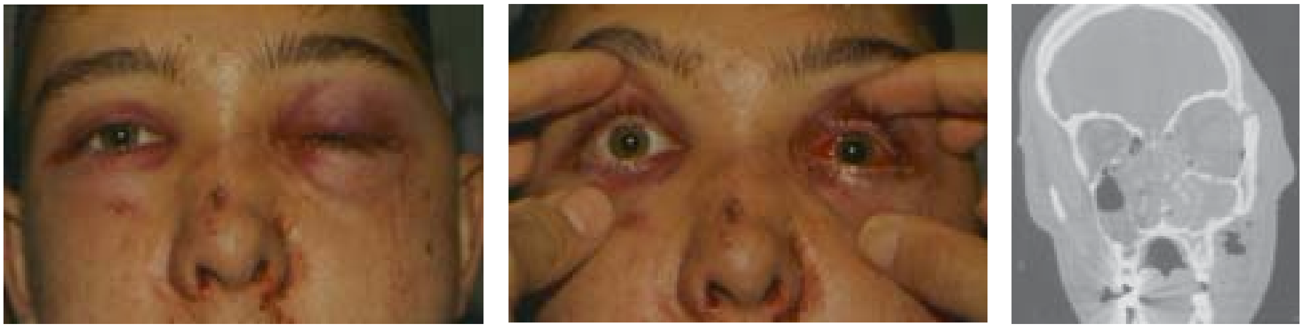
Fractures at the Le Fort II level (Figure 20-31) roughly parallel the pyriform aperture. Bilateral fractures extend across the bridge of the nose to involve the nasal bones. They also involve the medial orbital floor and rim. Consequently, the nasolacrimal duct is usually damaged, leading to traumatic dacryostenosis (see Figure 20-16).

Le Fort III: Craniofacial Dysjunction

Le Fort III fractures—total separation of the facial bones from the cranial base—are the result of significant trauma energies. Facial disarticulation occurs at the zygomatic arch, the lateral rim and wall, the posterior orbit and roof, the upper rim, and the root of the nose. Given the extent of orbital involvement, ocular symptoms are common. Because of the proximity of the fracture to the optic canal, the devastating complication of optic canal and nerve injury is not unusual. Nasolacrimal damage is also common. Such dysjunction is necessarily created intentionally during reconstructive craniofacial surgery for dysostotic syndromes, such as Apert's and Crouzon's syndromes (see Figures 20-16 and 20-31).

Orbital Floor

The isolated floor fracture (blowout) is the most common fracture that presents primarily to the ophthalmologist. It occurs after low- or moderate-energy impact, such as fist strikes, sports impacts, and injury with small missiles such as balls (Figure 20-32).[1,3,4] The most common location of the fracture is the posteromedial floor, because (*a*) the bone in this area is the thinnest of the floor and (*b*) it lacks the medial wall's corrugated reinforcement of the ethmoid air cells (see Figure 20-15). Various theories have been forwarded to explain the mechanics of a b c



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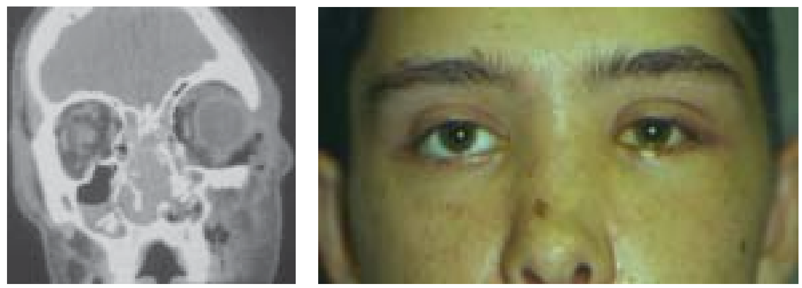


Fig. 20-31. Naso-orbital-ethmoid (NOE) fractures are the result of high-energy midfacial trauma. (**a**) This soldier was involved in a motor vehicle accident in which his face struck the steering wheel. Despite panfacial fractures, his eyes were minimally affected. Vision and motility were normal. (**b**) Although the patient suffered a marked nasal fracture with saddle deformity, he did not have traumatic telecanthus. (**c**) A computed tomography (CT) scan showed fractures of the left lateral wall, both floors, and the left zygomaticomaxillary complex, along with marked comminution of the midline buttresses (vomer, septum, ethmoid). (**d**) NOE fractures almost invariably affect the nasolacrimal system at the Le Fort II level. They are very likely to cause traumatic optic neuropathy. (**e**) The same patient 6 weeks after open reduction and internal fixation of the fractures.

a b c

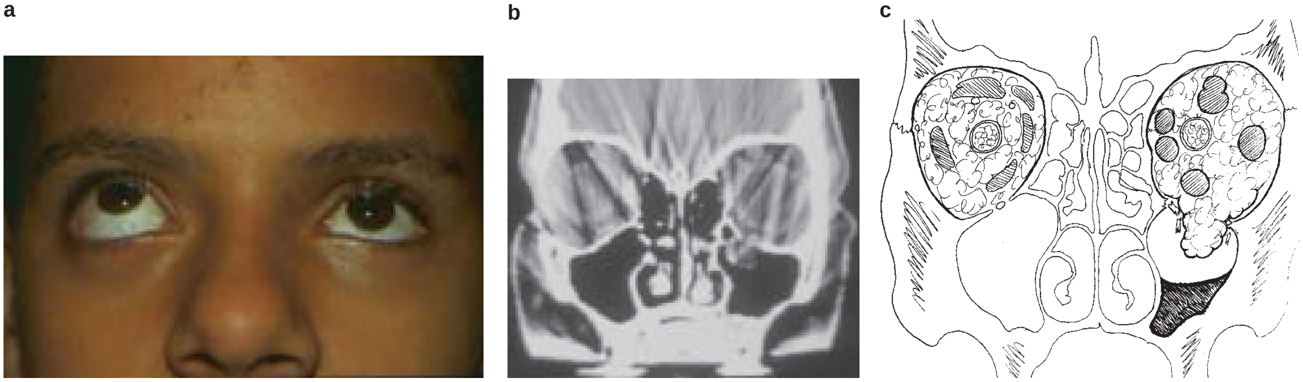


Fig. 20-32. This 13-year-old boy struck his left cheek and orbit in a snowboarding accident. He complained of vertical diplopia and numbness over the left cheek but denied dental dysesthesia; his vision was unaffected. (**a**) Examination revealed a restrictive deficit in up-gaze. (**b**) A coronal computed tomography (CT) scan demonstrates a small medial floor fracture with herniation of orbital fat. The left inferior rectus muscle is seen within the fracture. Notice the rounding of the muscle, indicating loss of the suspensory ligaments and rupture of the periorbita. (**c**) A schematic diagram illustrates the CT findings. Small fractures such as these are often the most symptomatic. Given the mechanism of injury, it is important to ensure that the patient did not suffer a concomitant zygomaticomaxillary complex fracture. This patient required open reduction and internal fixation to free the tethered tissues. Small fractures such as these can be repaired with absorbable implants (eg, Gelfilm and Vicryl mesh). Drawing prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

blowout fractures. Most accepted are the theories of increased orbital hydrostatic pressure leading to primary bony failure, and compression of the rim with transmission of buckling forces across the floor with subsequent failure. Scientific testing has validated both of these theories.[3,21] Many objects—such as baseballs, tennis balls, and squash balls—can deform sufficiently so as to actually protrude into the orbit well beyond the orbital rim. Not only can the increased hydrostatic tissue pressure thus exerted fracture the bony walls, it also can obviously cause significant concussive ocular trauma (eg, angle recession, hyphema, retinal dialysis, commotio retinae, vitreous hemorrhage, etc). Therefore, a complete ophthalmological examination is essential.

Symptoms and Signs

Vertical Diplopia. Vertical diplopia, with limitation of up- or down-gaze, is the most common presenting complaint and stems primarily from entrapment of orbital tissues in the fracture plate (see Figures 20-15 and 20-32). Although the inferior rectus and oblique muscles may become frankly entrapped within the fracture, the more common cause of restriction is entrapment of the fibrovascular septa of the orbital tissues (the ligaments of Koornneef), while the muscles themselves remain free (Figures 20-33 through 20-37).

Paradoxically—but not surprisingly—the larger and more comminuted the fracture, the less likely entrapment and diplopia are to occur. Smaller fractures tend to create trapdoor defects (opening long enough to allow tissue prolapse and then closing shut, thereby entrapping the tissue and creating restrictive diplopia), but more-comminuted and larger fractures, such as extensive floor fractures or zygomaticomaxillary complex (ZMC) fractures, are less able to create the trapdoor effect. The small, comminuted, bony pieces have neither rigidity nor elasticity and cannot entrap anything. *In these situations ocular motility is often normal, without diplopia* (see Figure 20-20). Examiners must be aware of this

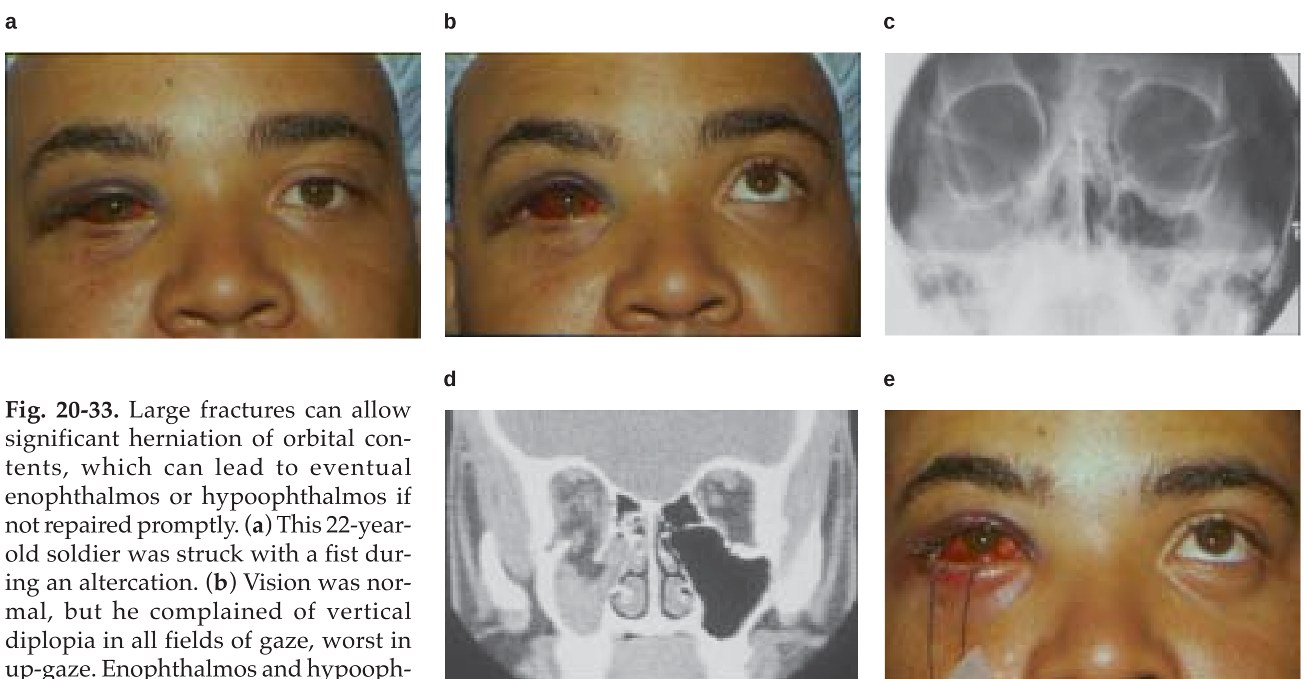
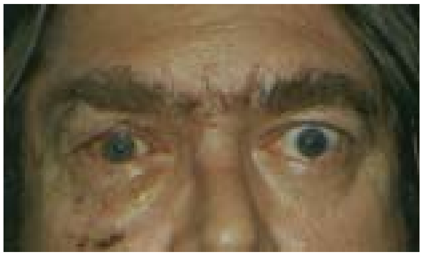


Fig. 20-33. Large fractures can allow significant herniation of orbital contents, which can lead to eventual enophthalmos or hypoophthalmos if not repaired promptly. (**a**) This 22-year-old soldier was struck with a fist during an altercation. (**b**) Vision was normal, but he complained of vertical diplopia in all fields of gaze, worst in up-gaze. Enophthalmos and hypoophthalmos are already evident here, 1 week after the injury. (**c**) This plain film radiograph (Waters's view) shows complete opacification of the right maxillary sinus and an intact orbital rim. (**d**) A coronal computed tomography (CT) scan demonstrates the large floor fracture, with herniation of orbital fat into the maxillary sinus (seen here as a negative shadow against the sinus hemorrhage), as well as frank herniation of the right inferior rectus muscle. The fracture was seen in 10 of the 12 coronal images in which the floor was identifiable. Unless repaired, such large fractures usually result in hypoglobus or enophthalmos. Because of orbital hemorrhage and proptosis, surgery was delayed for 1 week to allow swelling to subside. (**e**) The same patient, 1 day postoperatively after open reduction and internal fixation with placement of a rigid floor plate. Dramatic improvement of upward motility is evident. A Frost lid-traction suture was placed for 5 days.

a



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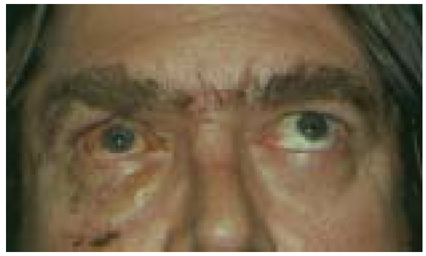

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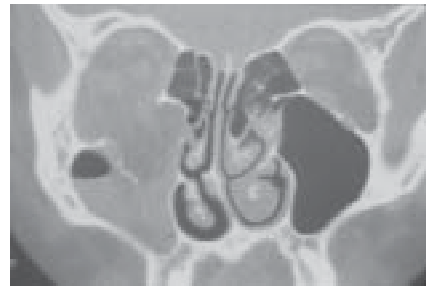

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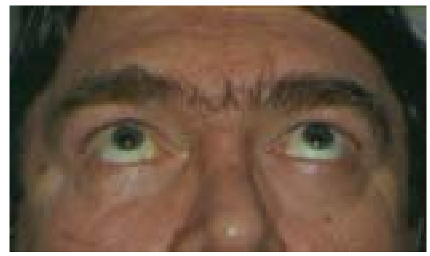

Fig. 20-34. This man tripped and fell in his house, striking his right cheek on a pot-bellied stove. His complaints included diplopia in all fields but worst in up-gaze, and numbness across cranial nerve V_2 and the upper bank of teeth. (**a**) Examination of the patient shows significant right enophthalmos and (**b**) limitation of motility. The orbital rim and the zygomaticomaxillary complex buttress were not tender. (**c**) This computed tomography (CT) scan shows a large fracture of the orbital floor, with herniation of both the orbital fat and the inferior rectus muscle into the maxillary sinus. Notice the rounding of the muscle shadow. The orbital volume is dramatically enlarged. The bony fracture plate has broken off at the orbital strut, the junction of the floor, and the ethmoid sinus. Reconstructing such a cavernous defect requires a rigid plate that can be cantilevered over the sinus and may require fixation to the orbital rim. Current choices for such plates include calvarial bone, porous polyethylene, silicone sheeting, and (**d**) titanium mesh of various designs. It is very difficult to reduce the most posterior aspect of these injuries because of possible surgical damage to the optic nerve. (**e**) This photograph shows the patient 1 year postoperatively, with resolution of all diplopia. He has mild, residual enophthalmos and sensory dysesthesia over V_2, both of which are inconsequential to the patient.

a

b

Fig. 20-35. Diplopia and dysmotility are not necessarily pathognomonic for orbital fracture. (**a**) This 21-year-old man suffered blunt trauma to the right orbit. He presented with diplopia, up-gaze limitation, and mildly decreased sensation over cranial nerve V_2. (**b**) Despite this cluster of symptoms, no frank fracture was identified on computed tomography (CT) scan. However, enlargement of the right inferior rectus muscle is seen, suggesting muscular contusion and intramuscular hemorrhage. Forced duction testing demonstrated free passive motility without restrictions. The patient was observed conservatively and all symptoms promptly resolved.

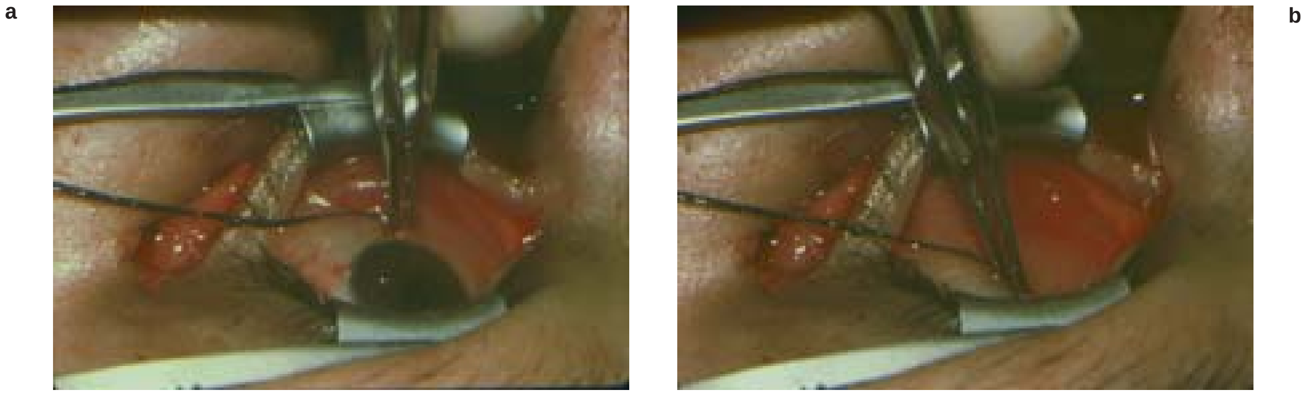

Fig. 20-36. Forced duction and force generation testing. Forced duction testing is extremely useful in determining whether dysmotility is restrictive or paralytic, and it can be used to test any muscle. Forced duction testing can be performed easily in the examination chair with topical anesthesia and should be the first step at surgery. The insertion of the muscle being tested is grasped firmly, and the eye is pushed into the desired field of gaze. These photographs illustrate (**a**) restricted duction of the inferior rectus before release of entrapped orbital tissues and (**b**) normal range of motion after release. In testing force generation, the muscle insertion is grasped and the patient is asked to look into the muscle's field of action. A paretic muscle will feel weak when compared with the fellow eye. Surgeons should avoid speaking in terms of "positive" and "negative" forced ductions and force generation, as these terms are imprecise and lead to confusion. Rather, the terms "restricted" and "unrestricted" should be used.

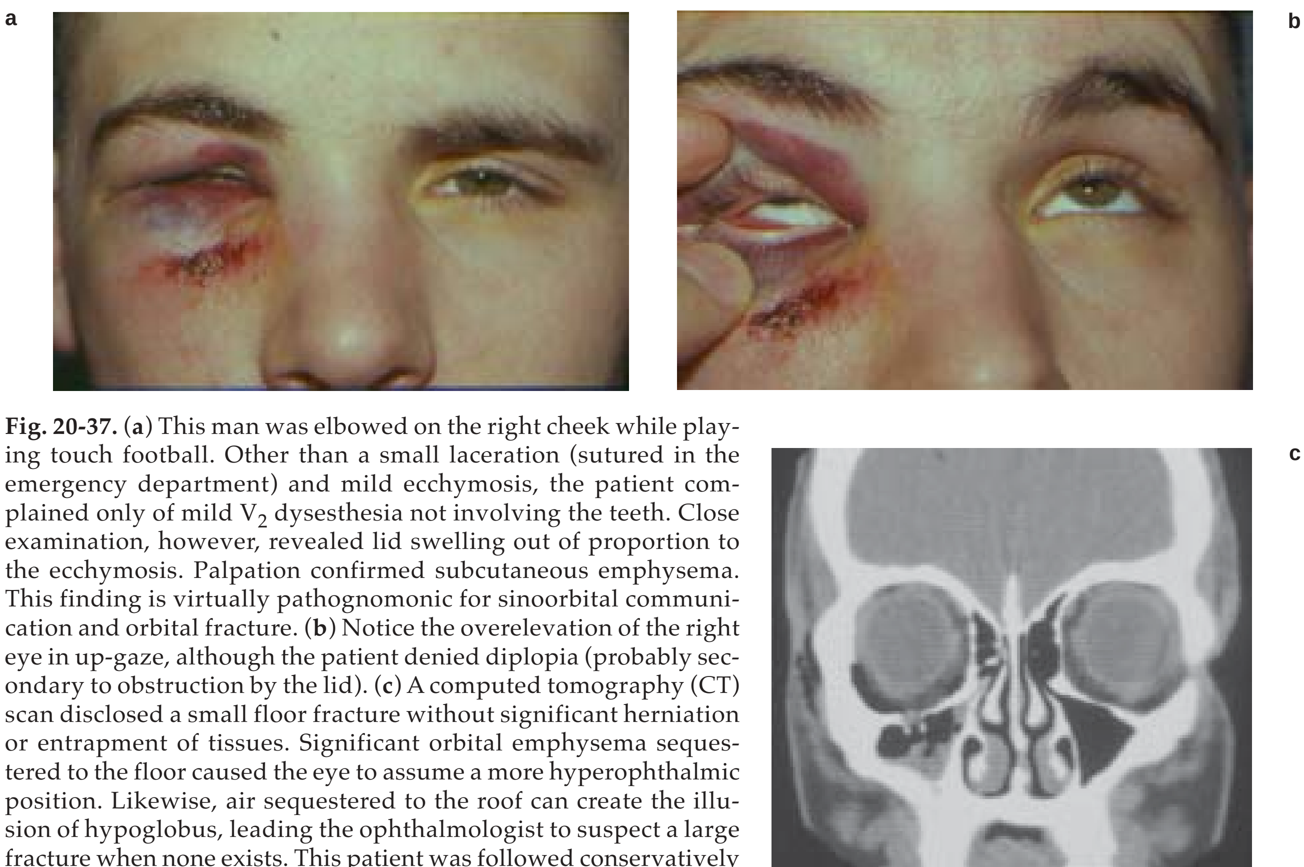

Fig. 20-37. (**a**) This man was elbowed on the right cheek while playing touch football. Other than a small laceration (sutured in the emergency department) and mild ecchymosis, the patient complained only of mild V_2 dysesthesia not involving the teeth. Close examination, however, revealed lid swelling out of proportion to the ecchymosis. Palpation confirmed subcutaneous emphysema. This finding is virtually pathognomonic for sinoorbital communication and orbital fracture. (**b**) Notice the overelevation of the right eye in up-gaze, although the patient denied diplopia (probably secondary to obstruction by the lid). (**c**) A computed tomography (CT) scan disclosed a small floor fracture without significant herniation or entrapment of tissues. Significant orbital emphysema sequestered to the floor caused the eye to assume a more hyperophthalmic position. Likewise, air sequestered to the roof can create the illusion of hypoglobus, leading the ophthalmologist to suspect a large fracture when none exists. This patient was followed conservatively and became asymptomatic without surgery as the emphysema resolved over the next few days.

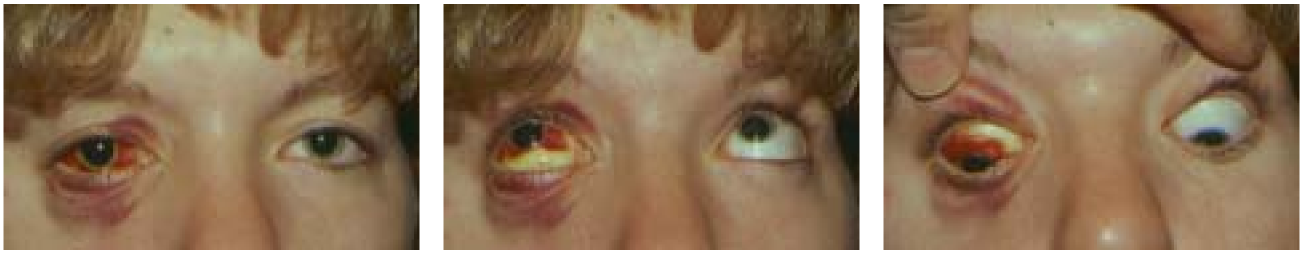

Fig. 20-38. Large fractures are often visually asymptomatic, and the ophthalmologist must have a high index of suspicion to pursue the evaluation. Associated symptoms and findings often herald a larger fracture. (**a**) This 24-year-old woman was accidentally struck on the right cheek with a softball bat. She denied diplopia, but persistent pain led her to seek care at the eye clinic. (**b, c**) She had full ocular motility but when questioned admitted dysesthesia of the cheek, nose, and teeth, as well as trismus (which was improving) and malocclusion. Palpation revealed point tenderness over the zygomaticofrontal suture and a large step-off deformity at the zygomaticomaxillary suture. (**d**) The patient had significant malar flattening but no appreciable canthal dystopia. (**e**) A computed tomography (CT) scan showed a large but noncomminuted zygomaticomaxillary complex fracture. Notice the flatness of the normal left zygomatic arch. This is the position to which a fractured arch must be reduced to maintain proper facial proportion.

possibility so as not to be fooled into thinking that there is no fracture (Figure 20-38). If doubt exists, a CT scan should be ordered.

Diplopia may also occur because of contusion of the inferior muscles. This temporary apraxia often clears over the span of 7 to 10 days (see Figure 20-35). Forced duction and force generation testing can usually distinguish paretic from restrictive diplopia (see Figure 20-36). Sometimes, a course of oral corticosteroids (40–60 mg prednisone daily for 5–7 d) can speed the resolution of swelling and make it easier to conclude whether diplopia is restrictive, mechanical, or paretic, but these medications should only be used selectively and not routinely.

Extraocular Muscle Rounding. CT can often reveal that the involved muscle has assumed a more rounded appearance than its typical flat or elliptical shape (see Figure 20-35). This rounding is probably due either to disruption of the normal fibrovascular septa holding the muscle in its elongated form, or to hemorrhage and fibrosis within the muscle sheath. In cases where the diagnosis of a fracture is equivocal, extraocular muscle rounding can help establish the presence of a fracture.

Hypesthesia of Infraorbital Cranial Nerve V_2. Hypesthesia of cranial nerve V_2 occurs from contusion or transection of the infraorbital neurovascular bundle, which traverses the orbital floor before it exits from the infraorbital foramen (see Figures 20-33 and 20-34). More posteriorly, involvement of the superior alveolar branch may cause numbness across the ipsilateral upper bank of teeth. Fractures of the inferior rim often extend along the anterior maxillary face to disrupt the nerve as it exits from the infraorbital foramen. The numbness across V_2 may become denser after surgery but generally resolves, although resolution may take months and may be incomplete.

Orbital Emphysema. Communication with the underlying maxillary sinus allows air and bacteria from the sinus to enter the orbit. Many patients will relate an accurate history of sneezing or nose blowing, followed immediately by the eyelids abruptly swelling. The emphysema is most readily diagnosed as dramatic, visible, swelling of the lids out of proportion to the limited ecchymosis present. Orbital emphysema can be felt with gentle palpation over the lids, but this is a subtle feeling at best. The sensation is not as dramatic as that felt along the chest and neck in the presence of pneumothorax but is rather likened to that of gently crushing crisped rice cereal through a glove. Emphysema may be significant enough to cause optic nerve compression and loss of vision. In such cases of acute pneumo-orbita, urgent orbital paracentesis can be sight-saving.

Occasionally, sufficient orbital emphysema will be sequestered to a wall so as to push the globe away, creating symptomatic hyper- or hypo-ophthalmia; the symptoms will resolve when the orbital air has resorbed (see Figure 20-37). Emphysema can also be so significant as to cause subcutaneous emphysema of the head and neck and has even been known to cause pneumomediastinum.[22] Patients should be told *not* to blow the nose. The role of prophylactic antibiotics in these cases is controversial but administering them is, nonetheless, common practice. If prescribed, a general, broad-spectrum antibiotic should be chosen (eg, amoxicillin/clavulanic acid or cephalexin) to prevent orbital cellulitis from common nasal pathogens, such as *Staphylococcus* species, *Streptococcus* species, and *Haemophilus influenza.*

Hypo-ophthalmos and Enophthalmos. Increased orbital volume associated with large fractures may result in axial retraction of the globe (enophthalmos) or downward vertical displacement (hypo-ophthalmos, hypoglobus). Loss of floor support lets the orbital contents and globe sink into the maxillary sinus (see Figures 20-16, 20-19, 20-33, and 20-34). The resulting deformity requires anatomical reconstitution of the floor, with restoration of the proper bony orbital volume and configuration.

Enophthalmos is primarily a consequence of increased orbital volume, *not*, as some believe, a result of orbital tissue atrophy. Tissue atrophy and resorption undoubtedly occur, but these are secondary factors.[23,24] Consequently, accurate restoration of the bony orbital volume is critical to the prevention of this complication. Two millimeters of enophthalmos is generally regarded as within normal variation and not cosmetically noticeable in most people. But, because of the tissue edema, hemorrhage, and swelling associated with acute orbital trauma, patients may not initially manifest either enophthalmos or hypoglobus. However, in the presence of a large fracture (> 50%), the risk of developing either hypo-ophthalmos or enophthalmos is high.

Late correction is difficult due to the development of significant fibrosis and Volkmann's contractures within the orbital tissues, which oppose mobilization of bony structures (see Figures 20-14, 20-19).[25] Although the primary abnormality, as stated above, is enlarged (ie, inadequately reduced) orbital volume, contracted orbital tissues make late attempts at reducing orbital volume difficult. If significant tissue swelling confounds the acute assessment of enophthalmos or hypo-ophthalmos, a short course of oral corticosteroids can speed resolution of the swelling and therefore help in making the diagnosis. As in the case of extraocular muscle paresis discussed above, steroids should only be used sparingly and should not be a routine first-line management tool.

Many patients will be asymptomatic to axial enophthalmos or purely vertical hypo-ophthalmos, because the visual axes are still essentially parallel (see Figures 20-14 and 20-16). If, however, a rotational component displaces the visual axis, then diplopia will most likely become intolerable (Figure 20-39).[23]

Oculocardiac Reflex and the White-Eyed Blowout. Attempting to move an eye that is entrapped by a blowout fracture may cause increased vagal tone, thereby stimulating the oculocardiac reflex, similar to that seen during strabismus surgery. This can manifest as nausea, vomiting, or severe bradycardia or heart block to the point of syncope on attempted ocular movement. Such symptoms must be specifically queried and noted; urgent surgical intervention is warranted in this potentially fatal condition. This may be more common in young patients (< 18 y), in whom the orbital bones are more flexible and consequently more likely to demonstrate greenstick fractures and trapdoor fractures of the floor. In these cases, the bony plate does not fracture completely but opens long enough to allow orbital tissues to herniate. The fracture plate then closes, entrapping the tissues. Very often, there is a corresponding paucity of external physical findings, with the exception of diplopia. In such cases (known as "white-eyed blowout"), clinical symptoms are often out of proportion to external findings. Unfortunately, long-term tissue ischemia can result from delayed release of the entrapped tissue, resulting in less-than-optimal surgical success, chronic diplopia, enophthalmos, and fibrosis—and disappointment for both patient and surgeon. Ophthalmologists should have a high index of suspicion for such injuries, especially if the mechanisms and energies involved in the injuries are sufficient to cause a fracture. Early surgery (within 24 h) is warranted for both conditions.[26–28]

Pupillary Abnormalities. Pupillary abnormalities result from damage to the pupillary fibers traveling with the inferior oblique muscle. The damage can occur as a consequence of either the primary injury or the corrective surgery.

Indications for Surgery

Surgery is indicated to correct or prevent functional visual loss or significant cosmetic deformity.

Fig. 20-39. Fractures involving the orbital roof are typically the result of significant head injury. This 24-year-old Coast Guard sailor was walking on his ship’s outside deck when an inside boiler exploded. He was struck by a portion of a ship’s door that was blown off by the force of the explosion. The patient suffered a massive craniofacial injury, which required emergent neurosurgery to save his life. The cranial defects were repaired concomitantly, using titanium mesh and plates to secure calvarial bone grafts that were used to reconstruct the orbit. (**a**) Two years later, the patient is left with marked orbital deformity and cicatricial contraction of the overlying skin. (**b**) He also has intractable diplopia in all fields of gaze, and (**c**) such significant enophthalmos that his left lids do not appose the globe. Fortunately, the patient’s naturally deep-set eyes help disguise the enophthalmos. (**d**) A postreconstruction computed tomography (CT) scan shows the extent of the injury, with marked orbital enlargement, (**e**) intraorbital bone grafts, cranialization of the frontal sinus, and (**f**) intracranial titanium mesh. (**g**) This CT image shows the posterior extent of the fracture, involving the orbital apex and middle cranial fossa. Despite prior reconstruction, the posterior 50% of the orbital roof was absent. With such a defect, ophthalmologists would expect the orbit to be pulsatile. Although acute roof fractures typically cause *ex*ophthalmos, *en*ophthalmos can result from such extensive injuries.

Specific indications include the following:

- restrictive diplopia in a functional field of gaze (either primary gaze or within 30° of primary in either up-gaze or down-gaze);
- CT evidence of entrapped muscle or orbital tissue;
- enophthalmos greater than 2 mm (asymmetry < 2 mm is normal and is not cosmetically noticeable);
- oculocardiac reflex (nausea, vomiting, bradycardia, syncope with attempted gaze) should prompt immediate surgery if a young patient (< 18 y) has a white-eyed blowout;
- hypo-ophthalmos; and

- large floor fracture (> 50%), based on CT estimate of the fracture size.

Failure to repair large fractures can lead to significant hypo-ophthalmia and enophthalmos. Late repair of these cosmetic deformities is difficult, and it is as frustrating for surgeons as it is for patients and their families. Fracture size can be estimated by simply counting the number of coronal images in which the fracture is seen versus the number in which the floor is seen.

Medial Wall

Medial wall fractures are much less common than floor blowouts and are probably found more often as an extension of a floor fracture or a component of naso-orbital-ethmoid (NOE) fractures than as an isolated entity. They occur secondary to moderate-to-high-energy impacts (Figures 20-40 and 20-41).[2,4]

Symptoms and Signs

Horizontal Diplopia. In contrast to the vertical diplopia associated with floor fractures, horizontal diplopia is usually the primary complaint when medial orbital tissues are involved. However, a vertical or oblique component is often found (see Figure 20-41).

Orbital Emphysema. It was previously taught that orbital emphysema was almost always indicative of a medial wall fracture.[11] We know this not to be the case, however, because a fair number of floor fractures also create orbital emphysema. Nevertheless, the mechanism is the same in either case: fracture into the adjacent sinus allows sinus air (and bacteria) into the orbit. The consequences are also the same, as are the general precautions regarding nose blowing and prophylactic antibiotics.

Orbital Hemorrhage. As noted above, because of the rich vascular supply to the orbit, hemorrhage is a constant companion to orbital trauma. Certainly, disruption of the highly vascular maxillary sinus mucosa by a floor fracture can create significant orbital hemorrhage; however, much of this hemorrhage will drain inferiorly with gravity into the maxillary sinus. Orbital hemorrhage from a medial wall fracture, on the other hand, can be more dramatic because it may lack the natural drainage afforded by a floor fracture. Additionally, the proximity and caliber of the anterior and posterior ethmoidal arteries—located at the frontoethmoidal suture line above the ethmoid plate—makes them exquisitely susceptible to disruption or transection with medial wall trauma and can make the bleeding more considerable (see Figure 20-41).

Enophthalmos. A sufficiently large medial wall fracture allows prolapse of enough orbital tissue to create significant loss of globe projection. This is the reason why the medial wall is intentionally removed in thyroid decompression.

Indications for Surgery

Indications for medial wall repair are similar to those for floor fracture:

- restrictive diplopia in a functional field of gaze;
- CT evidence of entrapped muscle or orbital tissue; and
- enophthalmos greater than 2 mm.

a

b

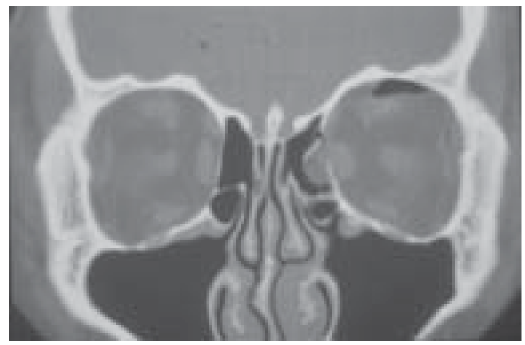

Fig. 20-40. Medial wall fracture. (**a**) Entrapment of the medial tissues results in horizontal diplopia, as demonstrated by this patient, who was kneed in the left orbit while playing soccer. (**b**) This computed tomography (CT) scan of a different patient demonstrates soft-tissue entrapment along the medial wall, as well as superior orbital emphysema. In such limited fractures, open reduction and internal fixation can be accomplished with thin absorbable or permanent implants, such as Gelfilm (absorbable) or porous polyethylene (permanent).

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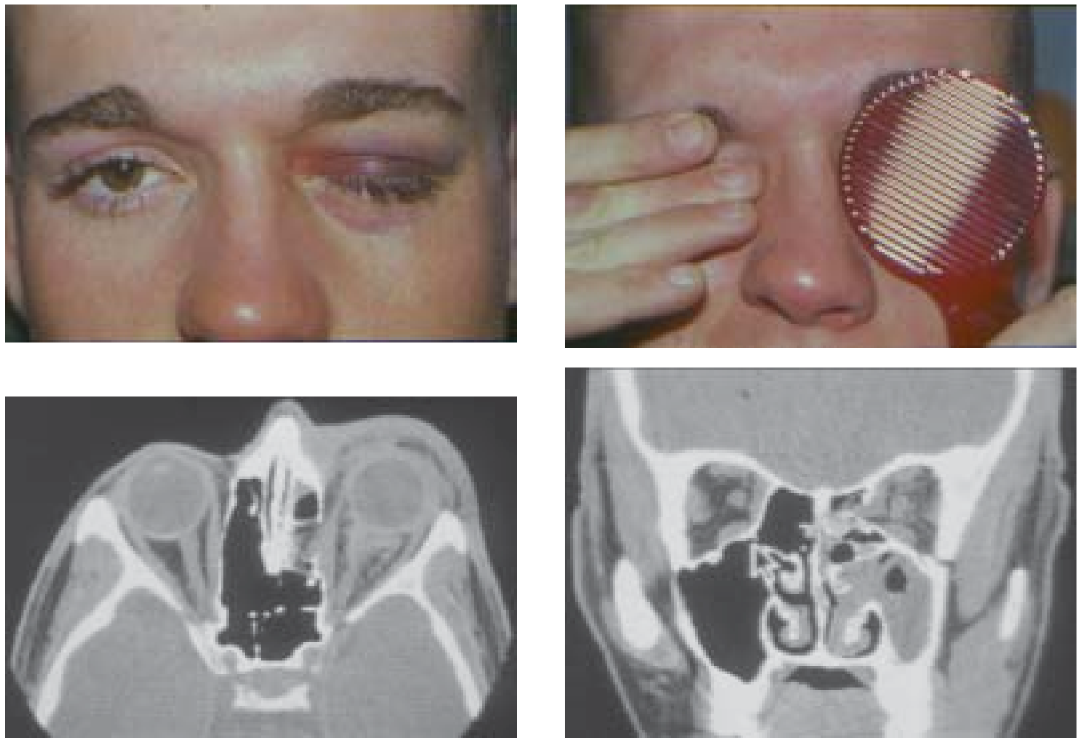

Fig. 20-41. Medial wall fracture. (**a**) This 19-year-old soldier was struck with a fist during a barracks fight. Marked lid and orbital hemorrhage prevented complete ocular examination for several days, although vision was always preserved. (**b**) When swelling abated, the patient complained of oblique and torsional diplopia in all fields, as demonstrated by the Maddox rod. (**c**) A computed tomography (CT) scan showed a large medial wall fracture with significant orbital hemorrhage. (**d**) Close inspection of the coronal CT scan shows the left orbital floor to be moderately thicker than the right (arrow). The patient later reported a history of a previous blow to the orbit with possible fracture but no surgery. This may explain why the medial wall, rather than the floor, buckled. The patient underwent open reduction and internal fixation via external ethmoidectomy incision, with placement of a thin (0.4-mm) porous polyethylene sheet implant. He was asymptomatic postoperatively.

Orbital Roof

Isolated roof fractures are distinctly uncommon, being almost always the result of moderate-to-high-energy injuries. As such, they are invariably associated with significant concomitant nonocular injury, such as frontal sinus fractures and intracranial injury.[2,4] Therefore, ophthalmologists are rarely the primary physicians managing these cases but are often called as consultants (see Figure 20-39).

Surprisingly, many patients are fully alert and oriented despite what is, in essence, a depressed skull fracture. Just as surprisingly, many patients will present initially to the ophthalmologist rather than the neurosurgeon, complaining of diplopia or ptosis after striking the head during, for example, a motor vehicle accident or a fall from a ladder (see Figure 20-27). Because other orbital fractures and ocular adnexal findings may be more impressive than the roof findings, primary physicians may, in addition, initially refer the patient to an ophthalmologist (Figure 20-42). On the other hand, there can be such a paucity of associated findings that physicians may discount the possibility that an isolated roof fracture can occur in such a setting and will simply never look for it, referring the patient to the ophthalmologist for evaluation of traumatic ptosis or management of the black eye. Therefore, the prudent ophthalmologist should always look for an associated roof fracture—even if the suspicion is low and he or she might end up not being the primary manager.

Symptoms and Signs

Restricted Up-Gaze and Ptosis. These findings develop secondary to (*a*) the inward displacement of the levator/superior rectus muscle complex by

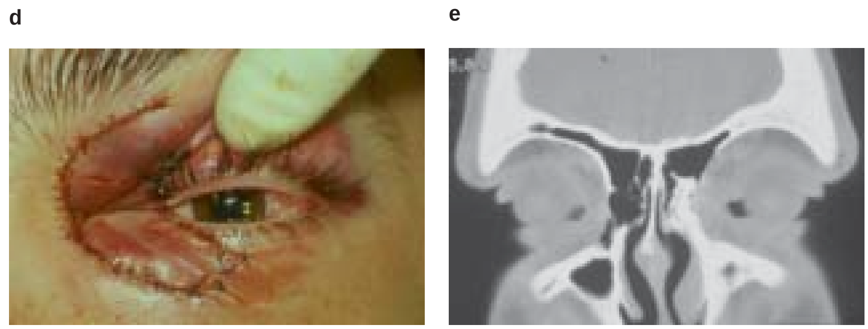

Fig. 20-42. Orbital roof fracture with combined injuries. External injuries should always prompt the search for significant associated injuries. (**a**) This 19-year-old man was struck with a polyvinylchloride pipe during a street fight. He was referred to the eye clinic for treatment of medial canthal and lower-lid lacerations. Lacerations in the medial canthal area should always prompt evaluation for associated canalicular damage. (**b**) The patient was fortunate to escape canalicular injury but sustained a full-thickness upper-lid laceration just lateral to the punctum. The location and extent of the lacerations prompted computed tomography (CT) evaluation. (**c**) The coronal CT scan shows a fracture of the floor of the frontal sinus, which also constitutes the partially pneumatized roof. Blood within the frontal sinus is easily seen. The injury was repaired via an external ethmoidectomy incision. (**d**) The lid laceration was repaired in conventional fashion. (**e**) Three months after open reduction and internal fixation, the orbit and frontal sinus are well reconstructed.

the bony fracture plate and (*b*) associated subperiosteal hematoma. Physical disruption of the nerve to the levator/superior rectus complex can occur, but it is uncommon. Even though traumatic ptosis occurs most commonly as aponeurotic damage unrelated to roof injury, ophthalmologists must, nevertheless, evaluate for roof injury when patients present to the medical treatment facility with ptosis after head trauma.

Epistaxis, Cerebrospinal Fluid Rhinorrhea, and Anosmia. Roof fractures often extend to the very thin bones of the ethmoid and cribriform plates, resulting in epistaxis. Additionally, if the dura is torn in these areas, cerebrospinal fluid (CSF) can drain from the anterior cranial fossa through the frontonasal recesses as clear fluid rhinorrhea. Anyone who has suffered a significant blow to the nose should also be queried regarding these symptoms. Fractures involving the cribriform plate can also damage the olfactory nerves, resulting in a decreased sense of smell. Because of the sensitivity of these nerves to trauma, smell sensations might never be fully recovered.

Occasionally, the frontal and ethmoid sinuses extensively pneumatize the orbital roof. In these cases, the roof has both an inner (calvarial) and an outer (orbital) table. In such a circumstance, a roof fracture represents the equivalent of an outer-table sinus fracture. Unless the inner table is also disrupted, however, CSF leakage will not occur.

Depression of the Supraorbital Rim. Roof fractures often involve the upper rim, which is also the anterior table and floor of the frontal sinus. The rim usually caves into the depth of the sinus, creating the hollow of a depressed skull fracture over the brow. The upper rim is also an important horizontal buttress.

Hypesthesia of Cranial Nerve V_1. Just as floor fractures extend through the infraorbital canal and foramen, disrupting infraorbital nerve (V_2) function, roof fractures often crack through the supraorbital notch or foramen, creating numbness across the forehead and scalp (cranial nerve V_1). Because multiple orbital fractures may coexist, and given the gravity of missing a roof fracture, ophthalmologists should routinely check V_1 sensation (on the forehead) in all orbital traumas.

Hypo-ophthalmos and Pulsatile Exophthalmos. Orbital floors tend to blow *out,* and roofs tend to blow *in*, because the orbit is more compressible than the brain, which is, after all, what is on the other side of the roof. Therefore, the bony fracture plate usually dislocates into the orbit, displacing the orbital contents anteriorly (exophthalmos) and inferiorly (hypo-ophthalmos). The open connection to the pulsatile intracranial pressure causes the globe to pulse, a phenomenon that is sometimes best seen when the patient is in the supine position. If the orbital periosteum is intact, a subperiosteal hematoma may be present. If the periorbita has been torn, blood and CSF can both dissect into the orbit proper. Care should be taken not to cavalierly perform a canthotomy and cantholysis for retrobulbar hemorrhage in these situations without neurosurgical approval, because CSF instead of blood can be liberated into the environment.

Indications for Surgery

Surgery is usually performed under the direction of neurosurgery, with extensive assistance from ENT. Craniotomy is often necessary for repair of dural tears and CSF leaks. Repair of the bony roof defect requires reestablishment of a rigid barrier between the anterior cranial fossa and the orbit. Various implant materials can be used, such as split-thickness calvarial bone; thin, porous polyethylene; or vascularized pericranial flaps. Whichever implant is selected, it should be well-secured to the surrounding bones, so as to prevent migration and transmission of intracranial pulsation (see Figure 20-39).

Indications for surgery of an orbital roof fracture include the following:

- depressed skull fracture (if the anterior cranial fossa is compromised, a craniotomy is often required);
- significant diplopia;
- significant exophthalmos; and
- frontal sinus fracture with compromise of the nasofrontal duct.

Even if the posterior sinus (calvarial) table is intact, the sinus must be explored and repaired so as to prevent the development of chronic sinusitis, mucocele, and mucopyocele. If the posterior table is intact, the sinus may be exenterated of its mucosa and the nasofrontal duct obliterated. If only the posterior table is fractured, the sinus may be opened widely and obliterated via craniotomy, thus "cranializing" the sinus.

Zygomaticomaxillary Complex

Fractures of the ZMC were formerly termed the "tripod" or "trimalar" fractures, because the zygoma was widely believed to have but three articulations: the zygomaticomaxillary (ZM) suture at the inferior rim, the zygomaticofrontal (ZF) suture along the lateral rim, and the zygomaticotemporal (ZT) suture along the zygomatic arch (ZA). The older terms are still commonly used, but since the introduction and common acceptance of the buttress concept, the zygoma is now believed to be a quadripod. Its articulations include the three of traditional teaching, plus a fourth—the ZMC buttress (see Figure 20-12). This last is probably the single most important component of the midfacial buttresses.

ZMC fractures occur as a result of moderate-to-high-energy injury. The greater the energy, the more comminution seen. Lower-energy injuries may be associated with variable degrees of displacement and dislocation, depending on the angle of impact. With higher energies, it is not unusual to find associated fractures of other midfacial buttresses and the mandible.[4,5]

After isolated orbital floor fractures, ZMC fractures are probably the second-most-common fracture presenting initially to the ophthalmologist. They are also among the most commonly missed. Patients suffering from facial trauma may initially present to, or be initially referred to, an ophthalmologist because of significant lid ecchymosis (a black eye), transient blurry vision, diplopia, or merely the history of "I got hit in the eye." Because the orbital and ocular symptoms associated with a ZMC fracture can be variable—including fully absent—it is incumbent on the ophthalmologist to always look for a ZMC fracture (see Figures 20-20 and 20-38). Just as large floor fractures can have minimal effect on ocular motility, ZMC fractures can have minimal effect on ocular function while still being significant enough to warrant surgical repair (Figures 20-43 and 20-44). Prompt recognition and diagnosis lead to timely surgical intervention and optimal results. Stated another way, delaying or missing the diagnosis of a ZMC fracture can lead to late intervention and suboptimal return of function, particularly cosmesis and dental occlusion (see Figure 20-14).

Symptoms and Signs

As stated above, symptoms and signs of ZMC fracture are highly variable, depending on the amount of energy causing the injury and the degree of bony displacement. Most patterns of ZMC

a b

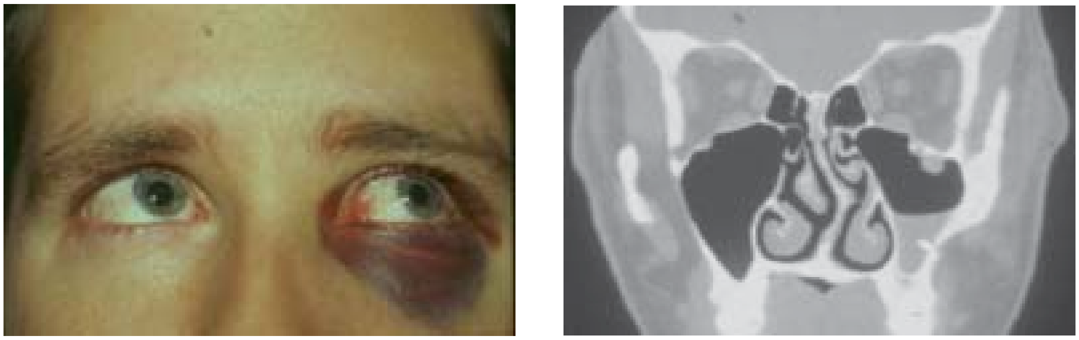

Fig. 20-43. Nondisplaced fracture of the zygomaticomaxillary complex (ZMC) with ocular symptoms. Small fractures can tether orbital contents due to a "trap-door" effect, producing symptomatic diplopia. (**a**) This 22-year-old man was the victim of an assault by his "best friend." The patient denied diplopia in primary gaze, dysesthesia of cranial nerve V_2, or trismus. On examination, however, he had significant diplopia in upper left gaze. (**b**) A computed tomography (CT) scan revealed a small, minimally displaced left ZMC fracture with probable herniation of orbital tissues. Inspection of the inferior rectus does not demonstrate significant rounding. The patient was followed conservatively for a week to allow contusion paresis to resolve. When the patient remained symptomatic at that point, he was taken to surgery for open reduction and internal fixation of the orbital floor. A small amount of orbital tissue was frankly entrapped. The floor was repaired with an absorbable gelatin plate (Gelfilm). Diplopia resolved completely by 1 day postoperatively.

a b

c

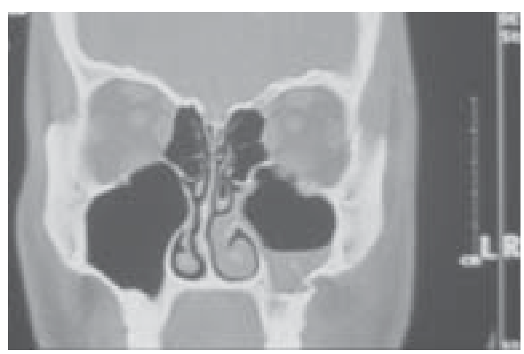

Fig. 20-44. Not all fractures cause ocular symptoms. (**a**) This patient fell on the ice, striking his left cheek. He was referred for evaluation of the "black eye." Examination revealed mild decreased sensation over cranial nerve V_2 and tenderness to palpation over the zygomaticomaxillary (ZM) and zygomaticofrontal (ZF) sutures as well as the ZMC buttress. He denied trismus, and had full ocular motility. (**b**) No enophthalmos or malar flattening were observed. (**c**) Because of the bony and intraoral tenderness, a computed tomography (CT) scan was obtained, which showed a minimally displaced zygomaticomaxillary complex (ZMC) fracture. The orbital floor was not significantly involved, but the inferior rectus muscle does show mild rounding. The patient went on to have open reduction and internal fixation for stabilization of the ZM and ZF sutures. At surgery, the orbital floor was explored, revealing a hairline fracture but no orbital incarceration. A gelatin implant was placed on the floor.

fractures exhibit some common findings, however.

Point Tenderness and Ecchymosis. Fractures of the ZMC affect all of its articulations to some degree. Frank dislocation of any of these articulations depends on the amount and direction of energy delivered. Palpation of the entire circumference of the bony rim usually discloses localized pain and tenderness at the ZF and ZM sutures. If pain is elicited, then the ZA and ZMC buttress should also be palpated. If the zygoma is dislocated, a tender rim step-off or separation can be felt, either inferiorly or laterally.

The ZMC buttress is best evaluated via intraoral examination. Ecchymosis at the gingival sulcus and upper vestibule are strong indicators of bony disruption (Figure 20-45). The buttress can be palpated by placing a finger into the upper gingival sulcus and following the anterior maxillary face laterally to just under the malar eminence. The bony pillar is easily felt as a prominent thickening of the bone. Point tenderness here indicates bony disruption, although not necessarily dislocation. While examining the ZMC buttress intraorally, the ophthalmologist can palpate the anterior maxillary face for comminution and examine the maxillary alveolus for Le Fort I stability. External palpation of the ZA can easily be performed.

Malar Flattening and Increased Facial Width. Because the zygoma is the major structure providing malar prominence, dislocation of the structure results in significant distortion of the cheek. Malar flattening typically occurs if at least one suture is frankly separated or dislocated. It can occur if the ZM suture is disrupted with rotation around an in-

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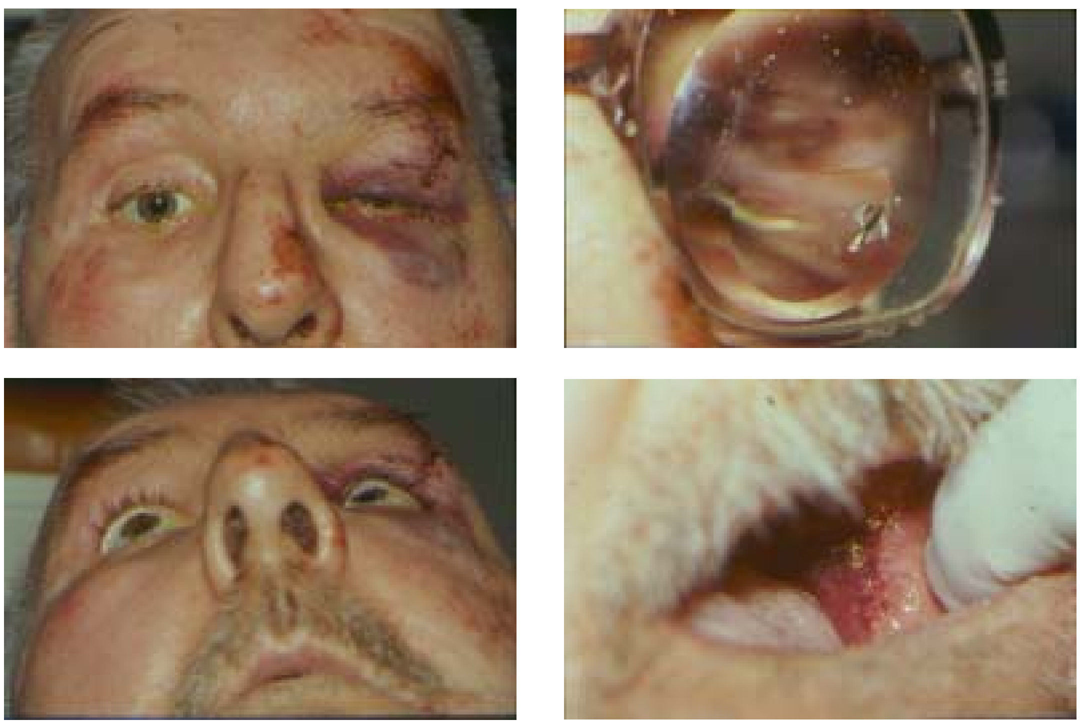

Fig. 20-45. Visually asymptomatic zygomaticomaxillary complex (ZMC) fracture. (**a**) This institutionalized patient passed out from unknown causes, falling onto a step, suffering an unprotected blow to his left cheek. (**b**) He was wearing his aphakic spectacles at the time, which exhibited significant damage. Fortunately, vision and the globe were unaffected. He complained of trismus and cranial nerve V_2 dysesthesia extending to the teeth. He denied diplopia and had full ocular range of motion. (**c**) Clinical examination showed point tenderness over the zygomaticofrontal suture and the zygomatic arch with a step-off deformity at the inferior orbital rim and malar flattening. (**d**) Oral examination showed buccal ecchymosis and significant tenderness at the ZMC buttress. Oral examination is an important part of the ophthalmologist's evaluation of a fracture, during which Le Fort I- and II-level fractures can also be identified. This patient refused treatment.

tact ZF suture, or vice versa, and it certainly occurs when more than one articulation is involved. If the ZA is affected, it generally dislocates laterally, increasing facial width (see Figures 20-14, 20-20, 20-38, 20-44, and 20-45).

Lateral Canthal Dystopia. If the lateral canthal tendon is still attached at the lateral orbital tubercle, downward canthal dystopia can be seen. The lid can also be dragged downward by the same mechanism.

Dysesthesia of Cranial Nerve V_2. The ZM suture runs very close to the infraorbital foramen along the anterior maxillary face. Therefore, fractures often compromise the neurovascular bundle, resulting in numbness of the cheek and, often, the ipsilateral teeth and gums.

Trismus and Malocclusion. The temporalis muscle originates along the temporalis fossa and passes medial to the ZA to insert on the coronoid process of the mandible. The masseter muscle arises from the inferomedial aspect of the ZA and the posterior-inferior aspect of the zygomatic body. It lies lateral to the temporalis and inserts along the ramus of the mandible. Together, the temporalis and masseter constitute the primary muscles of mastication.

Disruption of the zygoma, the ZA, or both dramatically affects the normal operation of these muscles. Significant bony dislocation of these structures—leading to direct impingement of the coronoid process as well as muscular swelling and hemorrhage—can lead to trismus (pain on opening the mouth) and limitation of movement. Likewise, tissue swelling and distortion can lead to frank misalignment of dental occlusion. Even though many patients have dental anesthesia, they can still perceive proper bite. Of course, malocclusion can also be a sequela of Le Fort I fracture or dental injury.[29]

Inferior or Lateral Rim Step-Off. Disruption or dislocation of the ZM or ZF sutures creates point tenderness and palpable separation.

Associated Floor Fracture Findings. Because the zygoma contributes to the lateral aspect of the floor, typical findings of floor fracture can be present. As stated above, this is why many ZMC fractures are sent initially to the eye clinic to rule out isolated blowout fracture. A good clinical examination can disclose the underlying larger fracture. However, as mentioned previously, a large fracture may not impede motility (see Figure 20-38).

Indications for Surgery

Minimally displaced or nondisplaced fractures can be followed conservatively. If orbital floor symptoms accompany a nondisplaced ZMC fracture (eg, restrictive diplopia), the floor should be explored independently. Occasionally, a minimally displaced ZMC fracture can be treated via closed, external reduction, but this is now uncommon practice. More typically, patients proceed to surgical reduction and fixation, via open reduction with internal fixation (ORIF). The goal of surgery is to restore stability of the four articulations. As previously mentioned, reestablishment of the buttresses—especially the ZMC buttress and arch—is the key to overall midfacial stability. Adequate ZMC fixation and stability require at least two points of rigid plate fixation. Wire fixation alone is insufficient to anchor the bone in three dimensions against the forces of normal jaw action, let alone the strong contractile forces of healing, fibrosis, and scarring.[24] Proper fixation is best accomplished with metal (titanium; see Figure 20-34) miniplates and microplates, but at times, interosseous wire techniques are still useful adjuncts.

Various surgical approaches are used, depending on the degrees of dislocation and comminution. The greater the injury, the wider the surgical exposure required. The ZMC buttress is typically approached via an intraoral gingival incision (eg, Caldwell-Luc procedure, Keen incision). The ZA can be exposed and reduced through a coronal flap or Gilles's approach. The ZM suture is typically repaired through any traditional approach to the orbital floor, although most oculoplastic surgeons would vastly prefer the transconjunctival or subciliary methods to a direct rim incision. Currently (2002), we believe the transconjunctival approach to be superior even to the subciliary, as the likelihood of postoperative cicatricial lid retraction and ectropion appears to be lower.

The ZF suture can be stabilized through an extended lid-crease incision, a direct lateral rim incision, or a coronal flap. Accurate reduction and alignment of the zygoma are critical to a good cosmetic result postoperatively, but relying solely on the external appearance of the reduction can be misleading. A more accurate perspective of proper reduction is gained by inspecting the internal (orbital) contour of the lateral wall and trying to attain a smooth internal contour at the zygomaticosphenoidal junction. Such reduction requires three-dimensional control of the zygomatic body. A handy instrument for achieving control in three dimensions is the Carroll-Girard screw, which temporarily secures into the body of the zygoma like a joystick. The bone can then be manipulated in multiple axes. Once the proper reduction is achieved, the zygoma is plated in place.[4] Another key concept in reconstruction is the reduction of the ZA, which, despite its name, is actually a rather flat, straight structure (see Figure 20-38). Taking pains to accurately reestablish the proper flat orientation of the ZA helps ensure proper reduction of increased facial width and the reestablishment of proper midfacial projection.[4]

If surgery is to be performed, then the orbit and floor should be explored to prevent orbital tissues from becoming inadvertently incarcerated during manipulation and reduction (see Figure 20-20). Additionally, as stated above, the internal aspect of the lateral wall is a very good indicator of correct alignment of the ZA.

Specific indications for surgical intervention include the following:

- significant malar flattening,
- lateral canthal dystopia or lower-lid malposition,
- trismus or malocclusion,
- significant orbital enlargement, with or without orbital floor symptoms, and
- significant displacement or comminution.

Naso-Orbital-Ethmoid

NOE fractures are the result of high-energy trauma that impacts on the central midface. By definition, these are complex, multilevel injuries, and they require management by several services. NOE fractures are almost always associated with significant craniofacial trauma, such as that resulting from high-speed motor vehicle accidents, and may be life-threatening because of vascular damage or airway compromise (particularly if the injuries are to the lower face). As the most complex of the facial fractures, more often than not they require more than one surgery for complete repair. Surgical stages may include initial ORIF with or without primary bone grafting, subsequent bone-graft harvests, several soft-tissue surgeries (such as scar revisions, telecanthus repair, and orbital volume augmentation), lacrimal repair, strabismus surgery, and oral surgery.[4,30]

The NOE region is typically injured in direct frontal impact, and the high energies involved crumple the bones of the nose and midface. The nasoethmoid labyrinth, however, often acts as a safety “crumple zone,” absorbing much of the energy as it collapses internally (Figure 20-46). Although the crumpling creates tremendous midfacial and orbital disruption, it can sometimes prevent serious ocular injury (see Figures 20-1, 20-2, 20-16, and 20-31).

The NOE region includes the confluence of various facial buttresses. Not only do the nasomaxillary, upper-rim, and lower-rim buttresses all converge in the area of the nasal root bilaterally, but the vertical buttresses also meet here (see Figure 20-12). Consequently, NOE fractures are invariably bilateral. Comminution is the rule. Loss of the buttresses leads to three-dimensional collapse of the midface (see Figures 20-31 and 20-46). As the nasofrontal processes of the maxillary and frontal bones and the ethmoid telescope, the bridge of the nose is depressed, which causes loss of facial projection. Loss of the anterior medial wall (particularly the anterior and posterior lacrimal crests) leads to instability of the medial canthal tendons and telecanthus, as well as to injury of the nasolacrimal duct. Telecanthus requires accurate reduction and fixation of the posterior horn of the medial canthal tendons (the more posterior and superior, the better). This can be done by cantilevered plates suspended from the anterior nasofrontal process, or may require transnasal wire fixation. Lacrimal drainage injury may eventually require dacryocystorhinostomy.

Loss of the horizontal stabilizers—the upper and lower rims and the maxillary alveolus—leads to decreased midfacial width. Injury at the Le Fort I level is common. Loss of the vertical buttresses can lead to loss of facial height, especially if the mandible is affected as well. Malocclusion and chronic open bites can persist, even after attempted ORIF, if the lower buttresses are not accurately reconstructed.

NOE fractures usually cause some degree of damage at the Le Fort II and III levels as well. Multiple orbital walls, as well as the cribriform plate, can be fractured. Energy transmitted posteriorly along the medial wall can result in frank fracture of the optic canal or concussive damage to the optic nerve (traumatic optic neuropathy) (see Figure 20-16). Consequently, vision must be monitored meticulously, but because these patients often suffer significant brain injury and may be comatose, vision is not always assessable early in the course of treatment. Damage to the cribriform plate can also lead to CSF leaks and anosmia.

Soft-tissue reconstruction in this area can be challenging. Despite the excellent vascular supply to the tissues, fibrosis and tissue contraction can make any reconstructive attempt unsatisfying. Unlike other areas of the face and body that have relatively large, flat areas of homogenous skin, the midface is characterized by compound curves of tissue of varying

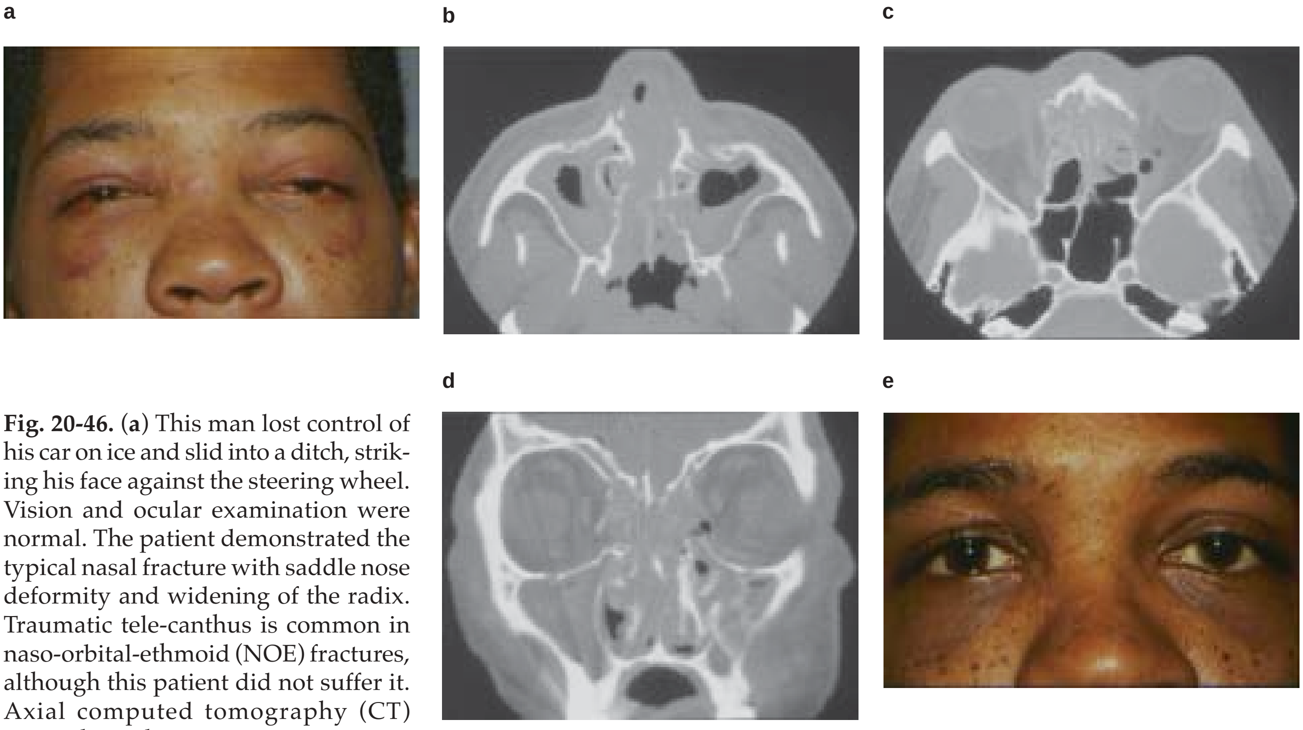

Fig. 20-46. (**a**) This man lost control of his car on ice and slid into a ditch, striking his face against the steering wheel. Vision and ocular examination were normal. The patient demonstrated the typical nasal fracture with saddle nose deformity and widening of the radix. Traumatic tele-canthus is common in naso-orbital-ethmoid (NOE) fractures, although this patient did not suffer it. Axial computed tomography (CT) scans show the massively telescoped collapse of (**b**) the midfacial skeleton, with marked comminution of the septum, bilateral medial maxillary walls, and (**c**) the ethmoid complex. The pterygoid plates are not fractured; therefore, these fractures are not true Le Fort fractures. (**d**) A coronal CT shows the degree of comminution of the vertical midfacial skeleton. Notice the marked hemorrhage, which fills all the sinus spaces. Notice also that the orbits are relatively spared, which is sometimes seen in NOE fractures. Fractures as extensive as these require early repair, and wide surgical exposure is required. (**e**) The same patient 3 weeks after open reduction and internal fixation, with a well-healed Lynch ethmoidectomy incision and normal intercanthal distance but with residual nasal depression. It is not unusual for NOE fractures to require further nasal, sinus, or lacrimal surgery.

thickness, pilosebaceous composition, and variable healing ability (see Figures 20-19 and 20-39).

Symptoms and Signs

The symptoms and signs of an NOE fracture are as follows:

- facial flattening,
- traumatic telecanthus,
- damage to the nasolacrimal system,
- epistaxis, CSF rhinorrhea, or anosmia,
- signs and symptoms of associated fractures, and
- traumatic optic neuropathy or optic canal fracture.

Indication for Surgery

The presence of an NOE fracture is the only indication necessary for surgery. Reconstruction of NOE fractures is difficult. Unlike other fractures described above, in which even comminuted bony fragments can often be salvaged for use in ORIF, NOE fractures often require bone grafts to replace the very small pieces of bone remaining (usually along the medial wall and nasomaxillary buttress). Wide exposure is mandatory, usually requiring bicoronal flap, bilateral gingival sulcus incisions, and orbital exposure. Total facial degloving in the subperiosteal plane allows mobilization of the facial soft tissues.

Early surgical intervention is crucial to successful facial restoration. Failure to operate in the acute setting can lead to irreversible contraction of the facial structures. In this setting of massive facial trauma, a delay of even a few days can lead to significant fibrosis. It is axiomatic that the soft tissues contract to conform to the underlying facial skeleton—wherever that framework should be. Contraction begins almost immediately after injury and, once set in motion, is very difficult to reverse.

Additionally, delaying surgery creates a separate traumatic insult. Soft tissues that suffered contusion damage during the initial injury are reinjured. Convalescing tissues are edematous and highly vascular. Operating soon after the initial insult takes advantage of the acute process and "disguises" the surgical insult within that of the original trauma. Soft tissues that were degloved traumatically or surgically can be redraped and reattached appropriately. In this way, contractile forces can be better controlled, and a better functional and cosmetic outcome results.

MANAGEMENT OF ORBITAL FRACTURES

The primary objective in managing orbital trauma is to *ensure the integrity of the globe*. Remember that any type of orbital trauma can cause loss of vision through either direct concomitant ocular trauma, or indirect optic nerve damage. Once the ocular injury has been evaluated, proceed with the orbital evaluation. A good clinical evaluation should look for all of the major fractures listed above. Remember that fractures can often be multiple: just because the patient has what looks to be (and probably is) an isolated floor fracture does not eliminate the possibility of an associated roof or ZMC fracture as well. The only way to be sure is to look for associated fractures. Ask about trismus and malocclusion. While checking for cranial nerve V_2 dysesthesia, check V_1 as well. Run a finger around the upper gingival sulcus and press on the ZMC buttress.

The thorough clinical examination can give a good idea of what to expect on imaging.[2] First, get good CT images through the orbit, and, if needed, the sinuses. As stated before, 3-mm axial and true coronal views usually suffice to evaluate the bone and most soft tissue. Consider thinner slices if looking for FBs, dealing with children, looking for optic canal trauma, or if true coronal views cannot be obtained. Depending on the type of FB or soft-tissue injury, an MRI may be needed as well, but only after metallic FBs have been ruled out.

Orbital fractures are considered "dirty" (ie, contaminated) whether the fracture is open or not, but thanks to the rich facial vascular supply, posttrauma infection is uncommon. Nevertheless, most surgeons feel that a course of prophylactic antibiotics is warranted. A broad-spectrum oral antibiotic will usually do, but, depending on the mechanism and extent of injury, intravenous dosing may be appropriate. To prevent orbital emphysema, tell the patient to refrain from nose blowing.

The orbit has several important neighboring structures that also may be involved. Even if the orbital injury is isolated, however, consider asking for help from other surgical services, such as ENT, OMFS, or plastic surgery. Trauma is always managed best when several minds work together. In addition, members of each service bring different perspectives and experiences to the case, enriching the learning experience for all.

Having put together a clinical picture of the extent of the trauma, the ophthalmic surgeon must now formulate a surgical plan. If the fractures are comminuted, will a plating set be needed? If so, where is the set kept? If multiple services are collaborating, whose plating set will be used? Is it a miniplate set, or a microplate set? Will one of each be needed? Is a microdrill available, and does it have a bit of the proper size for the particular plating set being used? Can all the needed specialties be present? Which instrument sets are needed? Who will do what first? (In complex trauma, OMFS or ENT will probably want to stabilize dental occlusion first, with intermaxillary fixation. If bone is missing, a calvarial graft may be harvested, in which case a bicoronal flap will be raised before the orbit is approached.) Will special cultures be needed?

Make sure that all needed equipment will be available at the time of surgery. Remember that each plating system has its own peculiarities: miniplate screws will not fit into microplate holes; one manufacturer's screws may not accept another's screwdrivers; mixing one type of screw with another type of plate throws off the profile, because each is milled for its own particular system.

When to operate depends on the nature and extent of the injury, but—unless vision is threatened—isolated orbital trauma rarely requires absolutely emergent intervention.[1–6,21,30] Most can be delayed at least overnight, when the regular eye surgical team is available, and many cases can be postponed for several days without jeopardizing the outcome. However, do not delay surgery needlessly, especially if the patient needs surgery anyway. For example, if the patient has a large floor blowout, or frank entrapment on CT with restriction on forced ductions and diplopia, or a frank surgical ZMC, or an injury in which surgery is clearly indicated, little or nothing will be gained by waiting 7 to 10 days; the decision that surgery is needed has been made. If there is significant edema, it is reasonable to wait for some of the edema to go down (corticosteroids may help speed the resolution), but in general, once the decision to operate has been made, the sooner the better. Waiting longer than 7 to 10 days allows significant fibrosis to set up. This may impair distraction of orbital tissues from sinuses and prevent accurate alignment of the buttresses, with resultant loss of facial proportion and projection.[2,4,5] To a large extent, the first operation sets the course for the eventual outcome, and in complex trauma, a delay of even 7 days can have a deleterious effect on results. As a general rule, the more complex the fracture, the sooner the operation.[2]

SURGICAL TECHNIQUES

The goal of treatment is to restore the orbital bony contour and volume. For the most part, this is accomplished through surgical ORIF. Currently, reduction and fixation are best accomplished by means of three-dimensional rigid plate fixation.[2,4,5,31]

Incision

Placement of the incision can be the single most important step in the surgical procedure. In orbital surgery—whether for trauma or tumor—exposure is the key. The desire to minimize a scar must not compromise surgical goals. Nevertheless, the surgeon should avoid making a huge incision if it is not necessary, and if the needed exposure can reasonably be achieved through an existing laceration or a hidden incision, then that is preferable to a new cutaneous incision. Experience has shown that almost every orbital structure can be reached via a variety of hidden incisions. These incisions include the bicoronal flap and transconjunctival, transcaruncular, and gingival sulcus incisions. In general, if a fracture fragment is at the furthest reaches of where an invisible incision would end, then the surgeon is better off not even attempting that incision.[5] Some bleeding invariably occurs once the area is exposed. Frank hemorrhage is rare, however; bleeding will most likely be a slow ooze. Resist the temptation to use monopolar electrocautery (eg, Bovie) in the orbit. Because of the prolapsed orbital tissue and its fibrovascular connections, not to mention the danger of inadvertently touching one of the metal orbital retractors and causing widespread damage, low-power bipolar cautery is preferred.

The pupil should be continually monitored throughout the case. If light is effectively obstructed from entering the fellow eye, pupillary size and reaction give a gross estimation of optic nerve function. To prevent iatrogenic direct optic nerve damage, posterior dissection beyond 30 mm should be undertaken only with extreme caution.[32]

Implants

Various implants are available for use in orbital reconstruction. If a bony wall is fractured with entrapment of tissues but the bony plates are relatively intact and not significantly displaced, then an absorbable implant can be used to span the defect and prevent reentrapment while the fracture heals. Examples of absorbable implants are fascia lata, gelatin film (Gel*film*, not Gel*foam*), polyglactin (Vicryl) mesh, and anterior maxillary wall (Figure 20-47).[33] The disadvantage of both Gelfilm and Vicryl mesh

Fig. 20-47. The overriding premise of orbital fracture repair is twofold: to release all entrapped tissues and to prevent recurrence of herniation by placing a barrier over the fracture site while the fracture heals. If the fracture is small, an absorbable implant can suffice. (**a**) If the fracture is large or comminuted, the implant must (**b**) be large enough to span the defect and substantial enough to withstand the weight of the orbital tissues. A variety of materials is available for use. Axiomatic to the placement of any plate is that the plate must accurately reconstruct the normal intraorbital contour. Drawings prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

a

b

c

Fig. 20-48. Extruding orbital implant. (**a, b**) This 33-year-old combat engineer was attempting to defuse a mine when it exploded, causing massive facial injury, including a shattered mandible, panfacial fractures, and lid and globe lacerations of the right eye. Although the lid and globe were repaired urgently, the patient eventually lost the eye to enucleation. Orbital and panfacial fractures were repaired at the time of injury via open reduction and internal fixation of the orbital floor and placement of a silicone plate. One year later, the patient developed increasing swelling, erythema, and discomfort of the right eye. (**c**) The floor plate eventually extruded and was removed surgically.

is their lack of rigidity, especially when wet; therefore, they may not be suitable for spanning large, open fracture cavities. In patients with these types of large defects, a more rigid implant that can be cantilevered over the defect is needed.

Silicone plastic (Silastic) sheets are still widely used and are available in a variety of thicknesses (rigidities). A major drawback to these implants is that they occasionally migrate or extrude because of their smooth, nonporous surfaces (Figure 20-48). Various methods have been used to secure these plates in place more permanently, including bending a tab into the fracture, suturing or wiring the plate to the rim, or spot welding the plate to the floor with high-temperature thermal cautery. *We strongly advise against the latter method* because the cautery temperature is generally well above the flashpoints of these petroleum-based silicone plastic materials, and they may ignite if this maneuver is performed.

Alternatives include porous implants, which allow incorporation of fibrovascular tissue into the material, thereby preventing migration (at least in theory). Porous polyethylene (Medpor), titanium mesh orbital floor plates, and split-thickness calvarial bone are examples of porous implants. These implant materials have the added advantage of being moldable or sculptable, which allows specific configuration to restore proper orbital volume. A significant drawback to these materials is the difficulty in removing them, should that become necessary.

The most dramatic recent advance in surgical technique is the increasing use of titanium plates to reduce comminuted fractures. These plates have allowed the accurate reduction and reconstruction of the major buttresses, with restoration of structural integrity to a degree not previously seen with surgical wire (Figure 20-49). Both miniplates and the lower-profile microplates are easier to place than surgical steel wire. Current technology allows the manufacture of very strong 1.0-mm, 1.3-mm, and 1.5-mm plates. Unfortunately, the availability of titanium plates on the battlefield is dubious. So although the use of steel wire during peacetime may be limited, military ophthalmologists should be familiar with it. Titanium has the added advantage of being nonmagnetic, whereas steel is not. Patients—particularly battlefield casualties—in whom wire is used must be told of its presence in the event of future MRI.

Before placing any implant on the orbital floor, all orbital tissue that has prolapsed into the maxil-

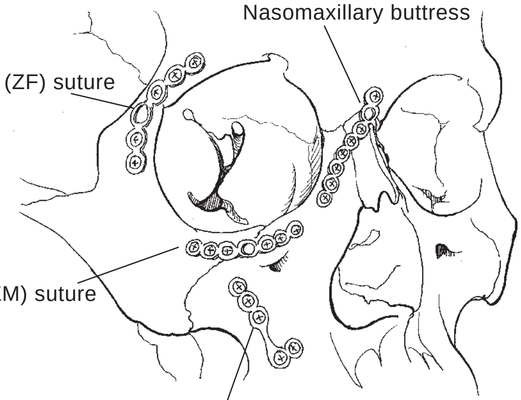

Fig. 20-49. Titanium microplates and miniplates allow more-accurate reconstruction of the facial skeleton in three dimensions than was previously possible with wire fixation. Plates are best used to reconstruct the facial buttresses. At least two screws should anchor the plates on each side of the fracture line. Drawing prepared for this textbook by Gary Wind, MD, Uniformed Services University of the Health Sciences, Bethesda, Md.

lary sinus must be extracted, using gentle hand-over-hand technique with a ribbon retractor and a blunt elevator as the primary tools. Occasionally, a bayonet forceps can help raise tissue that is tenaciously scarred in. Above all, remember that the neurovascular bundle of cranial nerve V_2 runs through the orbital floor and is supposed to be adherent to the floor. Unfortunately, many orbital tissues look alike after trauma, and it is not uncommon for even experienced surgeons to mistake the V_2 neurovascular bundle for incarcerated orbital tissue. During the heat of surgery, the surgeon must not tug overmuch on tissue and accidentally rip the nerve. *And under no circumstances should the surgeon cut it*.

Closure

In closing the incision, the surgeon should avoid suturing deep tissues. Incarceration of the septum into a microplate or deep closure often leads to lid retraction, particularly of the lower lid (Figure 20-50). The surgeon must also avoid the temptation to place an excessive number of deep sutures. The inflammatory response to trauma is active enough that adding another potential nidus of reaction only adds fuel to the fire. Most orbital incisions can be closed with simple cutaneous or vertical mattress sutures. Always consider placing a lid-traction suture at the end of the case to counteract early contraction.

Fig. 20-50. Middle lamellar cicatricial retraction. Postoperative lower-lid retraction is typically secondary to contraction and scarring of the orbital septum and middle lamella. This patient underwent open reduction and internal fixation of an orbital fracture via a subciliary incision. In closing the periosteum, the orbital septum was inadvertently incarcerated, resulting in progressive lid retraction. Repair of this deformity required extensive lysis of scar bands; placement of a spacer graft; Frost traction suture; and corticosteroids administered topically, intralesionally, and systemically. Transconjunctival approaches to the orbital rim and floor may be less prone to this complication.

POSTOPERATIVE CARE

Many surgeons opt against pressure patching the eye after orbital surgery, fearing devastating loss of vision from increased orbital pressure in the face of an unexpected postoperative orbital hemorrhage. Such concerns are valid. Other surgeons argue that an orbital hemorrhage may drain through any fracture into the adjacent sinus, thereby decompressing the orbit. This reasoning, too, is valid. However, we have seen compressive optic neuropathy and loss of vision from orbital hemorrhage in the face of large orbital fractures, which nonetheless required canthotomy and cantholysis to decompress. There is no absolute right or wrong answer. We prefer to patch lightly overnight and then to remove the patch the next day. Overnight vision checks are recommended, and we routinely prescribe antinausea medications.

Surprisingly, postoperative pain is usually mild to moderate after orbital surgery and only rarely requires strong narcotic pain medication to control. Aggressive treatment with cold or ice packs helps in several ways. First, it helps decrease postoperative swelling and ecchymosis. Additionally, it helps decrease pain. After several days of cold packs, the patient can switch to warm-water compresses. Oral corticosteroids may also help resolve postoperative swelling.

As stated previously, the risk of postoperative orbital cellulitis is extremely low, despite the frank communication between the orbit and contaminated sinuses. Nevertheless, most surgeons will prescribe at least a short course of prophylactic oral antibiotics; a broad-spectrum antibiotic that covers *Staphylococcus* and *Streptococcus* species and *Haemophilus influenza* is most appropriate. To guard against both producing orbital emphysema and inoculating the orbit with sinus bacteria, patients should refrain from nose blowing and vigorous straining for at least 2 weeks.

Diplopia resolves in a variable length of time. If preoperative diplopia was mostly restrictive, then postoperatively, the patient should be markedly improved. Some limitation of motility may persist, however, because of contusion, apraxia, or ischemic contracture of the muscle. Active range-of-motion exercises can help expand the field of single binocular vision over time.

If a lid-traction suture was placed, it should be left in place for several days. If the lower lid begins to retract, gentle upward massage can sometimes reverse the process. Topical corticosteroids, especially the potent fluorinated steroids (eg, clobetasol), can be very effective. These topical medications are not formulated for the eye and must be used very judiciously, as they pose all the risks of ocular steroids in addition to having potential systemic effects. Intralesional steroid injections can also help.

Return to duty is obviously predicated on the extent of the trauma, the complexity of the repair, and the patient's occupation. Most patients with isolated floor or medial wall fractures can be discharged from the hospital the same day or after overnight observation. These patients can return to light duty quickly, usually within 2 weeks. (It is not unusual to find professional athletes returning to full contact within a few weeks of facial fracture repair.) They should be encouraged to use the eye as much as possible, with the previously stated warnings about nose blowing and straining. There is a paucity of information regarding the timing and safety of flight or of diving after orbital fracture, but we believe that such patients should not be exposed to these conditions for 2 to 3 weeks. If a patient must fly, he or she should be counseled to watch for signs of compressive pneumo-orbita (increasing proptosis, increased orbital pressure, decreased vision), and the cabin should be immediately repressurized. More extensive traumas, especially those that may require additional surgery, should be evacuated to the higher level of care as quickly as possible to minimize soft-tissue fibrosis.

SUMMARY

Orbital trauma requires extensive evaluation. The injured anatomical structures can range from one to many, and cooperation and participation of multiple surgical services—of which ophthalmology must be a part—are required to repair the damage. Because extended formal training in oculoplastics is probably not realistic, the general ophthalmologist must be comfortable with the evaluation and treatment of myriad orbital injuries, ranging from FBs to fractures. He or she must also be conversant with the basic nomenclature and techniques of consulting services and must be suspicious enough of any injury to seek consultation quickly. Above all, the ophthalmologist must serve as the guardian of vision, ever vigilant to the potential threat to the globe, regardless of how well disguised that threat may be.

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