In the first article, Drs. Manson and Iliff present an historical overview of ideas on the etiology of orbital fractures, and the causes of diplopia and enophthalmos. They discuss the development of arguments for early repair versus conservative management. These authors now recognize that there is a subgroup of patients with resolving diplopia, minimal enophthalmos, and small pure orbital wall fractures in whom CT shows no evidence of entrapment. These patients do not require surgery. However, they correctly stress the unreliability of some clinical examinations, such as the evaluation of early post-traumatic enophthalmos. Drs. Manson and Iliff argue that with CT evidence of inferior orbital tissue entrapment, orbital volume expansion even without enophthalmos, or associated rim fractures, early surgical repair offers the best chance for a successful outcome. They emphasize the need to reconstruct normal orbital contour to allow soft tissues to heal in appropriate anatomic relationships.

In the companion article, Dr. Putterman discusses his experience with pure orbital wall fractures. He has tempered his earlier enthusiasm for conservative management, and now agrees that appropriate CT evaluation can help in the assessment of surgical necessity. Like Drs. Manson and Iliff, Dr. Putterman recognizes the need for early reconstruction in some patients. However, he differs in his continued belief that a significant proportion of patients can be managed conservatively, even in the face of entrapment of nonmuscular orbital soft tissue. He correctly points out that some clinical tests, such as the forced duction test, can be misleading, and a positive result does not always correlate with entrapment. He also feels that residual diplopia and late enophthalmos can be satisfactorily managed secondarily after four to six months.

In an attempt to summarize the conclusions of both papers, the indications for early surgery (within one to two weeks) are: symptomatic diplopia with positive forced ductions and CT evidence of muscle entrapment, and showing no clinical improvement over one to two weeks; early enophthalmos of 3 mm or more; significant hypo-ophthalmos; a large orbital wall defect likely to result in late enophthalmos; or associated rim or facial fractures. The indications for conservative observation without treatment are: minimal diplopia with good motility that shows evidence of clinical improvement over several weeks, and without CT evidence of muscle entrapment; absence of significant enophthalmos or hypo-ophthalmos; and small bony defects not likely to result in late enophthalmos. The authors differ primarily in their evaluations of the degree of fracture that requires repair, in the importance of always releasing nonmuscular tissue incarceration, and in the need to restore the bony orbit to normal volume and contour.

It is clear that the differences between these two approaches to orbital blow-out fractures is growing less distinct as our ability to evaluate orbital trauma becomes more precise. Hopefully, this set of papers will increase our mutual understanding of the complex issues involved in managing these patients, and will allow more open communication and cooperation between the various subspecialists dealing with these problems.

References


II. Early Repair for Selected Injuries. Paul N. Manson, M.D.,1,2 and Nicholas Iliff, M.D.,2 1Plastic Surgery, The Maryland Institute for Emergency Medical Services Systems, and 2The Johns Hopkins Medical Institutions, Baltimore, Maryland

Fractures involving the orbit are common injuries and multiple surgical specialties provide their treatment. The orbital rim and globe occupy a prominent place on the facial skeleton; as such, they are a frequent recipient of traumatic injury. Because the orbital cavity contains the ocular globe and extraocular structures, injuries in this area have profound functional and aesthetic implications.

The magnitude of fractures within the orbital region varies considerably. One may see a simple linear fracture, a circular "blow-out" fracture (Figs. 1 and 2), or a "blow-in" (Fig. 3) fracture. Portions of the orbit may be involved in a complex craniofacial...
injury in which several orbital walls and the orbital rim are all diffusely comminuted (Fig. 4). The diversity of orbital fractures and the fact that numerous surgical specialties, each with its own literature, participate in orbital fracture treatment, have made the identification of generalized recommendations for management difficult.

In the past, internal orbital wall (“blow-out”) fractures have enjoyed alternate “all” or “none” treatment philosophies; fractures were treated, not treated, or delayed until symptoms were obvious and stable. Recent clinical studies and research provide some unifying concepts for evaluation and treatment. These concepts are based on a precise knowledge of orbital bone and soft tissue anatomy, physical examination, and the unexcelled definition of bone and soft tissue injury by thin-slice CT scanning (Figs. 1–4). Surgeons may now make early, individualized decisions about treatment, based on physical findings and the pathological anatomy of the injury as identified on CT scan.

Some orbital fractures require only observation, while others require surgical treatment. The optimal time to reconstruct orbital injuries requiring surgical treatment is as soon as possible following injury, when other considerations permit. Early management avoids the compromises that accompany secondary revisions and reconstruction. The application of craniofacial reconstructive techniques provides complete exposure and the opportunity for immediate bone grafting of orbital fractures; both techniques improve the outcome of injuries requiring operation. Such exposure provides complete visualization of fracture sites permitting anatomic reconstruction of both the rim and deep orbit. Reconstruction of the bony orbital walls may proceed precisely and, where necessary, rigid fixation of bone grafts or alloplastic materials can be performed within the internal orbit, improving bone graft survival. These reconstructive techniques, guided by computerized imaging, provide direction and answers to questions long raised about operative management of fractures.

It should be emphasized, however, that many isolated internal orbital fractures do not require surgical treatment.

Historical Considerations

In order to provide a perspective on the evolution of our current management, a selective historical review is presented. This review is partially based on publications by Smith, Converse, Converse et al, Dulley and Fells, and Wilkins, and I have drawn extensively from their work. Since the first description of orbital fracture pathology in the 19th century, herniation of orbital...
soft tissue into the expanded bony orbit was postulated as the major cause of aesthetic deformity following orbital fracture. Lang in 1888 accurately suspected orbital enlargement as the cause of enophthalmos. LaGrange, in a classic monograph describing fractures involving the orbit, again focused on orbital enlargement as the cause of enophthalmos. Pfeiffer in 1943 proposed seven mechanisms of enophthalmos and presumed the most likely event was increased size of the bony cavity. He also mentioned fat atrophy, fibrosis of retrobulbar soft tissue, neurogenic mechanisms and incarceration of tissue posteriorly and inferiorly as causes of backward globe displacement. King in 1944 discussed downward displacement of the orbital floor as a mechanism of globe malposition. Pfeiffer and King identified the features on plain radiographs which corresponded with blow-out fracture pathology. Information provided by plain radiographs was often presumptive rather than definite, and did not offer any information on soft tissue injury. Therefore, the demonstration of a bone fracture was sufficient evidence for operative exploration.

The major sequelae of blow-out fractures are enophthalmos and diplopia. To remedy these conditions, Converse in 1944 described two surgical procedures for repair of the orbit and fractures of the zygoma. In this classic monograph, he described bone implantation to the orbital floor. In 1950 and 1957 Converse and Smith again described globe displacement in the condition of enophthalmos, with reconstruction by bone grafting procedures.

A nonoperative approach was proposed by DeVoe as early as 1947. He noted that simple blow-out fractures often produced few troublesome late symptoms. He may be considered one of the earliest advocates of conservative treatment. He found the appearance of many patients was acceptable even

---

**Fig. 2.** Coronal CT demonstrates the inferior and medial rectus muscles positioned away from displaced medial and inferior orbital fractures. Upper right arrow is medial rectus, lower lateral arrow is soft tissue in fracture site, and medial arrows are depressed bone of floor and medial wall.

**Fig. 3.** Coronal CT demonstrates a slightly displaced orbital roof fracture. Depressed roof "blow in" fracture is at upper arrow. A hematoma is seen at the lower arrow around the superior rectus and levator.

**Fig. 4.** An extensive fracture involving the frontal sinus, superior orbital rim, internal orbit, and nose. Left: Arrows show, from medial to lateral, a fracture involving the nasofrontal duct (medial arrow), orbital roof (middle two arrows) and lateral orbit (lateral arrow). Right: Axial CT of inferior portion of fracture involving the medial maxilla and unilateral nasoethmoidal area.
though small amounts of enophthalmos were present; frequently, double vision disappeared or was not functionally limiting.

In 1955 Schjelderup drew attention to the contribution of ligaments to globe support. He felt that orbital ligaments principally supported the globe. He also mentioned incarceration of prolapsed orbital tissue in fractures and proposed fibrous scarring within traumatized soft tissue as a mechanism of diplopia. He advocated release of incarcerated soft tissue and repositioning of displaced orbital bones. Implants of fascia were inserted to prevent scarring between fractured bones and orbital muscles.

In 1956 Bordenare produced evidence of extraocular muscles in herniated orbital soft tissue, and postulated muscle and soft tissue entrapment in the blow-out fracture as a mechanism for diplopia.

In 1957 Smith and Regan postulated that hydraulic pressure was the force producing fracture of the thin portion of the orbital walls. They suggested the term "blow-out" fracture to describe fractures of the thin inner portions of the orbital walls. Their findings reinforced Schjelderup's in that replacement of orbital soft tissue into its proper position seemed to minimize fibrosis. Smith and Converse initially felt that waiting beyond one to two weeks for surgical repair allowed scar tissue to set in an improper position. Surgical repair therefore seemed less effective when performed late, as the internal pattern of the scar tissue could not then be modified. They also recognized the difference between fractures of the inner orbit (so called "pure") and fractures of the rim and internal orbit ("impure"), a difference which must be appreciated today with the latter having broader indications for operation.

Fujino later reinvestigated orbital fracture mechanisms, and proposed that most fractures were the result of "buckling" (or bending) forces transmitted to the floor by bending of bones produced by a direct blow to the rim. The rim would not in-fracture itself, but would bend, creating a reciprocal deformation in the area of the floor (a "weak" area remote from the point of force application).

Plain radiographs do not identify the exact relation of the fracture and soft tissue incarceration. Therefore, many surgeons initially recommended operation on all blow-out fractures as they were unable radiologically to separate cases prone to unsatisfactory sequelae. The use of polytomography in orbital fracture diagnosis provided increased detail of the thin bony portions of the orbit, and allowed further definition of these injuries by characterization of soft tissue involvement.

For some surgeons, a vague roentgenologic evidence of a blow-out fracture justified operation, while others (in papers describing blow-out fractures of the orbit without initial diplopia or enophthalmos) implied that all patients did not need or benefit from surgery. Delayed surgical treatment, as described by Converse and Smith in 1961, was proposed for patients not having surgery who had significant residual symptoms. Converse and Smith felt late surgery improved enophthalmos, but was less effective than early surgical restoration. In their experience, stable diplopia was not corrected by bone surgery, it was more effectively managed by direct muscle surgery. Double vision was evaluated by Converse and Smith, Barclay and Bleeker. Converse and Smith in 1960 identified the frequency of diplopia and proposed that vertical muscle imbalance was caused by herniation and entrapment of the inferior rectus and inferior oblique muscles into defects produced by orbital bone fractures. Barclay stressed that diplopia was a result of interference with the excursion of extraocular muscles. He felt that diplopia would not be produced by vertical globe displacement of less than 1.5 cm; but rather, it was the result of scar tissue and neuromuscular damage to nerves and muscles.

In 1971 Nicholson and Guzak documented visual loss after repair of orbital floor fractures. Their reports described complications of surgery and others noted complications associated with orbital implants. These reports tempered enthusiasm for universal surgical treatment. A vigorous debate between surgical advocates and those suggesting observation followed, but did not resolve the issues.

In 1968 Converse strengthened his arguments with a classic paper, "Orbital Blow-Out Fractures: A 10-Year Survey," which reemphasized the benefits of early surgical repair. His experience was drawn from a referral center to which more complex fractures with potentially unsatisfactory outcomes were referred. Perhaps his patients represent a different group than those presenting routinely in emergency rooms. In his paper, late repairs corrected diplopia in only one-third of cases, but incomplete results were obtained with regard to correction of enophthalmos, where one-half of patients were improved. Earlier repairs were more successful. However, opinion remained divided into surgical and nonsurgical therapies. Hotte emphasized the rarity of actual muscle incarceration in blow-out fractures and felt that incarcerated fat, by virtue of its connections to muscle, tethered the muscle indirectly to the fracture site.

Improved understanding of diagnosis and management of blow-out fractures of the orbit was provided by Milauskas in 1969. His thorough study of the clinical, radiological and surgical aspects of or-
bital fracture management provided definition of the types of surgical pathology. The accuracy of radiographic diagnosis, and the soft tissue injury which produced symptoms of diplopia were carefully tabulated.

In 1971 Emery et al\(^{29}\) documented the frequency of spontaneous improvement of symptoms of untreated "isolated" orbital floor fractures. Interestingly, surgery and conservative treatment produced identical results with regard to diplopia. Enophthalmos, however, was improved by surgery. The nonoperative approach to diplopia received increasing emphasis in the literature and initial observation of all patients was recommended. Surgery was reserved only for those who failed to improve.

Smith\(^{29}\) felt that some small orbital fractures were more likely to incarcerate extraocular muscles than large fractures. His interest in the sequelae of smaller injuries persists to the present with his recent description of a compartment syndrome\(^{66}\) (analogous to that described by Volkman\(^{29}\)) producing muscle infarction.\(^{66}\) Tight muscle incarceration in confined fracture defects should be considered for immediate exploration.

The most quoted reference in conservative management was authored by Puttermann et al\(^{29}\) in 1974 with the description of prospective and retrospective treatment of orbital fractures. Patients were separated into surgical and nonsurgical groups. They found that double vision usually resolved in functional fields of gaze without surgical correction. One-fourth of patients had diplopia following nonoperative management, but usually at the extremes of gaze; the diplopia was therefore not functionally limiting. Puttermann diagrammed the anatomical characteristics of the posterior-inferior orbital fat, and showed how limitation of muscle movement would occur from hemorrhage, confusion or scar tissue tethering muscular activity through fibrous septal communications. Hemorrhage, edema, and incarceration initiate muscle and ligament fibrosis, limiting voluntary and forced duction movements of the globe. He then recommended that all fractures be observed for an initial four to six month period in order to determine whom might best benefit from surgical treatment. In 1977\(^{27}\) he described the late management of patients with blow-out fractures of the orbital floor. Stable, functionally limiting diplopia was managed by strabismus surgery. Enophthalmos was managed by alloplastic implants, and ptosis was corrected by a Muellers' muscle conjunctival resection to widen the palpebral fissure. Excision of skin and superior orbital fat deepened the contralateral lid crease to balance the appearance of the enophthalmic eye.

Dulley and Fells in 1974\(^{18}\) divided patients into surgical and nonsurgical candidates based on early resolution of diplopia. They felt that blow-out fractures with radiographic demonstration of large tissue prolapse outside the normal orbit would result in enophthalmos. A positive forced-duction test not resolving within a short period of observation, signs of globe retraction or increased applanation tension on attempted up gaze, or more than 3 mm of enophthalmos were advanced as criteria which justified surgery.

Halveston in 1976,\(^{30}\) also felt that hemorrhage, contusion and fibrosis in posterior-inferior orbital tissues and damage to the inferior oblique or inferior rectus muscles produced motility symptoms.

The argument between surgical and nonsurgical proponents extended internationally to Europe and Japan with vigorous recommendations for preferred options. Hakelius and Pontenz\(^{29}\) in 1973 found that 22\% of patients with midfacial fractures had diplopia. In comparing a series treated within two weeks after the accident with another series in which treatment was delayed, they found that 17\% of patients in the first group reported the presence of diplopia when fatigued, while 83\% had no diplopia. Of patients in Group II, 24\% had diplopia. Their surgical approach focused upon early reduction to minimize persistent diplopia.\(^{24}\) Tajima et al\(^{18}\) also emphasized that late surgical treatment of malunited orbital fractures was more difficult and produced less satisfactory results than early primary treatment.

The most important contribution to improved diagnosis of orbital fractures was provided by 2- and 3-dimensional CT scanning, which quantified the extent of herniation of orbital tissues and identified the pathological relation of the fracture segments to the extraocular muscles. In 1983 Hawes and Dortzbach\(^{28}\) emphasized the role of computed tomography in predicting persistent diplopia and late enophthalmos. Fracture defects involving over 25\% of the orbital floor resulted in enophthalmos, and a fracture "volume unit" scheme was proposed to correlate the size of the fracture defect with the amount of enophthalmos which could be expected. Significant enophthalmos required displacement of over one-half of the orbital floor. Patients with persistent extraocular muscle dysfunction seemed to benefit from early surgical repair (within two weeks of the injury). In 1985, Gilbard et al\(^{22}\) also emphasized the prognostic significance of computed tomography to predict enophthalmos and diplopia. Patients with "large" orbital defects were found to develop enophthalmos in half of the cases. At high risk for persistent diplopia were those cases in which the inferior rectus muscle was positioned adjacent to bone fragments on both sides. Those with "hooked" muscles (the inferior rectus muscle adjacent to a bone fragment on one side) had less diplo-
Fig. 5. Incarceration of the fine ligament system of the orbit is demonstrated with an orbital floor fracture. Fine ligaments run throughout the orbital soft tissue connecting all of the structures to the orbital walls. (Reprinted from: Koorneef LP: Ann Plast Surg 9:185, 1982, with permission of the author and Little, Brown Co., Boston.)

Fig. 6. The orbit is divided into three sections from anterior to posterior. 1) Anteriorly, the orbital rim consists of the supraorbital section superiorly, the naso-ethmoidal section medially, and the zygomatic section laterally and inferiorly. 2) The mid portion of the orbit is thin and fractures first following force application. 3) The posterior portion of the orbit is rarely displaced in orbital fractures. (Copyright, Johns Hopkins University, Art as Applied to Medicine, Reprinted from Manson PN, Iliff N with permission of BC Decker, publisher.)

pia, and those with free inferior rectus muscles had no diplopia.

A comprehensive microscopic characterization of the fine ligament system within the orbit was provided by Leo Koorneef, who in 1982 summarized his views regarding orbital fracture treatment. He showed how the fine ligament system connected all orbital soft tissue structures to each other and to the walls of the orbit. Damage to the ligament system (Fig. 5) was necessary for the production of enophthalmos by permitting herniation of tissue. Incarceration of any portion of the ligament system may produce tethering by restriction of the excursion of an extraocular muscle through the mechanism of fat and fascial entrapment. Entrapped fat with its contained ligament system, therefore, influences diplopia management, and actual muscle incarceration need not be identified on CT scan.

Wilkins and Havins in 1982 reinforced the concept of early treatment in those with persistent symptoms. They surveyed members of the American Society of Ophthalmic Plastic and Reconstructive Surgery for preferences in orbital blow-out fracture treatment. Two-thirds of respondents stated that they operated within two weeks of the injury. One-third waited two to six weeks, and only 2% waited four to six months. The complications of orbital floor exploration were identified in this survey: ectropion (1:220), lid retraction (1:280), and extrusion of the orbital floor implants (1:550). Serious complications were uncommon. Postoperative blindness was identified with a prevalence of 1:500. Diplopia in the primary or down gaze positions not showing evidence of resolution within one to two weeks following injury was identified as an indication for surgical treatment. Enophthalmos greater than 2 mm was also identified as requiring correction on an aesthetic basis.

Antonyshyn and Gruss recently evaluated the results of complex orbital reconstructions in 49 severe fractures, and reported that 12% of patients had residual strabismus and 10% had enophthalmos.

More recent contributions to pure orbital fracture management include that of Millman, who advocated the use of a steroid protocol consisting of 1 mg per kg of prednisone. Steroids hasten resolution of edema in order to unmask patients whose diplopia will not resolve.

Evaluation of Fractures

Presently, the most complete knowledge of normal and pathologic anatomy of the orbit is provided by thin slice computed tomography. True axial and coronal sections combine to reveal the information required for the diagnosis and surgical management of orbital fractures. The relationship of the bony orbit to its soft tissue contents has previously been defined by CT scan, and cadaver
sections.\textsuperscript{1,2,5,43-46,53,54,67} High resolution computed tomography yields information on fracture patterns, muscle relationships and displacement of bone and soft tissue. The optic nerve and the extraocular muscles are all easily visualized and the information may be imaged in multiple planes, such as the longitudinal axis of the optic nerve.\textsuperscript{36} The clinical examination and computed tomography together provide the basis for decisions regarding injury to both bone and soft tissue.

**Surgical Anatomy**

Conceptually, the bony orbit may be divided in anterior, middle and posterior sections (Fig. 6). The anterior third of the bony orbit consists of the orbital rim. This strong section may be subdivided into three parts: the zygomatic portion, forming the lateral and inferior rim, the nasoethmoidal area medially and the supraorbital region, consisting laterally of the strong frontal bone and medially the frontal sinus. In the rim segment, virtually any displacement benefits from reduction.

The middle third of the orbit is composed of thinner bone and includes four sections: the roof, the medial and lateral walls, and the floor. The amount and direction of displacement (increased or decreased orbital volume) plus the relationship of muscles and their adjacent soft tissue to the fracture site are used to characterize patients who might benefit from surgical treatment. Surgical decisions therefore involve two considerations: globe position (orbital volume) and diplopia.

The orbital roof, a thin extension of the supraorbital rim, is bowed both anteroposteriorly and mediolaterally. The arching anteroposterior contour of the roof must be reestablished if reconstruction is required. Reconstruction is most commonly indicated for inferior displacement producing exophthalmos. Both inferior displacement ("blow-in")\textsuperscript{2,25,48} and superior displacement ("blow-out") fractures are equally common. Interference with extraocular muscle function in roof fractures is rare.

The medial wall of the orbit is formed by the thin orbital plate of the ethmoid bone which is reinforced by multiple bony septae. It separates the orbit from the ethmoid sinus. Isolated medial wall fractures\textsuperscript{15} primarily produce orbital volume expansion; rarely do they result in muscle incarceration requiring surgical release.\textsuperscript{14}

The floor and the lower medial orbital wall are the most commonly injured areas of the middle orbit. Blow-out fractures usually involve the floor medial to the infraorbital canal and the lower half of the medial wall of the orbit. Surgery for fractures in the middle third of the orbit is based on evidence of muscle or tissue (fat or ligament) incarceration with symptomatic diplopia, and volume changes which would result in enophthalmos or exophthalmos.

The lateral portion of the middle third of the orbit is formed by the greater wing of the sphenoid bone and the orbital process of the zygoma. Fracture displacement in the lateral orbit allows volume expansion or contraction; lateral wall fractures rarely result in muscle incarceration, but do produce muscle contusion.

The posterior third of the orbit (or orbital apex) is constructed of thicker bone, and contains the superior and inferior orbital fissures and the optic foramen.\textsuperscript{35} Collapse of the thinner anterior and middle orbital bone minimizes transmission of displacement forces to the posterior orbit. Linear frac-
tures in the posterior orbit (apex) may cause symp-
toms of nerve contusion or compression; rarely
does fracture displacement in the orbital apex pro-
vide an indication for surgery. Of note are the con-
ditions requiring optic canal decompression.

Extraocular muscles in the anterior half of the
orbit are located a short distance from the orbital
walls, cushioned by small amounts of fat. Posterior-
ly, the muscles travel adjacent to the orbital walls,
a fact that is easily identified on CT scans. Here,
they are vulnerable to the effects of fracture and to
the trauma of surgical dissection.

The volume and quantity of intraconal orbital fat
is an important determinate of globe position. In
the posterior orbit, most of the fat exists within
the muscle cone. In the anterior orbit, some fat
exists outside the muscle cone along the floor. Su-
periorly, a sausage-shaped extraconal orbital fat
compartment isolates the superior extraocular
muscles from the orbital roof. In orbital fractures,
dystopia of the globe allows superior extraconal or-
tal fat to prolapse away from the upper lid pro-
ducing a "supratarsal hollow." When one elevates
the globe just behind the equator, the contents of
the anterior and middle third of the orbit are dis-
placed upward, and the hollow disappears as the
superior orbital fat is moved forward.

No significant change in globe position occurs
with loss of extraconal fat. Blepharoplasty, for
instance, causes no change in globe position. Loss
of intraconal fat, however, produces enophthalmos
both in clinical cases and in cadavers, and is a
mechanism of enophthalmos in patients with orbit-
al fractures, Romberg's disease and the shrinking
"sinus" syndrome. Fat displacement from the intra-
conal compartment into the extraconal space pro-
duces a loss of effective globe support, and a change
in globe prominence may occur. Fat displacement
produces soft tissue "disorganization"; intraconal
fat is displaced to an extraconal location. The
weaker ligament system in the posterior orbit al-
 lows intraconal fat to be relatively easily extruded to
the extraconal space after fracture. Early bone re-
construction is the only way to replace this fat to-
ward its proper position; late enophthalmos correc-
tions will not reverse this soft tissue disorganization.
Muscle length may shorten after posterior globe
displacement. Late corrections will not reverse this
shortened muscle length, which opposes restora-
tion of anterior globe position. Such considerations
argue for early correction of globe position.

Several studies have emphasized that fat at-
rophy is not the usual mechanism of post-traumatic
enophthalmos; the quantities of soft tissue usually
remain the same post-injury. Probably, 10% of pa-
tients have sufficient post-traumatic fat atrophy that
it may be a mechanism of volume loss. Restoration

of eye position therefore depends primarily on the
anatomical restoration of the shape and the volume
of the bony orbital cavity. This is the best guide that
the surgeon can use to reestablish proper globe
position. Anterior posterior globe position at the
time of surgery provides an inaccurate indication of
final globe position because of edema. At surgery,
vertical globe position, however, bears a better rela-
tionship to final globe level. Anatomic restoration of
the bony orbit must therefore be the guide at sur-
gery. If the bony orbit is restored anatomically, ac-
cetable globe position is usually obtained.

**Physical Examination**

Accurate physical examination is a necessary step
in the characterization of significant orbital frac-
tures. The necessity of fracture repair depends on
the assessment of ocular motility and globe posi-
tion. Significantly decreased ocular motility in the
presence of minimal swelling or hemorrhage is
strongly suggestive of muscle or ligament system
contusion or entrapment. Poor motility is most
commonly due to direct muscle contusion but may
represent entrapment. Forced duction examination
assists differentiation, but must be integrated
with CT findings, and may be positive from hemo-
rrhage, edema or fibrosis.

Early globe position does not predict late globe
position because of edema. Therefore, a normal
globe position is not a criterion for nonsurgical
treatment. A large fracture demonstrable on CT
associated with normal eye position and moderate
orbital swelling implies that late enophthalmos will
develop as swelling subsides.

Surgical repair is indicated, however, by clinical
evidence of enophthalmos, or vertical globe posi-
tional change. Also, positive forced ductions, with
CT demonstration of tissue incarceration or muscle
entrapment, and CT demonstration of volume ex-
pansion or contraction, are indications for surgical
treatment. Acute exophthalmos may simply repre-
sent orbital swelling. If orbital volume reduction is
demonstrated on CT scan, it is evidence supporting
surgical treatment. The exact nature of an orbital
fracture and the need for treatment for enophthal-
mos cannot be determined by physical assessment
alone. The need for diplopia surgery is predicted by
physical examination. Computed tomography ac-
curately demonstrates the exact fracture anatomy
of the anterior, middle, and posterior portions of
the orbit. Both axial (Fig. 7) and coronal views (Fig.
8) should be obtained and it is helpful to have both
soft tissue (Fig. 9) and bone windows. Reformatted
images (Fig. 10) are not as accurate as true axial or
coronal sections in identifying the degree of pathology and to demonstrate the relationship of the
extraocular muscles to the fracture. This critical rela-

Fig. 10. A coronal image reconstructed from axial cuts. It is more difficult to determine the relationship of the extraocular muscles to the bone fracture in reconstructed images. The medial rectus is above the medial arrow; the middle arrow shows a bone defect into the ethmoid sinus; the middle and lateral arrows point the depressed floor fragment; the inferior rectus muscle is seen over the two arrows free of the fracture. Reconstructed images are acceptable only when the patient cannot be positioned for coronal scans.

Fig. 11. A postreduction CT scan of an extensive orbital fracture involving both the orbital rim and the middle portion of the orbit has been treated with internal fixation and immediate bone grafting. The relationship of the extraocular muscles to the large bone grafts is visualized. Metal artifact is present beneath the bone grafts from the rigid fixation devices used to stabilize the rim fracture (Luhr Microsystems, Howmedica, Rutherford, N.J.).

For proper evaluation of an orbital injury, axial scan must begin at the superior aspect of the frontal sinus and progress through the entire orbit terminating at the maxillary alveolus. Coronal sections should begin anteriorly at the nasal pyramid and continue posteriorly through the orbital apex. It should be noted that postreduction CT scans (Fig. 11) can demonstrate the surgical result obtained, and allow evaluation of the accuracy of volume reconstruction. In some cases, spatial conceptualization of fracture displacement is improved with three-dimensional reconstruction (Fig. 12). Although three-dimensional reconstructions provide an additional perspective that may help perception of the displacement or conceptualize the reduction, they are not essential for treatment of the injury. In

Fig. 12. A three dimensional scan of frontal, right zygomatic and bilateral orbital, and nasal fractures provides a perspective but may obscure details of fracture anatomy seen on thin slice tomography. In this treated fracture, a nasal bone graft seen on the lower right image. Malaligned fractures are seen in the orbits, right zygoma and a bone defect is seen in the frontal area.
ORBITAL FRACTURES

Fig. 13. Left: Medial blow-out fractures result in enlargement of the orbit and enophthalmos. The medial orbital fracture is demonstrated with the medial rectus adjacent to the fracture (lateral arrow). Prolapse of soft tissue has occurred to the nasal septum (medial arrow). Right: The posterior margin of the fracture is at the level of the posterior ethmoidal foramen (posterior arrow). The medial three arrows demonstrate the compressed ethmoidal fracture (compare thickness of ethmoids with normal side). The lateral arrow indicates the contused medial rectus muscle.

Summing individual images, they obscure intricate details of fracture anatomy in the middle orbit. They provide no information regarding the relationships of bone and soft tissue.

The inferior oblique and inferior rectus muscles are easily visualized in coronal computed tomography of inferior blow-out fractures (Fig. 8). Frequently, the action of inferior extraocular muscles is compromised following fractures and the muscle, the fat or ligament system may be incarcerated. Although the medial rectus travels close to the medial orbital wall (Fig. 13), actual muscle incarceration is unusual in medial wall fractures. The lateral rectus muscle is immediately adjacent to the greater wing of the sphenoid. In zygomatic fractures, it is frequently contused, but rarely incarcerated. Superiorly, the levator palpebrae superioris is located beneath a small cushion of orbital fat. It is frequently contused in orbital roof fractures but rarely incarcerated.

During inferior orbital exploration, the nerve to the inferior oblique is vulnerable to injury as it travels next to the inferior rectus muscle. A small vascular coupling exists between the infraorbital neurovascular bundle and the inferior rectus in the midportion of the orbital floor. This coupling must often be sectioned during surgical exploration of the floor to provide visualization of the posterior orbit.

Surgical Technique

Anatomic reconstruction of orbital fractures is possible only after complete dissection demonstrates the entire defect by identifying intact normally positioned bone surrounding all edges of the fracture (Fig. 14). Posterior intact bone is known as the intact "ledge." Muscle or ligament incarceration is released in the course of dissection and confirmed by duction examinations. Following complete dissection, orbital rim fractures should be replaced into proper position and initially linked with wires. Final positioning is then accomplished, and secured with plate and screw fixation (Fig. 15). The intact or reconstructed rim and the intact posterior bone "ledge" provide guides for positioning and support for bone grafts or alloplastic material to span the bone gap in the middle portion of the orbit (Fig. 14). Currently our preferred alloplastic implant material is carved Medpor® block or the thinner sheeting which may be shaped with a Tessier® rib contour forcep.

The shape of the bony orbit is concave anteriorly and convex behind the globe, producing a central constriction of orbital volume. The curvature of the orbital walls must be reconstructed exactly in order to achieve proper orbital volume, and proper vol-

Fig. 14. Bone grafting of an orbital floor defect (silhouette over arrows) is accomplished after identification of an intact rim of bone all around the fractured area. One bone graft may be placed over the intact ledge posteriorly and led over the rim anteriorly. Other bone grafts may then be supported on an initial strut of metallic mesh (at arrows) (Luhr Microsystems, Howmedica, Rutherford, NJ).
ume provides for proper globe position. Position must be precise as small differences in orbital rim position produce dramatic differences in orbital volume. The musculo-fibrous ligament system, initially freed by dissection, must have its freedom reconfirmed by repeat duction examinations after graft insertion. Any restriction requires graft removal and reinsertion.

**Recommendations for Early Surgery**

We emphasize bony orbital volume because volume expansion and constriction of the bony orbit are the principal causes of enophthalmos and exophthalmos. Orbital expansion and constriction should replace the old terms “blow-out” and “blow-in” fractures. Fractures with more than 2-3 cc of orbital volume difference begin to produce globe positional changes, and result when over one-half of the orbital floor is involved in fracture displacement. Surgery is therefore discussed on aesthetic grounds with patients who will develop aesthetically significant globe positional change. The need for surgery for muscle incarceration is almost exclusively seen with floor fractures. Medial orbital fractures produce orbital enlargement, and, in fact, the incompletely reduced medial orbital fracture is one of the most common explanations for residual enophthalmos. In CT scans, the thickness of the ethmoidal walls must be compared to the normal side, and the medial orbit grafted to narrow it to the proper dimensions. Only rarely do medial fractures produce significant muscle incarceration.

Similarly, the inadequately reduced zygoma is a common reason for an enlarged orbit. Assessment of alignment in the lateral orbit with the greater wing of the sphenoid is helpful to confirm proper orbital volume.

On functional grounds, patients who have diplopia, with positive forced ductions (and especially those who demonstrate tight incarceration of muscle or adjacent fat in a confined orbital defect) benefit from early release of CT documented incarceration of the musculofibrous ligament system. Occasionally, patients may even benefit from late release of a documented incarceration.

**Single Versus Double Insults to Soft Tissue**

It is our feeling that studies now in progress will affirm the superiority of early versus late repairs for selected injuries, a fact that has been suggested by numerous previous studies. The syndrome of early muscle infarction produced by tight incarceration of the inferior rectus must be identified and corrected urgently. Early restoration minimizes the secondary problems of soft tissue shrinkage over collapsed bone and allows soft tissue healing and scarring to occur in an anatomical position. The injury and the trauma of surgery, if one event, produce the least injury to the soft tissue, as compared with separate injuries from initial trauma and later surgery (a double insult to the soft tissue).

**Final Thoughts**

This review has selectively focused on advances in thought regarding orbital fracture treatment which account for our present treatment philosophy. Many authors are quoted directly; the overview is selective, therefore incomplete, and many deserving contributions are omitted because of space considerations.

The contributions of Putterman are important, but they cannot be applied universally to all orbital fractures nor can they be focused properly without the recent contributions of CT. Putterman identified a group of patients whose injuries did not benefit from surgical treatment. This group is now better defined by CT scans in combination with physical examination. He dealt with only “pure” orbital fractures, and his initial concepts, proposed before the days of CT scans, must be tempered by new information. Things are seldom black or white but shades of gray. Today the CT scan and accurate physical examination allow us to differentiate injuries which benefit from early surgical treatment.

An unfortunate situation sometimes occurs when an ophthalmologist examines a patient with multiple facial fractures that extend beyond the orbital rims and outside the orbit. The consultation note may include a recommendation that “no surgical treatment is necessary.” Although surgery may not be necessary to correct diplopia, frequently it is required for facial aesthetics. The treatment of orbital volume problems and such fractures involves sepa-
rate considerations from those of diplopia, and many fractures do require surgical treatment. Also, treatment for major orbital fractures and combined fractures extending outside the orbit should not be delayed. Putterman's recommendations did not develop from nor can they be applied to fractures extending outside the orbit should not be delayed. Putterman's observations revolutionized fracture management of pure orbital fractures. Now, his recommendations must be integrated with CT evaluations, and focused by the recent experience of other investigators.

References
III. The Conservative Approach. Allen M. Puttermann, M.D., Department of Ophthalmology, Eye and Ear Infirmary, University of Illinois at Chicago, and Michael Reese Hospital and Medical Center and the University of Chicago, Chicago, Illinois

When the eye is struck by an object larger than the orbital entrance, such as a fist, a blow-out fracture of the orbital floor can occur. The force of the blow to the eye is transmitted to the orbital contents and then to the orbital walls. The weakest areas of the orbital walls — the medial wall and floor of the orbit — rupture, and the force of the blow is transmitted into the ethmoid and maxillary sinuses, which absorb the impact like a pressure valve. (This is most likely “nature’s way” of preventing an eye from rupturing.)

When an orbital floor fracture occurs, there can be associated diplopia due to entrapment of orbital fat or the inferior ocular muscles into the fracture site and maxillary sinus. Enophthalmos and hypophthalmos (downward sinking of the eye) can also occur due to displacement of the orbital contents into the maxillary and ethmoid sinuses. Infraorbital anesthesia is another symptom of the blow-out fracture; it is due to injury to the infraorbital nerve as it courses through the orbital fracture. The extraocular muscle motility and infraorbital anesthesia frequently improve, and the enophthalmos and hypophthalmos either persist or worsen as the edema and hemorrhage subside.

When a blow-out fracture of the orbital floor is suspected, a thorough eye examination should be performed. The trauma that causes a blow-out fracture can also lead to a 5–10% incidence of injury to the eye, such as iritis, hyphema, retinal detachment, or glaucoma.

When an orbital floor fracture is suspected, conventional orbital roentgenograms should be performed. If this does not demonstrate a fracture, orbital tomograms or computed tomographic (CT) scans of the orbit should be obtained. (I do not order CT scans routinely for all suspected orbital floor fractures. I do order them selectively to aid in differentiating an entrapped, inferior rectus muscle from a contused inferior rectus muscle or for evaluation of the size of the implant needed to treat late enophthalmos.)

Early Treatment

The treatment of orbital floor fractures remains controversial. From 1950 to 1974, most of these fractures were considered a medical emergency and immediate surgery was advocated. Most sur-

49. Milaukas AT: Diagnosis and Management of Blowout Fractures of the Orbit. Springfield Ill, Charles C Thomas, 1969
69. Volkmann R: Die ischmischen muskella hemungen und frakturen. Centralb Chir 8:801, 1881

The illustrations in this article are copyright, Johns Hopkins Department of Art as Applied to Medicine.

Reprint address: Paul N. Manson, M.D., Plastic Surgery, MIESS, 22 S. Greene Street, Baltimore, Maryland 21201.