Traumas that would likely produce fractures in adults often do not in children due to intrinsic anatomical factors. In addition to the unique anatomy of the pediatric patient, future growth and development must be accounted for when addressing these injuries. A growing appreciation of the pediatric craniofacial skeleton's resilience and the utility of late orthodontics is making practitioners more comfortable with conservative strategies. In deciding between operative and conservative management of pediatric facial fractures, the practitioner is essentially weighing the risk of growth disturbance against the benefit of precise reduction and rigid fixation. Craniofacial development, along with the resilience of the pediatric skull and supporting structures, often facilitates a less invasive approach to managing these complex injuries.

Pediatric facial fractures comprise less than 15% of all facial fractures and increase in frequency with age. One review found 54% of fractures to occur in the skull, one-third in the upper and middle thirds of the face, and the remainder in the lower third. In the authors' cohort, orbital fractures were the most common across all age groups. Pediatric orbital fractures represent anywhere from 3% to 45% of facial fractures. Midface fractures are uncommon (10.4% of facial fractures in the authors' series), likely secondary to the protection of the midface by the prominent forehead and mandible in children, in addition to the robust anatomy of this region. Zygomaticomaxillary complex (ZMC) fractures are the most common of the rare midface fractures. Nasal fractures comprise up to 50% of pediatric facial fractures. Nasal and maxillary fractures were the most common osseous injury among infants in the US National Trauma Databank, while mandible fractures supplanted these in older teenagers, with mandible fractures being the overall most common facial fracture. Mandible fractures are often cited as the most common pediatric facial fracture, accounting for 20–50% of all pediatric facial fractures. The prominence of this structure explains these findings. Of mandible fractures in the authors' series (n = 179), condylar head and subcondylar fractures were most common (48%). Anatomical distribution varies with age;
Growth and development

Craniofacial development is the culmination of a complex and incompletely understood interaction between intracellular processes, intercellular signaling, and environmental influences. Cranial-to-facial ratio decreases with maturity from 8:1 at birth to 2:1 in adulthood. Craniocerebral growth is continuous throughout childhood, with the majority of growth occurring in the first year of life. Facial growth is sporadic: it is 40% complete at 3 months, 70% at 4 years, 80% by 5 years, pauses until puberty, and resumes until 17 years of age. The upper face grows secondary to brain and ocular development; midfacial growth follows the development of the nasal capsule and dentition. Orbital growth is complete by 6–8 years and nasal growth is largely complete by 12–14 years. The palate and maxilla achieve two-thirds adult size by 6 years.

Condylar fracture incidence decreases, while body and angle fractures increase.

Demographics

In the authors’ series, there was a 69.3:31% male-to-female ratio. A total of 62.6% of patients were admitted to hospital, and 18.6% to an intensive care unit. In all, 35.9% of facial fractures underwent operative management. Half (48%) of fractures were sustained by patients 12–18 years of age; 6–11-year-olds accounted for 32% of fractures and children under 5 years of age contributed 20% of fractures. Similar patterns have been observed by other authors. Per the US National Trauma Databank, motor vehicle collision (MVC), assault, and falls were the most common cause of facial fracture across all age groups. In the authors’ series, the cause of injury varied by age: violence, assault, and MVC were the most common causes of injury in 12–18-year-olds, while activities of daily living caused the most fractures in 0–5-year-olds. Orbital fractures were the most common fracture type across all age groups. Nasoorbital ethmoid (NOE) fractures were the least common.

Associated injuries

Facial fractures are high-energy injuries, and as such are heavily associated with other injuries. The authors conducted a unique review of all patients with International Statistical Classification of Diseases 9 (ICD-9) codes indicative of facial fracture presenting to the emergency department of their center (n=782). Children were included regardless of whether they were treated operatively or conservatively, or as inpatients, outpatients, by plastic surgery, or by any of the other services handling facial trauma. The goal was to improve patient capture and remove selection bias that may otherwise have been present due to admission status, treating specialty, or need for operative intervention. In this series, excluding soft-tissue injuries, brain trauma was the most commonly associated with facial fractures across all age groups. A total of 55% of patients with facial fractures had associated injuries: 81% of these were considered “serious” and included cardiovascular, cervical spine, or intra-abdominal trauma. Some 47% had neurological injuries (60% of these were concussions), and 3% had ophthalmologic injuries, including blindness. In all, 1.4% died as a result of their injuries.
that do occur are more likely to be incomplete “greensticks.” In addition to mineralization, sinus pneumatization and dental eruption are responsible for the evolving craniofacial load-bearing capacity and subsequent fracture patterns (Figs 31.3 and 31.4). The maxillary sinus is aerated at 12 years of age; the frontal sinus is not aerated until adulthood. Oblique craniofacial fractures precede the Le Fort patterns seen in adulthood as an incompletely pneumatized frontal sinus transmits energy directly from the site of impact to the supraorbital foramen and then to the orbit and zygoma. In one large study, Le Fort fractures were only seen in patients greater than 10 years of age.\textsuperscript{18} Forehead fractures in children may develop into growing skull fractures (documented in 0.6–2% of pediatric skull fractures).\textsuperscript{25} These lesions develop secondary to brain pulsations transmitting through occult dural disruptions and driving a growing bony diastasis. Another consequence of the underdeveloped frontal sinus is an increased incidence of isolated orbital roof “blow-in” fractures.\textsuperscript{26} Blindness also occurs with increased frequency due to the direct transmission of force to the orbit.\textsuperscript{25} Trapdoor fractures are more common secondary to greater bony elasticity.\textsuperscript{27} Children tend to have fractures without enophthalmos or vertical orbital dystopia (VOD), likely secondary to more robust supporting structures existing in this population. Enophthalmos and VOD require composite injury to bone, ligaments, and periosteum allowing for an increase in intraorbital volume (Fig. 31.5).

Isolated midface fractures are rare in children as this region is shielded by the prominent forehead and mandible.\textsuperscript{28} Palatal splits are more common secondary to incomplete ossification of the hard palate. These injuries represent significant potential for growth disturbances secondary to the presence of growth centers in the maxilla and nasal capsule and because the midface is retruded relative to the cranium at this age.\textsuperscript{5,29,30} Incomplete zygomaticofrontal (ZF) suture union leads to fracture dislocations characterized by inferior displacement of the zygoma and orbital floor, further contributing to oblique fracture patterns.\textsuperscript{23} Oblique fracture patterns are also encouraged.

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Fig. 31.3  Pneumatization of the sinuses. Fracture patterns evolve with sinus development.

Fig. 31.4  (A–C) Development of the maxillary sinuses. The maxillary sinus plays an important role in determining how traumatic force will be transmitted through the midface.
by the underdevelopment of the midface skeleton and major buttress systems. Until 10 years of age, the underdeveloped maxillary sinus transmits force to the alveolus, resulting in alveolar fractures instead of Le Fort I fractures. Le Fort IIs are replaced by unilateral NOE fractures. Le Fort IIs are replaced by multiframe fragment oblique craniofacial fractures. The authors have consistently seen oblique fracture patterns in their patients (Figs 31.6–31.8). The less mineralized, more compliant pediatric mandible is more resistant to comminuted fractures. Condylar head and subcondylar fractures are seen more frequently in children due to incomplete ossification and a relatively weak condylar neck (Figs 31.9 and 31.10). While certain regions of the mandible are classically highlighted as growth centers (e.g., condyles and lingual tuberosity), condylectomy and differential masticatory strain studies point to a more diffuse,

dynamic process by which morphological change proceeds via coordinated bone deposition and resorption.\textsuperscript{24} Heightened awareness of potential growth disturbance and temporomandibular joint (TMJ) ankylosis is, however, justified in the setting of condylar fractures given an incomplete understanding of these injuries’ implications.

### Diagnosis and presentation

The importance of a consistent approach to craniofacial trauma cannot be overemphasized. The first step in treating acute craniofacial injuries is ensuring that the trauma ABCs have been completely addressed. The craniofacial surgeon’s most direct interaction with this process will likely be in assuring a secure airway in cases where anatomy has been severely distorted. While infants are obligate nasal breathers, their nasal airway is relatively narrow and thus easily obstructed.\textsuperscript{32} Meticulous hemostasis must be achieved given a child’s relatively decreased blood volume and ability to mask significant losses with normotension prior to rapid decompensation.\textsuperscript{32,33} Hypothermia is also more likely to be problematic given a child’s increased surface area-to-volume ratio.\textsuperscript{32}

A systematic physical exam is performed. Eyelid hematoma, hearing loss, hemotympanum, and cranial nerve (CN) palsy may herald skull base fractures. Exophthalmos and inferior globe displacement may represent a supraorbital or roof fracture. Ppitis may be present secondary to levator paralysis. Orbital trauma will likely be accompanied by periorbital ecchymosis and subconjunctival hematoma. Extraocular muscle restriction may cause diplopia (Figs 31.11 and 31.12). Forced duction is required to rule out muscle entrapment in obtunded patients. Superior orbital fissure syndrome (internal and external ophthalmoplegia (CN II, IV, VI paralysis), proptosis, and CN V paresthesia) and orbital apex syndrome (superior orbital fissure syndrome with blindness secondary to CN II involvement) must be emergently addressed (Fig. 31.13). In nasal-orbital-ethmoid fractures, a bowstring test (palpation of the bony medial canthal attachment on lateral distraction of the lower eyelid) will assess the integrity of the medial canthal tendon. Intraorbital distance is assessed to exclude traumatic telecanthus. Gaze limitations – even if other clinical signs and symptoms are minimal and radiographic studies are equivocal – may represent entrapment in an entity termed the “white-eyed blowout fracture.”\textsuperscript{34}

Maxillary mobility and malocclusion may represent midface fractures. ZMC fractures may be accompanied by upper buccal sulcus hematoma, epistaxis secondary to a fractured maxillary sinus, a preauricular depression, cheek flattening, or lateral canthal dystopia. Impingement of a depressed zygomatic arch on the coronoid process may yield trismus. Medial lateral wall displacement with subsequent decrease in orbital volume may yield exophthalmos (Fig. 31.14). Nasal deviation, compressibility of the nasal dorsum, and septal hematoma must be appreciated on exam. Nasal airway obstruction may represent septal hematoma.

Many pediatric patients are in mixed dentition; aside from ware facets, preinjury dental records are the surgeon’s only ally in establishing preoperative occlusion. Occlusive splints can be fabricated based on these materials. Signs and symptoms consistent with mandible fracture include malocclusion,
Patient selection

In deciding between operative and conservative management of pediatric facial fractures, the practitioner is essentially weighing the risk of growth disturbance against the benefit of precise reduction and rigid fixation. Below is a fracture-specific discussion of anatomical and developmental factors to aid the practitioner in making informed decisions on a fracture-by-fracture basis. While some favor delaying intervention until swelling resolves, others note the pediatric craniofacial skeleton’s resilience: loose fragments may adhere within 3–4 days of injury. Converse advocated prompt repair in the 1960s. The authors maintain that if the decision is made to operate, this should be done early so long as the degree of swelling is not prohibitive.

Indications for operative management of cranial base and skull fractures include significant displacement, cerebrospinal fluid (CSF) leak persisting despite conservative measures, intracranial hematoma, deformed facial contour, frontal-lobe contusion with mass effect, and growing skull fracture.

In adults, there are fairly straightforward criteria for operative management of orbital fractures (fracture area greater than 1 cm² or if over 50% of an orbital wall is involved). Other indications include superior orbital fissure syndrome and frontal-temporal-orbital fractures resulting in exophthalmos. Operative indications in children are less clear; it is likely that enophthalmos and VOD are less likely in children secondary to more robust orbital periosteum and supporting ligaments (Fig. 31.5). Stronger supporting structures may render open reduction, internal fixation (ORIF) less necessary in these fractures. The authors analyzed operative necessity in the context of a three-group orbital fracture classification system (n = 81): type 1, pure orbital fractures (limited to the orbit without extension to adjacent bones); type 2, craniofacial fractures (oblique fractures extending from the skull into the orbital roof and face); type 3, orbital fractures contributing to described patterns (impure blowout, ZMC, NOE) (Table 31.1). Type 1 fractures were nonoperative (88%) unless there was evidence of acute enophthalmos, VOD, or muscle entrapment on forced duction. Type 2 fractures were managed conservatively and tracked with serial scans until an absolute operative indication was encountered (17% were ultimately operative). Type 3 fractures were more likely (72%) to require operative intervention. Overall, 23 (28.3%) orbits were managed operatively. Success with this conservative strategy is evidenced by a low rate of adverse outcomes.

Conservative management is indicated for minimally displaced and greenstick midface fractures, especially in younger children. Displaced and unstable fractures require ORIF. Nasal fractures warrant immediate intervention if a septal hematoma is evident. While closed reduction is often inadequate secondary to insufficient release of tension on the septum, cartilages, and bony pyramid, aggressive open treatment in children has significant potential to affect facial growth adversely. Therefore a closed reduction is usually offered to children with definitive open management delayed until skeletal maturity.

Dentoalveolar fractures are usually nonoperative, while displaced mandibular fractures require operative management unless there is a clear indication for ORIF. Many have significant displacement; however, it is not always necessary to perform ORIF. In younger children, conservative management is preferred due to the risk of growth disturbance.
management. Conservative management is warranted if these fractures are isolated, minimally displaced, and occlusion is preserved. Assuming preserved occlusion, the operative indications for condylar fractures are more controversial. The pediatric condyles ("vascular bony sponges") are regarded as growth centers, sensitive to disruptions of blood supply and morphology with resultant susceptibility to ankylosis and altered mandibular development. Intracapsular injuries should be managed conservatively to minimize growth disturbance and TMJ ankylosis; the pediatric mandible has the potential to undergo restitutial remodeling (condylar head regeneration). Some argue for a more aggressive approach to dislocated condylar neck fractures in older children since the condyles are less likely to regenerate in children greater than 7 years of age, and may require eventual osteotomy and cartilage grafting for TMJ function and normalization of occlusion. In the case of bilateral neck fractures in the older patient, ORIF of one side is reasonable, with a short
Patient selection

Other indications for open management include a foreign body in the TMJ, failure to normalize occlusion with closed management, and a condyle displaced into the middle cranial fossa. Every effort should be made to avoid open management for intracapsular fractures, high condylar neck fractures, coronoid fractures, and any fracture in which there are no barriers to motion and baseline occlusion is preserved. \(^{17}\) A condylar head fracture in the presence of another mandible fracture is an indication for ORIF of the other fracture to allow for early TMJ motion.

Of the 96 consecutive patients in the authors’ series, 53% underwent operative management. \(^{16}\) Each child undergoing surgery had a 64.7% chance of an adverse outcome as compared to 45% in children receiving conservative therapy. However, none of the adverse outcomes recorded (i.e., limited

![Computed tomography (CT) scans](image)

**Fig. 31.8** Computed tomography (CT) scans in the axial plane demonstrate an oblique fracture at the level of the cranium (left) and cranial base (center). Right, the CT scan represents a sagittal reconstruction of the same patient, with the course of the oblique fracture outlined in red.

![Anatomical vocabulary](image)

**Fig. 31.9** Anatomical vocabulary pertaining to the mandibular condyle. The condylar head is green (except its articular surface, which is blue), the condylar neck is yellow, and the subcondylar region is orange. Vague terminology in reference to these structures often causes confusion in the clinic and in the literature.

### Table 31.1 The authors’ orbital fracture classification system

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>Pure orbital fractures</td>
</tr>
<tr>
<td>1a</td>
<td>Floor fractures</td>
</tr>
<tr>
<td>1b</td>
<td>Medial wall fractures</td>
</tr>
<tr>
<td>1c</td>
<td>Roof fractures</td>
</tr>
<tr>
<td>1d</td>
<td>Lateral wall fractures</td>
</tr>
<tr>
<td>1e</td>
<td>Combined floor and medial wall fractures</td>
</tr>
<tr>
<td>Type 2</td>
<td>Craniofacial fractures</td>
</tr>
<tr>
<td>2a</td>
<td>Growing skull fractures</td>
</tr>
<tr>
<td>Type 3</td>
<td>Orbital fractures associated with common fracture patterns</td>
</tr>
<tr>
<td>3a</td>
<td>Fractures of the floor and inferior orbital rim</td>
</tr>
<tr>
<td>3b</td>
<td>Zygomaticomaxillary fractures</td>
</tr>
<tr>
<td>3c</td>
<td>Naso-orbitoethmoid fractures</td>
</tr>
<tr>
<td>3d</td>
<td>Other fracture patterns</td>
</tr>
</tbody>
</table>
TMJ opening, persistent pain) was of functional significance.

**Treatment/surgical technique**

**General principles**

Certain principles may be applied to the management of all pediatric craniofacial fractures. The younger the patient, the higher the threshold for operative intervention. While it is critical to visualize fracture lines adequately, periosteal stripping should be minimized as, in accordance with Moss and Salentijn’s “functional matrix” principle, stripping may adversely affect growth and development. Growth disturbances are felt by some to be minimized by using absorbable plating systems in skeletally immature patients.

**Cranial base/frontal skull fractures**

Goals of cranial base and skull fracture repair include protection of the neurocapsule, dural reconstruction and control of...
CSF leaks, prevention of infection, and aesthetic restoration of craniofacial contour. A functioning sinus capable of adequate drainage through growth and development must be achieved. A coronal incision allows for craniotomy and ORIF (Figs 31.15–31.17). After exposing fractures with subperiosteal dissection, fracture fragments must be removed to inspect the underlying dura. Epidural hematomas are evacuated and dural lacerations are repaired by the pediatric neurosurgical team. The bone fragments are then replaced and fixated. Caution must be exercised in manipulating frontal-temporal orbital fractures given the proximity to the middle meningeal artery. With patients mature enough to have a frontal sinus, Rodriguez et al. present a useful algorithm of approach. If the nasofrontal duct is obstructed, obliteration or cranialization is indicated (Fig. 31.18). Advantages of cranialization over obliteration include wide exposure of the injured area and single-stage elimination of the sinus as a potential focus of infection. If the duct is traumatized but still patent, nondisplaced anterior and posterior table fractures can be carefully followed. Severely displaced anterior table fractures can be reconstructed. If the frontal sinus is preserved, serial CTs must be followed to ensure proper sinus development and adequate drainage, and the nasofrontal ducts may be stented via an endonasal approach. The presence of a CSF leak directs management decisions regarding frontal sinus fractures. Leaks are observed for 4–7 days of bed rest and possible lumbar drain, and cranialization performed if the leak persists. If the leak stops, and the nasofrontal duct is unobstructed, the sinus may be preserved. In the case of an auto-corrected leak with an obstructed duct, anterior table ORIF is accompanied by “partial obliteration” (use of fracture fragments to obliterate only the nasofrontal duct and the base of the frontal sinus) following complete removal of sinus mucosa.

Bone loss is a difficult problem, especially in children too old (over 2 years) to heal large calvarial defects spontaneously, yet in whom split calvarial grafts are unavailable due to an underdeveloped diploic space (under approximately 9 years). Significant donor site morbidity (infection, pain, hemorrhage, and nerve injury) in up to 8% of patients, as well as low tissue yield, limits the usefulness of autogenous bone grafts. Bone substitutes are limited by a lack of biocompatibility and susceptibility to infection. In patients with favorable wound conditions, the authors favor a bilaminate construct composed of intra- and extracranially placed biodegradable mesh with interposed demineralized bone matrix mixed with bone dust and chips. The authors are optimistic that a potential future role exists for protein therapy in pediatric craniofacial reconstruction.

**Orbital fractures**

The goals of orbital fracture treatment include the restoration of globe position and the correction of diplopia. If ORIF is necessary, the transconjunctival approach to the orbit is preferred secondary to good cosmesis and a lower risk of ectropion. If lateral exposure is necessary, a subciliary or mid-lid incision avoids the lateral cantholysis that would be necessary with a transconjunctival incision. If medial exposure is necessary, a transcaruncular approach with/without a coronal incision is performed. A gingival buccal sulcus incision can be added if necessary. Herniated tissues are reduced from the fracture, the fracture is cleared of debris, and stable foundations for fixation and grafting are identified. When reduction is achieved, the residual defect is repaired with resorbable materials.
Fig. 31.16 Fracture of frontal bone.

Fig. 31.17 The fracture shown in Figure 31.16 has been reconstructed according to the method depicted in Figure 31.15.

Fig. 31.18 Galea flap pedicled at the level of the brow have been raised to line the reconstructed anterior cranial base. A maneuver such as this is required to ensure that a barrier is in place to protect the intracranial contents from “the outside world.” (Reproduced from Guyuron B, Eriksson E, Persing J, et al. Plastic surgery: indications and practice. Philadelphia, PA: Elsevier; 2008.)

Fig. 31.19 Coronal computed tomography scan demonstrating orbital reconstruction with split calvarial grafts (the image on the right is a magnified view of the area outlined in red in the image on the left).

mesh or split calvarial graft (Fig. 31.19). Care must be taken to resuspend midface soft tissues.

Maxillary and midface fractures

Minimally displaced maxillary fractures in young children may be managed conservatively with a soft diet. Palatal split fractures may require ORIF or may be splinted with mandibulo-maxillary fixation (MMF). Incompletely developed dentition renders arch bars difficult to apply, often requiring creative strategies such as circummandibular wiring and piri-form suspension wiring (Figs 31.20 and 31.21). Depending upon the patient’s age, shorter courses of MMF are acceptable: some authors advocate fixation for 1 week or less, followed by dental elastics in the very young. When ORIF is necessary, the operator must avoid injuring developing tooth buds when plating the facial buttresses.
Treatment/surgical technique

Zygomaticomaxillary complex fractures

Operative goals in ZMC fracture management include resolution of orbital injury (VOD, enophthalmos), correction of malocclusion, and the restoration of appearance (malar flattening). The zygoma is aesthetically responsible for the malar eminence, and an inferiorly displaced zygoma may displace the lateral canthus with it by way of the tendon’s attachment to Whitnall’s tubercle. Access to the ZF suture may be gained through a subciliary incision, a subconjunctival approach with lateral cantholysis, or the lateral portion of an upper-lid blepharoplasty incision. Additional exposure is obtained with an upper buccal sulcus incision. Some authors have reported that medially impacted large fragment fractures may be addressed through an upper gingival buccal sulcus incision alone with exposure of the anterior face of the zygoma, fracture reduction, and confirmation of orbital floor continuity with endoscopy via the maxillary sinus.\(^{25}\) It is generally accepted that adequate reduction at the lateral wall of the orbit or the greater wing of the sphenoid is essential to proper reconstruction; reduction must also be achieved at the lateral orbital rim / ZF suture, inferior orbital rim, and the zygomaticomaxillary (ZM) buttress. Fixation is then performed sequentially at the ZF suture, the inferior orbital rim, and the ZM buttress. The operator must ensure that orbital volume and morphology are not altered by the initial injury or the reduction, and floor reconstruction may be required in the procedure.\(^{26}\)

Nasal and naso-orbital ethmoid fractures

Nondisplaced or minimally displaced fractures may be externally splinted. In the case of a displaced fracture, due to the significant potential for growth disturbance with aggressive open management of nasal injuries in children, many favor acute closed reduction and external fixation whenever feasible. An elevator or knife handle may be passed endonasally to outfracture depressed nasal bones and maxillary frontal process fragments. Conversely, infracture may be achieved with digital repositioning. The septum may be relocated with Asch forceps. When necessary, fractures are splinted internally and externally. Septal hematomas must be managed early with an incision through the mucoperiostium. If bilateral septal incisions are made, overlap must be avoided as septal perforation may result. Dead space may be eliminated with septal quilting sutures or internal splints to compress the mucoperichondrium to the septal cartilage.

NOE fractures are characterized by posterior and lateral displacement of the nasal bones and medial orbital rims, with fractures of the medial orbital walls and ethmoids. A free medial orbital rim segment containing the insertion of the central canthus (the “central fragment”) (Fig. 31.22) results in traumatic telecanthus. Even if not immediately apparent, telecanthus may develop 7–10 days after trauma. Intercanthal distance must be restored to age-specific norms (Table 31.2) by reduction of the medial orbital rims. If necessary, the medial canthal tendons are reattached with transnasal wires passing superior and posterior to the posterior lacrimal crest. A cantilever bone graft is employed to restore the nasal dorsal

<table>
<thead>
<tr>
<th>Age</th>
<th>Normal interorbital distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>10–15 mm</td>
</tr>
<tr>
<td>2-year-old</td>
<td>20 mm</td>
</tr>
<tr>
<td>12-year-old</td>
<td>25 mm</td>
</tr>
<tr>
<td>Adult</td>
<td>35 mm</td>
</tr>
</tbody>
</table>

100 = dacryon to dacryon or 100 = medial intercanthal distance (MICD): 4–6 mm.

Fig. 31.21 Drop piriform wires being placed for mandibulomaxillary fixation in a pediatric patient. (Reproduced from Guyuron B, Eriksson E, Persing J, et al. Plastic surgery: indications and practice. Philadelphia, PA: Elsevier; 2008.)
mandibular border and a dental bridle wire may be adequate in combination with a short course of MMF (Fig. 31.23). Transosseous wiring and bicortical screws may be considered after 11 years of age (or as early as 8 years of age for symphyseal fractures). 17

Postoperative care

In the postoperative period, appropriate rest and supervision are paramount in preventing undue stress to operative repairs. Steroids may be given after extensive manipulation of the orbital contents. The surgeon should maintain a low threshold for aggressive evaluation (i.e., CT scan, ophthalmologic evaluation, etc.) after orbital surgery in the presence of unexpected pain, regardless of visual acuity. For nasal fractures, if intranasal splinting is used, it may be discontinued after 1 week, and external splints should remain in place for 2 weeks. Antibiotic prophylaxis is used if internal splints are employed. Mandible fractures warrant a period of jaw rest. If conservatively managed, stabilization can be enhanced with a cervical collar, jaw bra, or Ace wrap. Depending upon the patient age, some argue that metallic fixation used for ORIF should be removed once adequate healing has occurred to minimize growth effects.

Outcomes, prognosis, and complications

General principles

Outcomes and complications in pediatric facial fractures are understudied. A broad range of complication rates in the
literature (2.6–21.6%) implies vague documentation of these injuries.\textsuperscript{18,55,56} Photographic, radiographic, and functional documentation over time is essential in developing literature to inform our ongoing treatment of these potentially life-altering injuries. Meaningful outcomes analysis in this field is dependent on improved standardization of data collection.\textsuperscript{57} To this end, the authors have introduced a classification system to facilitate the clear characterization and discussion of adverse outcomes in these injuries.\textsuperscript{68} Type 1 complications are intrinsic to the fracture itself (i.e., blindness following orbital fracture, tooth loss following mandibular fracture). Type 2 complications are directly secondary to an intervention: conservative or surgical management (i.e., ectropion following subciliary incision, enophthalmos following orbital fracture repair). Type 3 complications are subsequent to growth and development with potential contributions of the fracture itself and subsequent treatment (Table 31.3).

Infection, nonunion, and malunion are rare in comparison to adults secondary to increased osteogenesis, less frequent indications for open reduction, and a lower frequency of severely displaced fractures in children.\textsuperscript{13} To the contrary, disturbances in growth and development secondary to facial trauma and its management are a common concern. Growth disturbance secondary to facial trauma is, however, an incompletely understood phenomenon. The contribution of hardware to growth retardation is not clear. In one study, the authors report 6 of 96 children with facial fractures undergoing ORIF to have experienced delayed or restricted growth. As they state, however, it is impossible to separate the developmental effects of fixation from other intrinsic and extrinsic factors.\textsuperscript{59} Mustoe et al. concluded that closed reduction of nasal fractures is not deleterious for growth;\textsuperscript{60} invasive rhinoplasty is similarly benign according to Ortiz-Monasterio and Olmedo.\textsuperscript{61} Other authors express significant concern for subsequent growth effects.\textsuperscript{62,63} Complete resection of the septum, as in hypertelorism correction, is well documented to have devastating effects on the growth and development of the midface.\textsuperscript{64} Metallic cranial hardware may pose a direct hazard to growing children as it may translocate intracranially secondary to cranial bone deposition (Figs 31.24 and 31.25).

### Cranial base/skull fractures

These injuries may be complicated by CSF leak, meningitis, sinusitis, mucoceles, mucopyoceles, or brain abscesses. CSF leaks usually resolve spontaneously within 1 week; if the leak persists, a 5–7-day lumbar drain trial should precede operative intervention.\textsuperscript{65,66} A cranial base fracture with an occult dural disruption may lead to a “growing skull fracture” secondary to cerebral pulsations enlarging even innocent-appearing cranial base fractures. Growing skull fractures complicate 0.03–1% of skull fractures, and usually occur in patients younger than 3 years of age.\textsuperscript{67,68} Missed growing skull fractures may lead to gliosis, lateral ventricular dilation, and cerebral herniation, pulsatile exophthalmos, and VOD.\textsuperscript{25} In the authors’ series, 40% of patients with skull fractures exhibited an adverse outcome: type 1: 5%, type 2: 20%, and type 3: 35%, including growing skull fractures, CSF leaks, enophthalmos, VOD, ptosis, amblyopia, and exophthalmos.

### Orbital fractures

The most worrisome adverse outcomes of orbital reconstruction include persistent diplopia and enophthalmos.
Enophthalmos can be measured objectively by exophthalmometry or subjectively by noting posterior displacement of the globe on worm’s-eye view, asymmetry of the upper eyelid creases, and asymmetry in the distance between ciliary margin and superior and inferior limbus. Enophthalmos can sometimes be corrected by orbital floor or wall bone grafting, but may require osteotomies and bony relocation and possibly lateral or medial canthal adjustment. In the authors’ series, 10.7% of isolated orbital fractures suffered adverse outcomes: type 1: 3.6%, type 2: 3.6%, and type 3: 3.6%. Three patients with isolated orbital fractures had enophthalmos, all less than the clinically significant threshold of 2 mm. Persistent diplopia did not occur in the authors’ series, but was reported to be as high as 36% in a study by Cope et al.41,69

Nasal fractures
Nasal fractures may result in an appearance deformity or functional airway obstruction. Nasal deviation may result from cartilaginous warping or incomplete reduction. An untreated septal hematoma may yield septal thickening or perforation, and ultimate saddle-nose deformity. Excessive callous formation and bony overgrowth may lead to a dorsal hump. One study reports a 5% rate of late lacrimal obstruction after ORIF of NOE fractures. This is managed with dacrocystorhinostomy.70 In the authors’ series, 21.7% of nasal fractures exhibited adverse outcomes (type 1: 8.7% and type 3: 17.4%) consisting of persistent nasal deformity or airway obstruction.71 Secondary corrective surgery should be delayed until after skeletal maturity unless clinically significant nasal airway obstruction is present.

Zygomaticomaxillary complex fractures, maxillary and midface fractures
Adverse outcomes following ZMC fracture repair include persistent V2 hypothesia, enophthalmos, VOD, facial widening, malar flattening, canthal deformity, and ectropion secondary to lower-lid approaches. Maxillary fractures may result in nasolacrimal obstruction or malocclusion. Zygomatic-coronoid ankylosis may occur after severe zygomatic fracture.23

Mandible fractures
Mandible fractures may be complicated by growth disturbances or functional impairment such as malocclusion,
advancement genioplasty or distraction. Secondary correction of enophthalmos requires anterior globe repositioning, reduction of the orbital contents, and osteotomy and repositioning of skeletal components. VOD may require four-wall osteotomies for optimal results. Diplopia is most likely to occur secondary to extraocular muscle dysfunction as opposed to globe malposition; the inferior rectus and superior oblique are the muscles most commonly involved. Growing skull fractures require dural repair and cranioplasty. Hardware removal may be indicated to minimize growth disturbances, avoid risks associated with transcranial migration, or if the hardware is causing discomfort or aesthetic concern.

Conclusions

The craniofacial skeleton undergoes a dramatic structural and topographical metamorphosis as it matures from the infant to the adult state. The neonatal skull is profoundly different from its adult counterpart, and therefore responds to traumatic forces with unique injury patterns. Specific functional and aesthetic criteria must be met in reconstructing the various regions of the pediatric craniofacial skeleton. These objectives must be achieved with strategies that properly balance respect for future growth. Craniofacial development, along with the resilience of the pediatric skull and supporting structures, often facilitates a less invasive approach to managing these complex injuries.

Access the complete references list online at http://www.expertconsult.com.

This large series describes more than 900 pediatric facial fracture patients. Demographics and associated injuries were assessed.
This is an excellent review of the literature pertaining to human mandible development. It sets the stage for the companion article, “The pediatric mandible: II. Management of traumatic injury or fracture,” also cited here.
Frontal sinus fractures often represent difficult management decisions. Here, an extensive clinical experience is distilled into a practical, clearly presented algorithm.
BMP-2 is shown to address subtotal cranial defects effectively in a rabbit model. Clinical implications are discussed.
This review presents an introduction to BMP-2 for craniofacial surgeons. Topics range from molecular mechanisms to clinical concerns.