Frontal Basilar Trauma: Classification and Treatment

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We report our experience with 14 consecutive cases of frontal basilar trauma occurring in children and adolescents aged 18 months to 18 years (mean 9.5 years). Brain parenchymal injury resulting in functional deficit occurred in 5 patients (36 percent), 2 patients suffered bilateral blindness, and 1 suffered unilateral loss of vision. A classification system and treatment algorithm based on the clinical fracture pattern seen by computed tomography are introduced. Type I, central, is confined to the upper nasoethmoidal complex, central frontal bone, and medial third of the superior orbital rims. Type II, unilateral, involves the entire supraorbital rim and the upper lateral orbital wall, extending into the squamosa of the temporal bone and ipsilateral frontal bone. Type III, bilateral, involves fractures of the upper nasal ethmoidal complex, bilateral supraorbital and upper lateral orbital wall fractures, and bilateral frontal bone fractures. This classification was utilized to plan elective orbital and cranial osteotomies, similar to those used for frontal orbital advancement at the time of acute fracture repair. Frontal orbital osteotomies were used to access the anterior cranial fossa, orbital apices, and nasofrontal ducts and to obtain an intact bony template for side-table reassembly of the fracture fragments. There was no significant operative morbidity, one late cerebrospinal fluid leak, and no infections. Reoperation was necessary in four patients (29 percent) for aesthetic indications. (*Plast. Reconstr. Surg.* 99: 1314, 1997.)

Fractures involving the frontal basilar region are the result of high-energy impact forces and often coexist with other generalized traumatic injuries.[1] Frontal basilar fractures are not isolated to a single anatomic area but rather involve injuries to the superior orbits, nasal ethmoidal complex, and frontal bone, frequently resulting in significant ocular and intracranial trauma. The paranasal sinuses border on the anterior cranial fossa to varying degrees, and fragments of bone from the anterior cranial fossa or superior orbital rims may impinge on the orbital contents.

Current management of frontal basilar trauma relies on relatively limited exposure, through the fracture sites and occasional craniotomy with in situ reduction and rigid fixation of bony fragments, repair of dural tears, and separation of the paranasal sinuses from the dura.[1–7] Lauritzen et al.[4] have popularized side-table reassembly of fracture fragments in complex craniofacial trauma.

Access to the anterior cranial fossa, paranasal sinuses, and superior orbital contents is often inadequate, making repair of dural lacerations, removal of bone fragments, and isolation of the paranasal sinuses from the brain very difficult, if not impossible. In order to facilitate and systematize the treatment of frontal basilar fractures, we have developed a treatment algorithm based on computed tomographic (CT) scan evaluation.[8–10] Radiographic examination reveals three predominant fracture patterns: type I, central; type II, lateral; and type III, bilateral (Figs. 1 through 3). Elective orbital osteotomies were designed, according to this classification, to include traumatized areas, craniotomy bone flaps, and intact bone segments to serve as templates for side-table reassembly (see Figs. 1 through 3).

Patients and Methods

Fourteen consecutive patients (6 females, 8 males), ranging in age from 18 months to 18 years (mean 9.5 years), were admitted with isolated frontal basilar fracture trauma (Table I). All underwent evaluation and stabilization by the trauma service, followed by neurosurgical and craniofacial service evaluation. Preoperative radiographic examination included cervical spinal radiographs and CT scans of the

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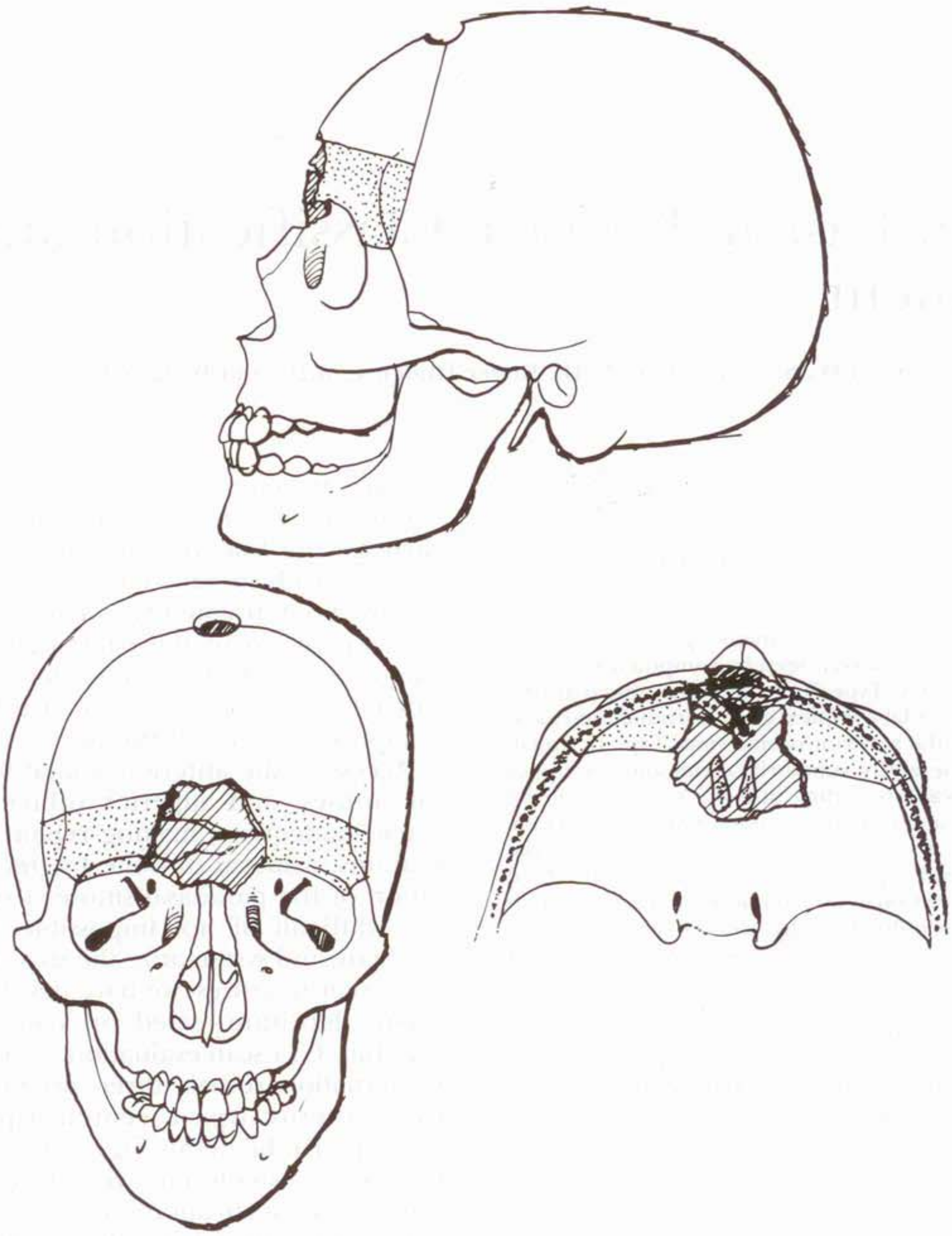

FIG. 1. Drawing of type I central fracture pattern involving superior orbital walls, medial to the supraorbital foramen, upper nasal ethmoidal complex, and middle of frontal bone. *Stripes* mark fractures; *stippled pattern,* elective osteotomy segments; *solid lines,* craniotomy bone flap.

face and cranium. The CT scans allowed us to classify the fractures into one of three patterns (see Table I). Shared characteristics include fractures involving the superior orbits, frontal sinuses, ethmoid sinuses, and anterior cranial fossa with comminution (Fig. 4). *All patients had radiographic evidence of brain injury and dural laceration.* Three patients had no demonstrable vision in one or both eyes at initial evaluation.

All patients underwent simultaneous neurosurgical and craniofacial reconstruction. The treatment algorithm based on fracture pattern was used to plan frontal craniotomy and elective osteotomies (Fig. 5).

The craniotomy bone flap, osteotomized orbital segments, and all fracture fragments were reconstructed as a single unit on a side table by the craniofacial team while the dura was repaired by the neurosurgical team (Fig. 6). The orbital contents were then inspected, and any bony fragments were removed. The frontal sinus was cranialized, on the side table, with removal of all mucosa. The lateral orbital osteotomized bone segments and the craniotomy

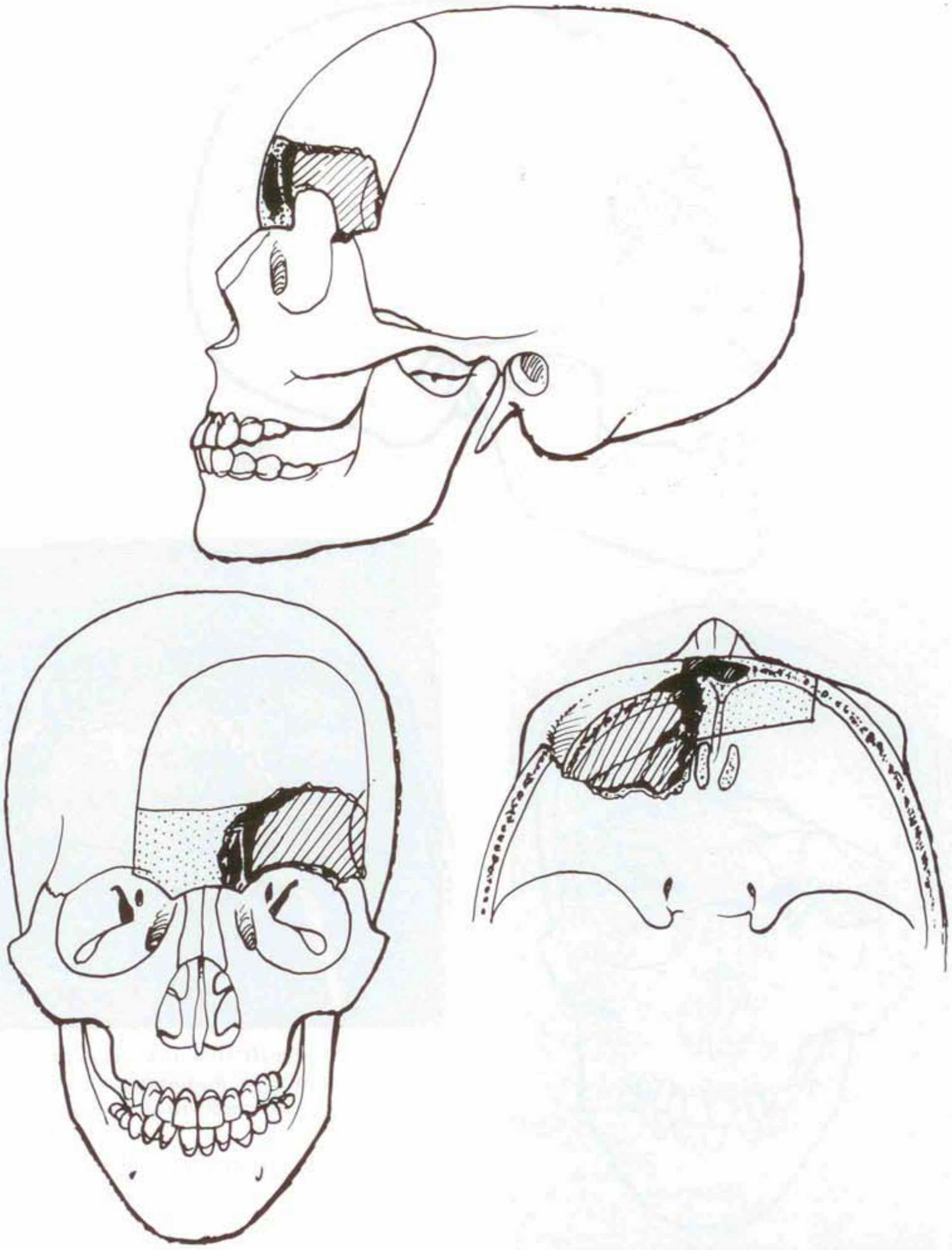

FIG. 2. Drawing of type II lateral fracture pattern involving half the superior orbital wall but not the nasal ethmoidal complex and lateral frontal bone. Frontal sinus involvement depends on the extent of lateral pneumatization. *Stripes* mark fracture; *stippled pattern,* elective osteotomy segments; *solid lines,* craniotomy bone flap.

bone flap were then used as templates for anatomic reassembly of the fracture fragments using microplates and screws (see Fig. 6). When large defects were present in the anterior cranial fossa or nasal frontal complex, split calvarial bone grafts were harvested from the inner table of the frontal bone for immediate repair. Careful removal of ruptured ethmoid air cells in communication with the anterior cranial fossa, as well as inversion of the nasofrontal duct mucosa into the nasal cavity, was carried out. Small temporalis muscle grafts or contoured bone grafts were used to plug the nasofrontal ducts. Anteriorly or laterally based vascularized pericranial flaps were then placed between the frontal lobe dura and the nasal cavity. After completion of the neurosurgical repairs, the entire construct was reinserted into anatomic position and microplated to the intact bordering skull. Lateral canthopexies were

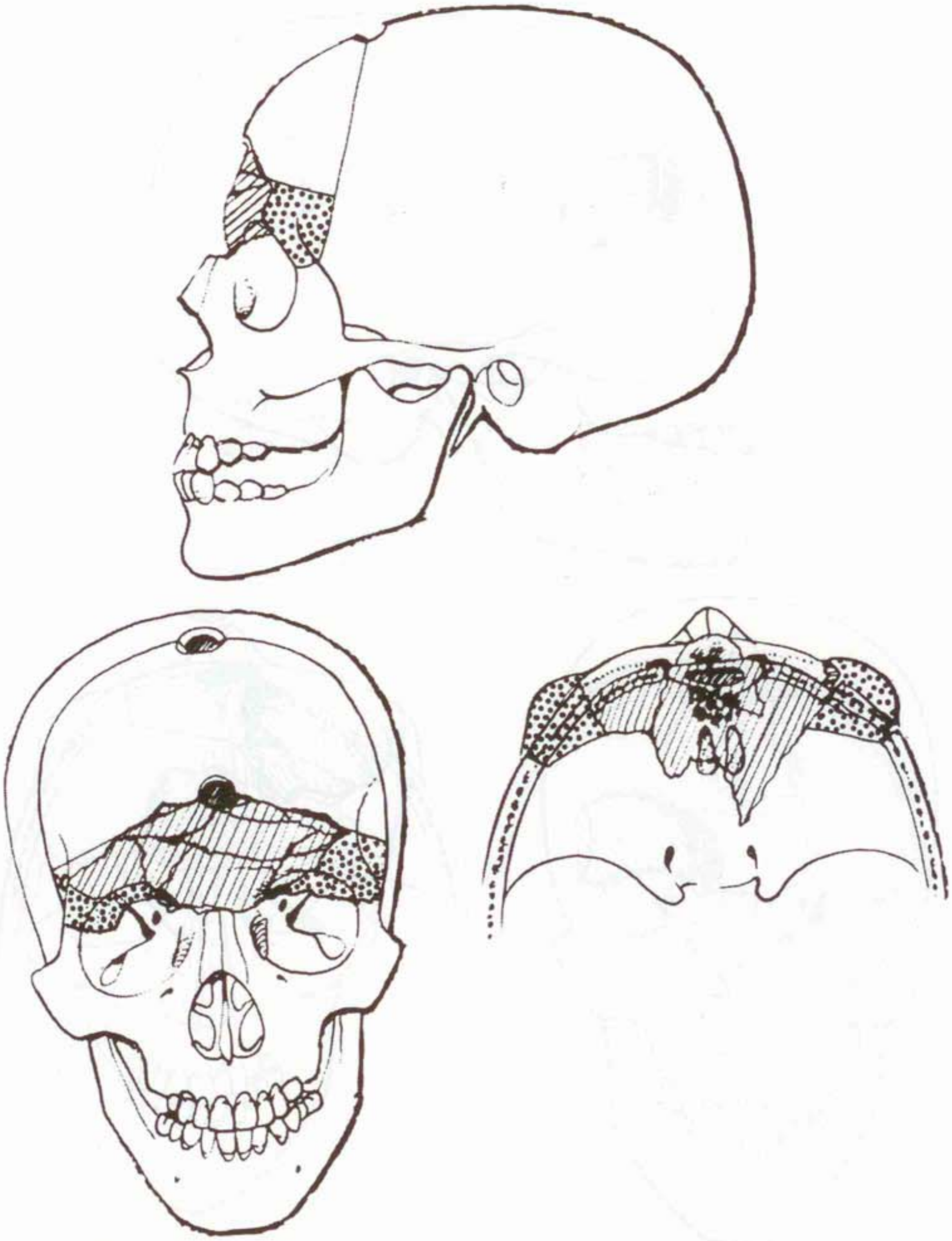

FIG. 3. Drawing of type III bilateral fracture pattern involving both superior orbital walls, upper nasal ethmoidal complex, and bilateral frontal bone segments. *Stripes* mark fracture; *stippled pattern,* elective osteotomies; *solid lines,* craniotomy bone flap.

performed, if needed, and the scalp was closed with absorbable subcuticular sutures and skin staples. Patients were then returned to the intensive care unit for observation. Intravenous antibiotics were continued for 5 days and oral antibiotics for another week.

RESULTS

Follow-up ranged from 6 to 48 months (average 14 months). There were no deaths, no perioperative infections, and no sinus-related problems. One patient developed a persistent cerebrospinal fluid leak from a supracellar dural laceration necessitating reoperation. Ten patients had good aesthetic results, and reoperations were not necessary (Fig. 7). Four patients (29 percent) required further reconstructive surgery for residual bony defects, canthal repositioning, or scar revision (see Table I), and all had type III fracture patterns. None of the patients with preoperative loss of vision regained useful vision in the affected

TABLE I
Characteristics of Patients, Injury Patterns, Morbidity, and Reoperations

Age (years)	Sex	Cause	Pattern	Blindness	Dural Injury	Secondary Surgery
1.5	M	MVA*	I	No	Yes	No
12	M	MVA	I	No	Yes	No
2	F	MVA	II	No	Yes	No
15	M	Ped/MVA	III	No	Yes	Yes
18	M	Fall	III	Unilateral	Yes	Yes
15	M	MVA	II	No	Yes	Yes
8	M	MVA	III	Bilateral	Yes	Yes
13	F	MVA	II	No	Yes	No
2	F	MVA	II	No	Yes	No
8	M	MVA	II	No	Yes	No
4	F	MVA	II	No	Yes	No
18	M	MVA	III	Bilateral	Yes	No
7	F	MVA	I	No	Yes	No
6	F	MVA	II	No	Yes	No

* Motor vehicle accident.

FIG. 4. CT scan of patient with type III bilateral fracture pattern. Note extreme comminution of supraorbital and frontal bones with frontal sinus involvement.

eye. No patients had loss of vision attributable to operative intervention.

DISCUSSION

Manson[1] and others[5–7] have noted, and our experience confirms, that "pure" frontal basilar fractures occur much less frequently than other facial fractures and that they have unique, clinically relevant features. Frontal basilar fractures are the result of high-energy impact and are frequently accompanied by multiple systems trauma, and all involve various combinations of damage to the supraorbital rims, frontal bone, and anterior cranial fossa, often extending to the nasal ethmoidal complex. The complex nature of these injuries dictates cooperation among the trauma surgeon, craniofacial surgeon, neurosurgeon, and

FIG. 5. Preoperative appearance of patient with type III fracture pattern (CT scan in Fig. 4). He was involved in a high-speed motor vehicle accident.

ophthalmologist. In two patients there was bilateral loss of vision secondary to direct trauma to the optic nerve, and one patient lost vision in one eye because of globe rupture. All had type III fractures with extension into the optic cannals. The high incidence of vision loss in

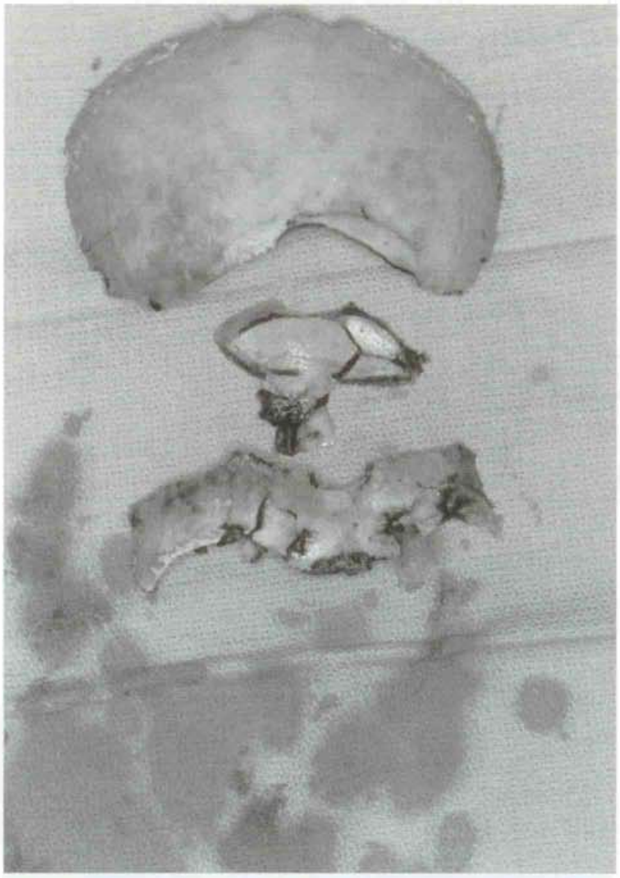

FIG. 6. Intraoperative view of patient in Figures 4 and 5 demonstrating side-table reassembly of fracture fragments, lateral osteotomy segments, and frontal bone flap.

FIG. 7. Postoperative view of patient in Figures 4 through 6. Note essentially normal appearance of frontal bone and supraorbital areas 24 months after original operation. He underwent hardware removal and frontal bone contouring 12 months after original surgery.

bony and supraorbital bony trauma makes preoperative ophthalmologic consultation imperative.[11–15]

In our series of frontal basilar fractures without accompanying midfacial fractures, three distinct patterns emerge (see Figs. 1 through 3). Type I involves the central frontal bone, upper nasal ethmoidal complex, and medial superior orbital rims, with bilateral frontal sinus involvement. Type II is unilateral, involving the frontal bone, ipsilateral superior and lateral orbital rims, and unilateral frontal sinus fractures. Finally, type III involves both superior orbital rims, the nasal ethmoidal complex, and the entire frontal sinus. In all our patients there was significant damage to the dura, frequently accompanied by parenchymal brain damage and/or epidural hematoma. Our proposed preoperative classification system is based on use of computed axial tomography and allows accurate planning of craniotomy site placement and elective osteotomies as well as delineating the extent of dural and parenchymal brain injury. The high correlation between CT scan findings and actual clinical injury has been well established.[8–10]

Our use of elective osteotomies in acute frontal basilar trauma represents an evolution in the application of craniofacial techniques utilized in treating congenital deformities. These principles were pioneered by Tessier and later applied to acute and delayed facial fracture treatment, as exemplified by the work of Wolfe and Kawamoto.[16–19] We observed, during frontal orbital surgery for synostosis, that removal of the frontal orbital segment resulted in excellent visualization of the entire anterior cranial fossa, cribriform plate, nasofrontal duct, and superior ethmoid regions. As Manson[1] has observed, fractures in the frontal basilar region are often associated with injuries to the frontal and ethmoid sinuses, superior orbital rim, and anterior cranial fossa, as well as dural and frontal lobe injuries.[1] Displacement of bony fragments into the soft tissues of the orbit with globe or extraocular muscle injury is also frequently found.[11] Traditional techniques utilizing exposure provided by frontal craniotomy and the removed bony fracture fragments often are limited at best and may necessitate forceful retraction of the frontal lobes. We developed three osteotomy designs, based on the fracture pattern (I to III), to gain maximal exposure of the damaged dura and obtain nontraumatized frontal-orbital bone segments on which to base the bench reconstruction (see Fig. 4). The anterior cranial fossa osteotomies were carried far enough back so that the orbital apex could be visualized directly. The nasofrontal osteotomies were made just above the medial canthal attachments if there was not a major nasal ethmoidal component, in order to include the entire frontal sinus in the osteotomized segment. The nasofrontal ducts were visualized directly and obliterated by this approach while allowing complete removal of all frontal sinus mucosa and cranialization on the side table. With this approach, there have been no late sinus complications to date.

Our reoperation rate of 29 percent is in keeping with other reports with equally severe injuries.[20–22] All these patients had type III injury patterns with severe comminution and displacement of the bony fragments. We had no cases of late enophthalmos, which we attribute to precise repair of the orbital walls, immediate bone grafting, and rigid fixation made possible by the elective osteotomies. The principal reasons for reoperation were palpable hardware and contour defects secondary to bone resorption (see Table I). Bone resorption was confined to the most comminuted areas of the frontal bone. One patient had a cerebrospinal leak 1 week postoperatively from a dural tear that communicated with his sphenoid sinus. It was controlled by packing the sphenoid sinus with fat and septal cartilage.

Our approach could be criticized for increasing the amount of devascularized bone by making elective osteotomies and for adding a degree of complexity to an already complicated clinical problem. We maintain that adequate exposure is crucial to anatomic repair of traumatized structures and that the potential risk of devascularized bone has not been borne out in clinical practice. In the secondary reconstruction patients, we observed that the osteotomized segments were never the sites of bone resorption and maintained their original rigidly fixed positions. The ability to use large, intact segments of the orbits as templates for side-table reconstruction simplifies rather than hinders the operative procedure, allowing a two-team simultaneous operative approach.

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