Pediatric Panfacial Fractures

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KEYWORDS

• Panfacial trauma • Pediatric facial fracture • Craniofacial growth

KEY POINTS

- Pediatric craniomaxillofacial trauma differs from that of adults in terms of management, epidemiology, injury pattern, and long-term growth.
- Although pediatric panfacial fractures are rare, they are associated with polytrauma that risks severe morbidity and mortality and requires high-acuity multidisciplinary care.
- The surgical management of pediatric panfacial fractures is generally more conservative not only due to inherently augmented healing and remodeling capacity but also due to concern over future growth impairment.
- Undertreatment of displaced fractures in the pediatric population, however, may lead to deformities in adulthood that are exceedingly challenging to treat secondarily.

INTRODUCTION

Although rare, pediatric panfacial injuries pose significant bony and soft tissue reconstructive challenges owing to anatomic differences and the potential for future growth and development. Manson and colleagues defined panfacial fractures as those involving the upper (frontal bone), middle (midface), and lower (occlusal unit) facial thirds (**Fig. 1**A).[1] Contemporaneous definitions have broadened to include fractures of the midface and mandible because reconstruction follows the same principles as those for a true panfacial fracture (see **Fig. 3**A).[2–4] In pediatric patients, facial trauma often involves the soft tissue or dentoalveolar structures.[5] The presence of multilevel injury is frequently indicative of a high-energy trauma with potential life-threatening consequences that must be appropriately prioritized according to Advanced Trauma Life Support (ATLS) protocols.

Management of pediatric facial fractures is more conservative than that of adults to minimize deleterious effects on future growth and development. In the largest reported series of pediatric panfacial injuries, Dalena and colleagues reported an operative rate of 46% with most patients managed nonoperatively to preserve osteogenic and growth potential.[4] Nevertheless, surgical indications for fracture fixation relate to the presence of displaced fractures. Undertreatment of displaced pediatric fractures often results in exceedingly challenging end-stage deformities encountered at skeletal maturity. Limited soft tissue dissection, autogenous bone grafting, and fixation using titanium or resorbable devices are used to minimize the appearance of premature aging while yielding appropriate anatomical reduction and stable fixation.

Unlike the adult population, operative sequencing of pediatric panfacial fractures may favor a top–down rather than bottom–up approach due to routine conservative management of critical growth centers including the mandibular condyle.[4,6,7] Similar to the adult population, dissection and fixation should extend from stable to unstable regions to appropriately reestablish facial width, height, and projection.

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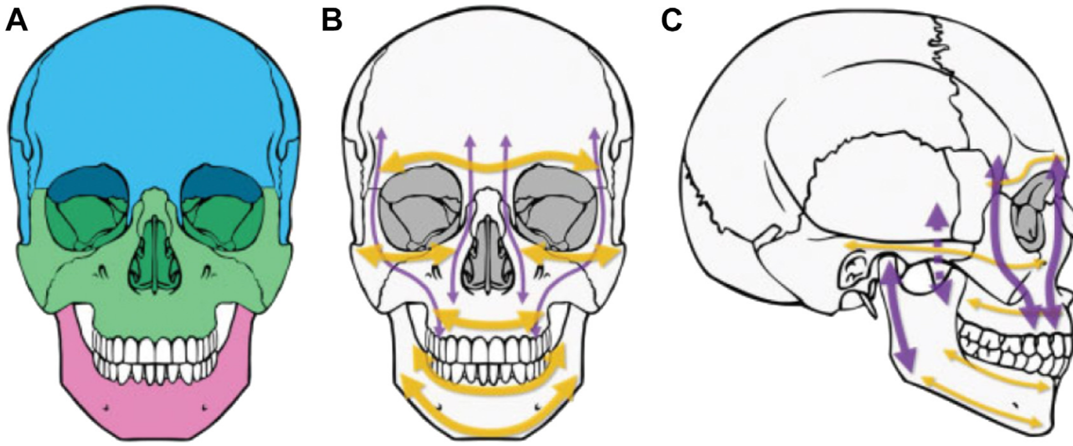

Fig. 1. (*A*) Three bony subunits of the face. Frontal bone and cranium (*blue*), midface (*green*), and mandible (*pink*). The midface consists of the maxilla, zygoma, nasal, lacrimal, ethmoid, and palatine bones. (*B*) Horizontal buttresses (*gold*). Supraorbital bar, infraorbital rims and zygomatic arch, lower maxillary and palate, upper mandibular, and lower mandibular buttresses. (*C*) Vertical buttresses (*purple*). Posterior vertical mandibular, pterygomaxillary, maxillary-zygomatic-frontal, and the medial maxillary naso-frontal buttresses. (*From* Massenburg BB, Lang MS. Management of Panfacial Trauma: Sequencing and Pitfalls. Semin Plast Surg. 2021;35(4):292-298. Published 2021 Sep 23.)

Pediatric Facial Anatomy and Fracture Patterns

The various regions of the craniofacial skeleton achieve skeletal maturity at different times, which correlates with the variable patterns of facial fractures seen in growing children. Upper, middle, and lower facial growth occurs in a cranial to caudal direction from infancy to adolescence. The cranial-to-facial ratio begins at 8:1 at birth with prominent frontal projection and decreases to 2:1 at maturity, which accounts for the comparatively increased incidence of cranial vault fractures and severe head injury observed in the pediatric population.[8] By 2 years of age, the neurocranium has achieved 75% of its growth. By 10 years of age, the neurocranium has achieved 95% of its growth potential, although facial growth lags behind at 65%.[9] Unlike cranial growth, which demonstrates continuous development, facial growth demonstrates discontinuous growth until adolescence.[9] Specifically, facial growth at 3 months approximates 40% of its adult growth potential, 70% at 2 years, and 80% at 5 years. The completion of facial growth subsequently occurs during the pubertal growth spurt.[9] Consequently, facial fractures occurring during the periods of mixed dentition and the pubertal growth spurt may lead to facial asymmetry, particularly if displaced and untreated.

Craniofacial growth centers include cartilage/synchondroses and sutures/periosteum.[10–12] With sinus aeration beginning around 4 to 5 years (as early as 2 years), maturation of the frontal sinus occurs throughout puberty. Underlying brain and ocular signaling determines maturation of the upper face and orbits, with orbital growth typically complete by 6 to 8 years. Maxillary sinus pneumatization correlates with dental development, as the sinus reaches the nasal floor around 12 years when most of the permanent dentition has erupted. The septal midface drives nasomaxillary growth while the condylar growth center dictates posterior height. Alveolar development during eruption of the permanent dentition drives vertical maxillary growth.[5] The mandibular symphysis fused around 2 years, which coincides with the eruption of the primary dentition. Muscle activation signals vertical mandibular growth at the condyles, with bony surface remodeling continuing into puberty.[13] Enlow's theory of apposition and resorption (ie, bony deposition on one side followed by resorption on the other) helps to explain maxillary and mandibular growth.[14] Furthermore, Moss's "functional matrix" theory highlights the importance of the periosteum as a major contributor to bone formation.[10] Applying this conceptual framework to management, subperiosteal exposure of fractures in pediatric patients should be limited only to the extent required to visualize the fracture and apply fixation.

With increasing age, pediatric facial fracture patterns shift in frequency from a cranial to caudal direction. Anatomic factors associated with this change include further development of the midface and mandible and increased bone mineralization, which decreases bony elasticity after age 2 to 3 years.[9] The lack of well-developed facial buttresses results from unerupted dentition, decreased paranasal sinus pneumatization, and increased cancellous bone.[9] Unlike the characteristic LeFort fracture patterns observed in adults, pediatric facial fractures typically present in oblique orientations due to these distinct anatomic differences.[15,16] These obliquely oriented fractures extend across the prominent frontal bone, radiate into the anterior cranial base, and extend across the orbit into the maxilla while typically sparing the mandible.[9,15]

Epidemiology of Pediatric Facial Fractures

Although a detailed epidemiologic overview will be discussed in another article, a brief review is critical to understand the complexities posed by multilevel pediatric facial trauma. In a review of the National Trauma Database, Imahara and colleagues identified 277,008 pediatric trauma patients with 4.6% sustaining facial fractures.[8] The proportion of patients with facial fractures increased with increasing age, suffered from unrestrained blunt trauma (eg, motor vehicle collision [MVC]), and was more likely to be men and Caucasian.[8] Nasal and maxillary fractures were most common in infants, whereas mandible fractures were most common among teenagers. A quarter of patients underwent operative fracture fixation during their initial hospitalization, with increasing age predicting operative management—unsurprisingly, only 11% of toddlers aged 2 to 4 years underwent operative management.[8]

As described above, key anatomical differences help to explain the overall decreased incidence of pediatric facial fractures when compared with adults. Craniofacial disproportion, underdevelopment of the paranasal sinuses, added bimaxillary strength from unerupted dentition, relative micrognathia, well-developed fat pads, compliant sutures, and a viscoelastic skeleton are protective mechanisms unique to the pediatric population.[8,9,17–22] The finding of displaced facial fractures in the pediatric patient consequently suggests a high-energy mechanism and the possibility of severe concomitant injuries outside of the craniofacial skeleton. Based on the Abbreviated Injury Scale, patients with facial fractures demonstrated a 2-fold increase in their Injury Severity Scores, when compared with patients without facial fractures.[8] The prevalence of brain injury, skull base fracture, cervical spine fracture, and blunt cerebrovascular injury were considerably higher among patients found to have facial fractures.[8] Moreover, the facial fracture cohort had a 3-fold increase in intensive care length of stay, 2-fold increase in total length of stay, increased ventilator requirement, and higher mortality rate (4.0 vs 2.5%).[8]

CLINICAL EVALUATION

The increased incidence of severe concomitant injuries to the head and chest that typically accompany pediatric bony trauma necessitates age-appropriate ATLS protocols that prioritize the primary survey and resuscitation while deferring management of potentially "distracting" craniofacial injuries to the secondary survey.[5,23] As head and neck trauma accounts for more than 66% of child abuse, nonaccidental trauma should be suspected if there are inconsistences in the history, prolonged duration between injury and presentation, noncompliance, and/or multiple presentations.[24,25]

Airway management may be challenging in the context of inherently flaccid pharyngeal and anterior laryngeal structures that may be concomitantly injured leading to hypoxia.[5] Associated comminuted mandible fractures may lead to tongue base collapse owing to decreased support of the genioglossus and geniohyoid muscles anteriorly.[3,26] Established mechanisms for airway control including oral intubation, nasal intubation, submental intubation, and tracheostomy.[27] Oral intubation may affect appropriate reduction and fixation of the occlusal unit unless there is the absence of occlusion or absent teeth to allow for posterior placement. Nasal intubation limits comprehensive management of nasal and naso-orbito-ethmoid (NOE) fractures and may be contraindicated in the setting of skull base injury. Submental intubation, which is less morbid than a tracheostomy, allows for the management of complex midface fractures and restoration of the occlusal unit but may be contraindicated in comminuted mandible fractures that require a transcervical approach.[28] Tracheostomy may ultimately be indicated to secure a stable airway away from extensive craniomaxillofacial injury, however, carries its own complication profile.[27]

Arterial bleeding may be present from wounds involving the scalp, tongue, and/or nose. Large scalp wounds may be temporarily controlled with staples or tacking sutures while the nasal passages may be packed with intranasal gauze or Foley catheters to tamponade anterior nasal bleeding. Posterior midface bleeding may require prompt interventional embolotherapy.[29] Hypotension and hypothermia are inherent risks for the pediatric polytrauma patient in the setting of increased cardiopulmonary compensation despite significant blood loss and increased body surface

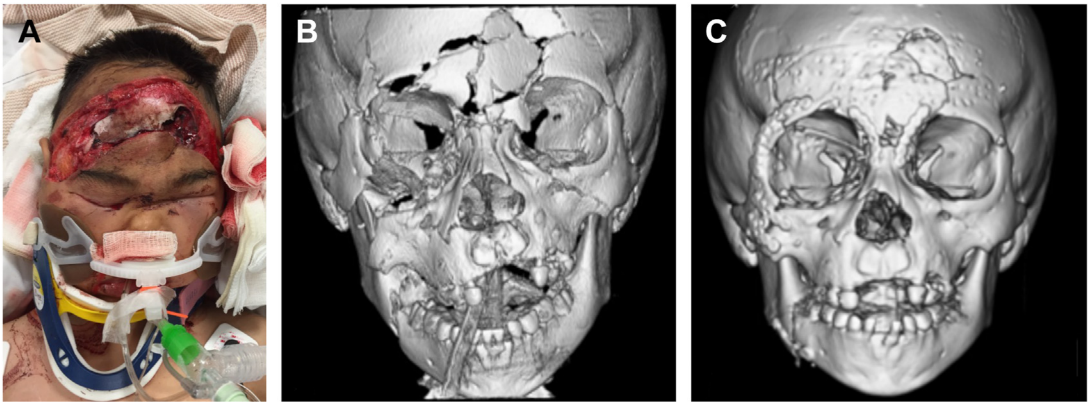

Fig. 2. (*A*) Traditional panfacial presentation. A 5-year-old boy involved in an all terrain vehicle (ATV) rollover presenting with panfacial fractures. Secondary survey is notable for a large transverse full-thickness forehead laceration with open, comminuted fractures of the frontal bone. (*B*) Preoperative CT imaging. Underlying fractures include comminuted, displaced frontal bone fractures, severely displaced right LeFort 1/2/3 fractures, mild-to-moderately displaced left LeFort 2 fracture, and severely displaced right mandibular body fracture with malocclusion. (*C*) Immediate postoperative fracture fixation. Through a top–down, outside–in approach, he underwent ORIF of his bifrontal bone fractures using a resorbable plating system followed by titanium fixation of the right zygoma and the bilateral NOE segments. Following established of midface width and projection, he underwent upper titanium fixation of his right maxilla along the zygomaticomaxillary "buttress" to restore midfacial height through an upper sulcus intraoral approach. Finally, he underwent titanium fixation of the right mandibular body using monocortical fixation along the inferior border through an extraoral approach to control for lingual splay. The remaining nondisplaced and mildly displaced fractures were allowed to heal and remodel.

area:volume ratio.[5] As previously discussed, the increased risk for intracranial, ocular, and cervical spine injuries highlights the importance of prompt neurosurgical and ophthalmologic evaluation to preserve brain, vision, and hearing function. In infants and toddlers, the cervical spine should be carefully supported despite radiographic clearance given their increased cranial-to-facial ratios and increased cartilaginous component of the vertebral column.[24] Periorbital fractures and injuries with concern for visual loss should be promptly evaluated by ophthalmology.

Physical examination should include assessment of characteristic signs and patterns suggestive of underlying fractures such as hypertelorism, Battle sign, malocclusion, trismus, entrapment, periorbital ecchymoses, paresthesia, otorrhea, and rhinorrhea (Fig. 2A).[24] Computed tomography (CT) imaging serves as a critical diagnostic and surgical planning tool especially for maxillofacial fractures that may be greensticked or nondisplaced (Fig. 2B). High-dose CT imaging risks the development of cataracts, whereas low-dose CT imaging compromises visualization of the overlying soft tissues and intracranial structures.[5] Plain film radiography may be of limited value in fracture detection due to distinct pediatric anatomy including developing tooth buds and nonpneumatized sinuses, for example.[30–32] In panfacial trauma, a systemic review of imaging in a top–down approach, for example, helps to ensure identification the full catalog of facial injuries.

Sequencing

Unlike the adult population where fracture fixation may be delayed within 7 to 14 days of injury in the setting of prohibitive localized edema, malunion may develop within 3 to 4 days of injury given the enhanced healing potential of pediatric patients.[24] In the setting of panfacial injuries, reconstructive principles include (1) preservation of brain, vision, and hearing function; (2) stabilization of open mandible fractures; (3) provisional skeletal support until definitive reconstruction; (4) preservation of the soft tissues including neurovascular and ductal elements, cranial nerves, and lacrimal system; (5) systematic fracture fixation planning; (6) limited bone grafting in the setting of precise sequential fracture reduction; and (7) soft tissue reconstruction.[29] In general, panfacial injuries compromise the relationship between the occlusal unit and skull base with a loss of customary structures needed for anatomic alignment (Fig. 1B, C).[2] Gruss and colleagues popularized the top–down/outside–in approach, which begins with establishing facial width along the frontal bar and cranial base articulation (Fig. 2A–C).[33] This approach serves as the historical preference for plastic surgeons owing to their comparative comfort with establishing facial width and projection.[34] Markowitz and Manson popularized the bottom–up/inside–out approach, which focuses first on the occlusal unit and has been championed by oral and maxillofacial surgeons.[29,35–37] Often, patient presentation will dictate one approach over the other in the setting of significant comminution of the occlusal unit or cranial bone, for example.

Operative considerations include working from stable bone to unstable bone, adequate sequential bony reduction of displaced fractures, avoiding unnecessary grafting of malreduced segments, and careful autologous bone grafting of severely comminuted or missing bone.[3] Autologous bone grafting may be obtained from the iliac crest, rib, or cranium.[38] Incision patterns follow standard approaches utilized in the adult population in addition to utilization or extension of preexisting lacerations. Additional pediatric considerations include conservative treatment of greenstick-type fractures owing to a comparatively increased periosteum-to-bone ratio, iatrogenic injury to growth centers from extensive periosteal stripping, growth suture restriction from rigid fixation, and evolving scar formation.[5,39]

Top–down/outside–in approach

Cranium and orbital roof Existing scalp lacerations or a formal coronal incision may be used to access the fronto-orbital region. Goals of frontal bone management include correcting the cranial contour especially along the supraorbital ridge, adequate fracture reduction with relation to other cranial bones, and management of cerebrospinal fluid (CSF) leak. The pediatric cranium, which is more elastic than the mature bicortical skull, can develop “ping pong” or nondisplaced linear fractures that are challenging to identify and treat.[5] These fracture types, as well as growing skull fractures, are covered elsewhere in this volume.

Interestingly, children who sustain significant trauma to the frontal/glabellar region may develop hypoplasia of the frontal sinus—as seen in patients who undergo fronto-orbital reconstruction for craniosynostosis in infancy.[39,40] Although nondisplaced fractures do not require operative fixation, displaced fractures or underlying injuries to the nasofrontal ducts require reduction and fixation. After the frontal sinus has pneumatized, operative management mirrors the algorithmic approach utilized in the adult population.[41] Before frontal sinus aeration, direct cranial trauma may propagate along the orbital roof toward the orbital apex, resulting in injury to the optic nerve, dura mater, and brain with associated hypoglobus, proptosis, gaze restriction, and pulsatile exophthalmos.[5,42] Associated intracranial injury, bony fragment impingement, and ocular findings (eg, exophthalmos, mechanical gaze restriction, lid ptosis, ophthalmoplegia, and vision loss) warrant surgical repair in the form of open reduction and fixation or removal and replacement with autologous bone via a coronal approach and bifrontal craniotomy.[5,43] An anteriorly based pericranial flap may be utilized to reinforce an underlying dural repair if there is any concern for CSF leak.

Zygoma and Orbit

Once the fronto-orbital frame has been reestablished, the zygomatic body and arches are reduced to narrow the facial width, correct orbital dystopia, and restore appropriate malar projection. Displaced zygoma fractures may be managed similarly to the adult population with the caveat of avoiding fixation-related damage to unerupted maxillary dentition. Consequently, fixation can be limited to the superior portions of the zygomaticomaxillary complex in the setting of increased capacity for pediatric bony remodeling (see Fig. 2C).[5] Inadequate reduction of the facial width results in a commonly observed broad, flat facial appearance in panfacial injuries.

Orbital floor fractures in children occur following pneumatization of the maxillary sinuses.[39] Fractures with true extraocular muscle entrapment warrant urgent treatment within 8 hours to prevent critical muscle ischemia, Volkmann’s type contracture, and subsequent motility issues, which can portend a need for strabismus surgery.[44,45] Unlike the adult population, entrapment of the periorbita results from increased elasticity and greenstick-type fractures observed in pediatric patients. The mechanism involves blunt ocular trauma that transiently increases intraocular pressure and temporarily displaces the orbital floor into the maxillary sinus. The inferior periorbital tissues subsequently herniate into the maxillary sinus. Once the intraocular pressure normalizes, the displaced orbital floor returns to its anatomic alignment, leaving the periorbita/inferior rectus muscle trapped within the sinus.[5,39] Orbital entrapment remains a clinical diagnosis with examination findings including extraocular movement restriction, diplopia, increased scleral show of the contralateral eye during upward gaze (ie, “white eye fracture”), and oculocardiac reflex with vagally mediated symptoms including nausea, vomiting, bradycardia, and hypotension.[5] Reconstruction can be performed through a transconjunctival or transcutaneous incision as part of panfacial fracture exposure. Following reduction of the periorbital contents, autologous bone graft from the iliac crest, rib, or cranium (eg, split cranial bone graft or pericranial shave graft) may be used for orbital floor reconstruction.[5,45] Recently, resorbable alloplastic materials have demonstrated equal efficacy when compared with autologous grafts.[46]

Naso-Orbito-Ethmoid and Nasoseptum

Once the upper, outer bony support (ie, frontozygomatic) has been established, the medial vertical buttress can be restored. NOE fractures account for less than 1% of pediatric facial fractures but present significant reconstructive challenges as a significant portion of patients ultimately require revision to restore appropriate projection of the nasal dorsum and correct secondary telecanthus.[9] Similar to the adult population, NOE fractures are classified and treated according to the same Markowitz system.[5,8,47] Lopez and colleagues proposed nonoperative management of Type I fractures, case-by-case operative management of Type II fractures depending on the presence of permanent dentition, degree of displacement, and presence of open fracture, and consistent operative management of Type III fractures with transnasal wiring, canthal barb resuspension, or suture canthopexy.[5,48]

The increased cartilaginous composition, bony elasticity, and decreased dorsal projection of the pediatric nose results in relative protection of the nasoseptal unit when compared with the adult population.[5] However, this increased deforming capacity results in increased septal distortion and increased risk of hematoma, which must be promptly drained to prevent abscess and saddle-nose deformity. When possible, nonoperative or closed reduction of nasoseptal fractures should be performed due to the septum's role as a critical growth center. Nevertheless, severe injuries of the central midface result in the loss of nasoglabellar support that benefit from open reduction and/or reconstruction in the form of dorsal nasal cantilever bone grafting to restore adequate projection.[3,49]

Occlusal Unit

Following central midface reconstruction, the remaining panfacial injuries relate to the occlusal unit (**Fig. 3**B, C). Unerupted maxillary dentition and the lack of maxillary sinus pneumatization in patients aged younger than 5 years provide relative protection against maxillary fractures. Similar to adult reconstructive principles, the medial and lateral maxillary buttresses should be restored through reduction and/or judicious autologous bone grafting if needed. Iatrogenic growth disturbances can be avoided by limiting subperiosteal dissection and appreciating future dental compensation in patients presenting with injuries during the period of mixed dentition.[5] In severely displaced fractures requiring open reduction and internal fixation, patients should be counseled on future growth impairment in the form of nasomaxillary hypoplasia telecanthus, and/or vertical growth deficiency.[50]

Once the maxillary width is restored, a palatal split may be fixated using hardware or a prefabricated splint based on the preinjury arch width. Interdental fixation remains a challenge in the pediatric population and securing wires may need to pass around the zygomatic arch or piriform through the palate using a passing trocar to avoid injury to primary or developing dentition.[5] If there is significant maxillary comminution or easier access to the mandible, maxillary reconstruction can be deferred until after mandible fixation. Alternatively, lower midface fractures may be allowed to heal with an understanding that expectant malocclusion, tooth loss, and/or contour irregularities will require subsequent orthognathic surgery, osteointegrated implants, and onlay grafting/alloplastic reconstruction.[39] Proponents of this approach cite the cleft literature, which documents undergrowth of the maxilla in the setting of periosteal elevation of the hard palate.[51]

Assuming prior fixation of the midface with restoration of the maxillary width, the mandible can then be placed into alignment. The presence of developing tooth buds and increased bony elasticity results in pediatric mandible fractures that are typically nondisplaced or mildly displaced. Growth centers located along the condyles, posterior border of the ramus, and dentoalveolus favor conservative management of pediatric mandible fractures, given their remarkable remodeling capacity (**Fig. 3**D, E). Mild malocclusion may resolve spontaneously with eruption of the permanent dentition and subsequent remodeling with growth. Consequently, minimally-to-mildly displaced pediatric mandible fractures may be reasonably managed with observation and a soft, nonchew diet.[5] With the top–down/outside–in approach, open fixation of a mandibular condylar fracture can be avoided, which is especially important in the growing mandible. Injury to the condyle, whether posttraumatic or iatrogenic, can lead to growth arrest and temporomandibular joint bony ankylosis, resulting in retrognathia, facial asymmetry, malocclusion, and limited mouth opening.[39] Several studies have demonstrated reasonable results concerning subsequent growth following conservative treatment.[52,53] Stratifying by dentition, Lopez and colleagues suggested nonoperative management of condylar fractures in the

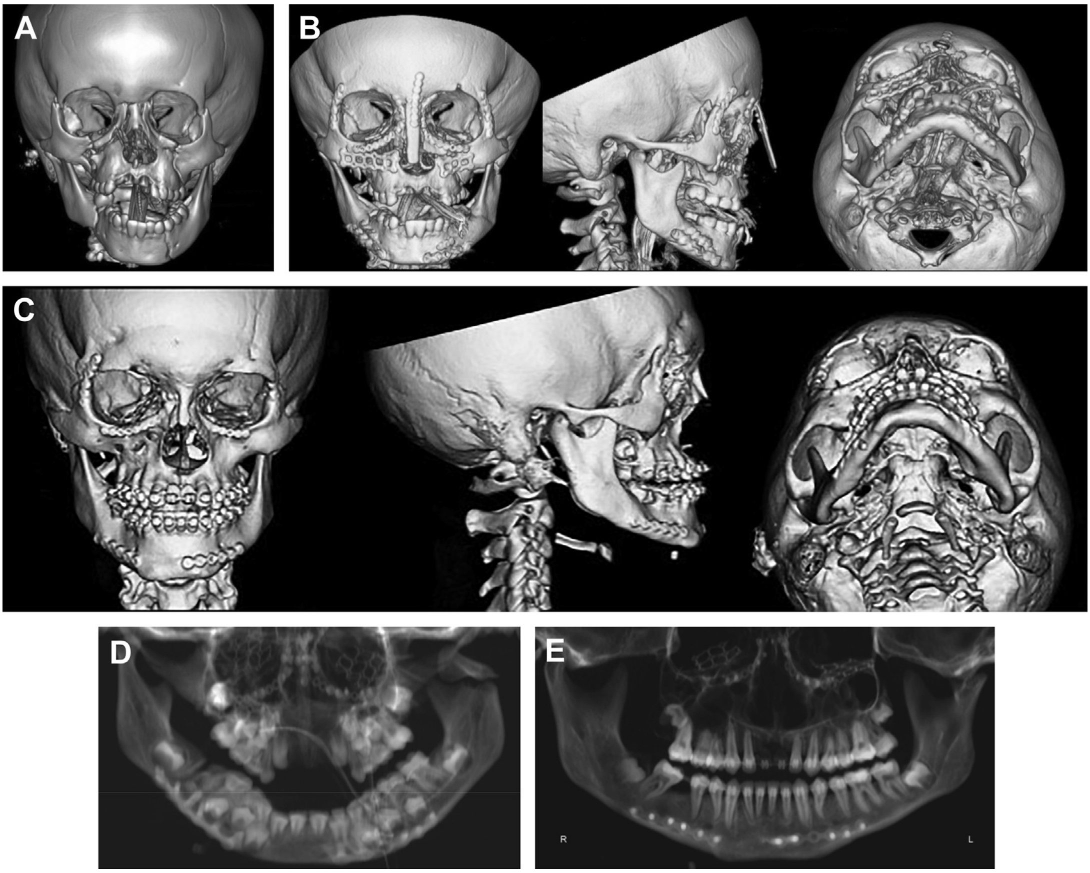

Fig. 3. (*A*) Contemporaneous panfacial presentation. A 6-year-old girl involved in an MVC presenting with significant injuries to the occlusal unit while sparing the frontobasilar region. Preoperative CT imaging is notable for displaced bilateral LeFort 1/2/3 fractures and 4-piece mandible with severely displaced right body, minimally displaced left parasymphysis, and displaced left subcondylar fractures. (*B*) Immediate postoperative fracture fixation. Through a top–down, outside–in approach, she underwent open reduction and internal fixation (ORIF) of bilateral zygoma fractures from to restore facial width followed by bilateral orbital floor reconstruction using titanium mesh implants to correct orbital dystopia and ORIF of bilateral NOE fractures with cantilever reconstruction of the nasal dorsum using split cranial bone graft to restore central midfacial projection. Next, she underwent spanning ladder plate reconstruction of the maxilla from the zygomatic body to the nasomaxillary buttresses to restore midfacial weight and set the midfacial height. Finally, she underwent ORIF of her right mandibular body fracture using inferior border and tension band plates through an extraoral approach to control for lingual splay and ORIF of his left mandibular parasymphyseal fracture through an intraoral approach. Given the inherent benefit of the top–down approach and general avoidance of the condylar growth center, the displaced left subcondylar fracture was managed nonoperatively. Conventional titanium plate fixation systems were utilized. (*C*) Interval growth. CT imaging obtained at 12 years of age, nearly 6 years postoperatively demonstrates interval facial growth with significant healing and remodeling. Note removal of the lower midfacial fixation plates and mandibular tension bands at 8 years of age, approximately 2-year postoperatively. (*D*) Immediate postoperative dentition. Note the placement of inferior border plates along the mandible with monocortical fixation to avoid the developing dental follicles. Note the lack of consistent paranasal sinus aeration with unerupted maxillary dentition. Note the position of the displaced left subcondylar fracture, which was left to remodel. (*E*) Dental development into permanent dentition. At 12 years of age, nearly 6 years postoperatively, panoramic radiograph demonstrates extensive bony remodeling along the mandibular fractures with largely uninterrupted eruption of the permanent maxillary and mandibular dentition. Note some flattening of the left condylar head and mild vertical discrepancy along the ramus condyle unit.

deciduous period, case-by-case operative management during the mixed period, and closed versus open reduction and fixation during the permanent phase.[52]

In comparing the use of resorbable plate fixation to conventional titanium hardware, Chocron and colleagues found no differences in complication profiles.[54] It is our preference to utilize temporary traditional rigid fixation along the mandibular inferior border in a monocortical fashion to decrease injury to developing dentition (see **Fig. 3**D, E). Hardware is typically removed 8 to 12 weeks following fixation to prevent growth restriction and bony overgrowth.[5] Interdental control remains a challenge in the pediatric patient given a lack of fully erupted dentition, developing tooth buds, and/or loose, conical primary dentition that complicates conventional circumdental wiring techniques. Similar to maxillary wiring techniques, a lingual mandibular splint may be used to control splay using circumandibular wires.[5] If maxillomandibular fixation is needed, length of treatment should be less than 10 days followed by guiding elastics with functional therapy for an additional 10 days to decrease the risk of bony ankylosis.[5,55]

Bottom-Up/Inside–Out Approach

Unlike in the adult population where various operative approaches remain equally efficacious, the bottom–up/inside–out approach popularized by Markowitz and Manson may be more challenging.[4,37] The approach begins with the occlusal unit and frequently requires open reduction and internal fixation of displaced condylar fractures to restore lower posterior facial height and width, which is generally avoided in the pediatric population given the remodeling capacity of the condyle and its critical role as a growth center.[36] Moreover, the lack of erupted dentition may obviate the ability to obtain preoperative dental impressions and splints used to recreate the preinjury occlusion.

In the absence of mandibular condyle fractures and appropriate restoration of lower facial height, a bottom–up/inside–out approach may be considered.[4] Delena and colleagues reported the bottom–up approach as the second most common in their single institution retrospective review of pediatric panfacial fracture management.[4] Interdental control of the occlusal unit is critical in this approach because the remainder of the craniofacial skeleton builds on this foundation.[29] Mandibular splay from symphyseal and/or parasymphyseal fractures must be carefully reduced along the lingual cortex. Following reduction of the mandible and interdental control, the panfacial fracture articulates at the LeFort 1 level.[3,29,37] Next, the NOE segments are overcorrected to correct the interorbital distance and to allow for the reduction of the ZMC fractures to restore appropriate facial width. The reduction of the NOE and ZMC segments is assessed along the temporal and (naso)frontal bones. Finally, the midfacial height is set by reducing the occlusal unit to the fixated upper midface with or without judicious autologous bone graft.

Soft Tissue Management and Postoperative Care

Despite limited subperiosteal dissection in the pediatric population, inadequate soft tissue redraping following degloving of the craniofacial skeleton results in soft tissue ptosis and the appearance of premature aging.[56] Resuspension of the soft tissues around the lower eyelid, malar eminence, and pterygomasseteric sling prevents the development of tear trough deformities and cicatricial scarring along orbital rim hardware, midface descent and nasolabial fold deepening, and jowling, respectively.[3,57] Temporal hollowing may be avoided by resuspension of the deep temporal fascia and meticulous dissection along the temporalis. Mentalis strain and chin ptosis can be avoided by resuspension of the mentalis. Canthal dystopia should be addressed with fixation of the lateral canthi in an overcorrected superior and posterior vector and fixation of the medial canthi in an overcorrected posterior and superior vector. Additionally, disruption of the medial canthus region warrants the use of external nasal bolster splints to compress and allow for readaptation of the medial canthus soft tissues and NOE fractures, respectively.[2]

Postoperative care largely follows adult fracture fixation protocols including a nonchew diet for 4 to 6 weeks, sinus precautions for 2 weeks, head of bed elevation greater than 30°, chlorhexidine oral rinses versus brushing in the setting of intraoral manipulation, and antibiotic ointment application along cutaneous incisions/lacerations. Vision checks and airway monitoring should be routinely performed.[3]

Complications

Beyond the site-specific complications that mirror the adult population, the most significant long-term consequence of pediatric fracture fixation remains its effect on subsequent growth and development. Rottgers and colleagues previously proposed a classification scheme of adverse outcomes following pediatric facial fracture repair.[58] Type 1 outcomes were defined as those related to the fracture itself, such as telecanthus following NOE fracture. Type 2 outcomes were defined as outcomes related to management, such as hardware infection. Type 3 outcomes were defined as outcomes related to impaired growth and development, such as midface hypoplasia. The authors further substantiated the prevailing pediatric fracture fixation theme in that nonoperative management is preferred to reduce the risk of Type 2 and 3 adverse outcomes.[4,5,9,39,58]

Growth disturbance following nasal trauma may occur due to premature ossification of the septovomerine suture.[9] Zygomatic fractures and fronto-orbital injuries after approximately 7 years of age (ie, radiographic evidence of frontal sinus pneumatization) traditionally do not lead to significant growth restriction.[9] NOE fractures may lead to compromised vertical and anterior-posterior growth of the midface.[9] Injury to the nasofrontal and frontomaxillary sutures and septum in displaced maxillary fractures is associated with midface hypoplasia requiring subsequent subcranial surgery.[59] Mandibular trauma, especially at the condyle, may result in malocclusion requiring orthognathic surgery at skeletal maturity.[39]

SUMMARY

Although rare, pediatric panfacial injuries typically result from high-energy mechanisms and lead to life-threatening polytrauma that requires an ATLS approach before facial fracture management. A systematic methodology to fracture reduction and fixation is essential to optimize immediate surgical outcomes and minimize future growth impairment. Although conservative management is preferred, there is equivocal evidence that primary surgical versus nonsurgical treatment leads to different rates of secondary surgery.

CLINICS CARE POINTS

- Panfacial trauma can be distracting injuries in critical ill patients. Follow standardized ATLS protocols during initial evaluation.
- Limit the extent of soft tissue and subperiosteal dissection needed to achieve the desired reduction/fixation, as wide undermining may lead to iatrogenic growth disturbance.
- Conventional titanium plating systems may be safely used to provide temporary rigid fixation for a period of 8 to 12 weeks without an increasing complication profile when compared with resorbable plating systems.
- Consider nonoperative management of non-displaced or minimally displaced fractures given the extensive remodeling capacity of the pediatric patient. Consider operative management of displaced fractures to prevent the development of challenging end-stage deformities.
- Regardless of the management strategy used, counsel patients on the unpredictable need for secondary revision at skeletal maturity.

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