Pediatric Facial Plastic and Reconstructive Surgery

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Chapter 19: Maxillofacial Injuries in Children

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So it was when my life began;
So it is now I am a man:
So be it when I shall grow old,
    Or let me die!
The Child is father of the Man.

(William Wordsworth, "My Heart Leaps Up When I Behold," 1802)

Curious, rambunctious, energetic, and often clumsy, children routinely suffer small hurts. Fortunately, the natural elasticity of their facial bones, abundant padding, and the prominence of the skull provide anatomical protection and account for the rarity of facial fractures in childhood. Nevertheless, in our fast-paced culture, children do occasionally sustain severe injury to the maxillofacial skeleton requiring appropriate therapy. The principles in the management of facial trauma are the same for all age groups. However, the reconstructive techniques for children must be modified to accommodate their unique anatomy, rapid healing, fragile psychology, and, most importantly, their potential for facial deformity as a consequence of altered facial growth.

Epidemiology

Pediatric facial fractures account for approximately 5% of all maxillofacial injuries, although the incidence has been reported to be as low as 1.5% and as high as 15%. Children under the age of 5 have a substantially lower risk ranging from 0.9% to 1.3%. With increasing age, there is a rise in the incidence of facial fractures; however, it is not until late adolescence, with the maturation of the face and the adoption of a fast-paced life-style, that the frequency and distribution of facial fractures evolve into the pattern seen in the adult population.

There is an overall male preponderance among children with facial fractures varying between a radio of 1.5:1 to 2.4:1. In children under 8 there is no difference between genders; between 8 and 15 years of age the male to female ratio rises to 4.5:1, reflecting the more aggressive and risk-taking behavior of preteen and adolescent boys.

There is a consensus that nasal fractures are the most common facial bone injuries in children. Precise statistics on their frequency are difficult to determine because many nasal fractures are treated in an office setting, whereas other types of fractures are usually managed in hospitals. In a series of 560 facial fractures, 60% were of the nasal bones. Another study reported a 45% incidence of nasal fractures among 122 children with facial injuries.

Mandible fractures are the most common facial fractures in children requiring hospitalization. In reports including nasal fractures, the incidence varies between 20.7% and 32%. The condyle is the most vulnerable part of a child's mandible and is the site of fractures 40% to 70% of the time. Body fractures (10% to 20%), angle fractures (3% to 17%), ramus fractures (3% to 10%), and symphyseal fractures (2% to 30%) occur less frequently. Dentoalveolar fractures, like nasal fractures, are often treated in an office setting; hence, it is difficult to gauge their true frequency, which is likely higher than the 14% incidence reported in one large series.

Mid- and upper facial fractures are quite rare in children. Several authors have reported a wide range of anatomic distribution, including 2.7% to 13.5% zygomatic complex fractures, 0% to 16% Le Fort-type fractures, and 0.2% to 19.4% orbital fractures. The sporadic distribution of upper facial injuries in children highlights their uniqueness and emphasizes how limited one surgeon's experience may be with these complex pediatric injuries.

Associated injuries are a common feature of childhood maxillofacial trauma. McCoy et al described 57% having injuries other than facial wounds, including 41% with skull fractures, 14% with cerebrospinal fluid (CSF) rhinorrhea, 9% with extremity fracture, 3.6% with blindness, and a 25.6% with aspiration pneumonitis. McGraw and Cole reported an incidence of 88% associated injuries with 61% multiple associated injuries in 72 children with facial fractures. Skull fractures or intracerebral trauma occurred in 61% of patients, particularly in younger children. Soft tissue injuries of the face occurred in 63% and temporal bone fractures occurred in 17%. In Kaban et al's series, 26% had associated injuries, including 6% with craniocerebral injury.

Etiology

The types of traumatic events that result in injury to a child's face, and the unique anatomical features of a child's facial skeleton that predispose it to the pattern of injuries observed in the pediatric population are two important factors to be considered when examining the etiology of pediatric facial fractures. In 1899, Lang described the case of "Hugh, S, age 13, who was struck on the right eyebrow, as he was running in the street, by the shaft of a cart driven at a trot". This injury resulted in a traumatic enophthalmus with diplopia and residual facial deformity. Since this early and famous case report, road traffic accidents have been a well-recognized cause of serious childhood maxillofacial injuries. McCoy et al reported that motor vehicle accidents accounted for 45% of the injuries in their series (20% pedestrian, 25% passenger). In Hall's series, 27% were due to motor vehicle accidents (5% pedestrian, 22% passenger). Reil and Kranz described a 37% incidence of motor vehicle accidents as the cause of trauma in their series (21% pedestrian, 16% passenger). McGraw and Cole found 67% incidence of motor vehicle accidents (25% pedestrian, 42% passenger). They emphasized that although the overall incidence of passenger injuries was higher and gender neutral, pedestrian injuries among boys under 5 outnumbered passenger injuries.

Although the major cause of serious pediatric facial fractures are from motor vehicle accidents, it turns out that childhood play is the most common cause of these injuries (15% to 30%), when all forms of fractures are considered, including nasal fractures and dentoalveolar fractures. Other etiologies include bicycle accidents (2% to 20%), falls (20% to 30%), blunt strikes to the face (8% to 30%), and sports injuries (2% to 30%).

Two other causes, although uncommon, deserve special mention. These are birth injuries and child abuse. Prolonged and difficult deliveries result in a wide range of facial injuries, most of which are mild and transient. The more severe ones, such as soft tissue lacerations, facial fractures, and facial nerve injuries are usually due to forceps compression. Facial fractures, as a cosequence of child abuse, have been reported. All emphasize the importance of considering such a possibility, especially in facial injuries among children under 5 years of age, since the great majority of all cases of child battering occur in this age group. Consideration of abuse requires reporting to the appropriate child protective agencies.

Both social and anatomical differences account for the disparity in the incidence and in the nature of facial fractures between children and adults. During child's play falls are frequent but generally from low heights and low speeds; hence the likelihood of serious fractures is diminished. Although children can be subject to the same hazards of modern life as adults, they usually live in protected environments that reduce the risk of major injuries.

Paralleling the changing social environment of a growing child, is the maturation of the facial skeleton, an appreciation of which is necessary to understand the difference in the patterns of fractures between children and adults. About 80% of cranial growth occurs in the first 2 years of life. Facial growth is also rapid during this period, but it is only after the second year that facial growth outpaces cranial growth. Brain and ocular growth are near completion by age 7; however, facial growth continues into the second decade of life. The cranial volume of the newborn in proportion to the facial volume is 8 to 1. In the adult this ratio is 2 to 1. The higher craniofacial ratio in children results in a greater proportion of impacting force being absorbed by the cranium, especially the prominent forehead, which overhangs the face. This accounts for the higher proportion of pediatric skull fractures compared to facial fractures and the rarity of serious midface fractures in young children, in whom the force necessary to cause major maxillary disruption often results in brain injury and death.

Another characteristic of the face of young children that reduces their likelihood of facial fractures is the more soft and elastic bone protected by thick layers of fat and muscle, and unweakened by the development of the paranasal sinuses. The greater elasticity, which is due to the thin cortical plates and a greater proportion of cancellous bone, also explains the higher incidence of "greenstick" fractures in children. The presence of unerupted and mixed dentition in the maxilla and mandible renders these structures more stable and resistant to fracture, despite fractures that can occur through the developing tooth crypts. As the child nears adolescence and adulthood the concomitant pneumatization of the paranasal sinuses, maturation of the dentition and bone, thinning of the facial soft tissues, concurrent with more risk-taking behavior, renders the face more liable to fracture.

Emergency Management

The inital assessment of the child with a facial fracture should follow the basic principles of trauma management. A primary survey must be made of the child's airway, breathing, and circulation. A hierarchy of airway interventions are available depending on the severity of the injury. In most cases, where the only injury is to the maxillofacial area, careful posturing of the child is adequate. If indicated, the oral cavity should be suctioned of blood, secretions, loose teeth, and bone fragments. In case of mandibular displacement, a midline traction suture on the tongue can be most helpful.

Orotracheal intubation is generally indicated when there is coincidental cranial trauma, severe midfacial fracture associated with bleeding or oropharyngeal obstruction, and posterior retrusion of the mandible. This should ideally be accomplished after radiographic evaluation of the cervical spine. Consideration of performing the intubation in the operating room with rigid instrumentation is appropriate if there is anticipation of a difficult intubation, as with concurrent oropharyngeal or laryngeal injuries.

Tracheotomy is generally not necessary for routine facial fractures; however, it should be considered for severe panfacial injuries, and is routinely performed when a major facial fracture is associated with intracranial, thoracic, or abdominal injuries. Crash tracheotomies and cricothyrotomies on children in the emergency department should be avoided in favor of orotracheal intubation, with a controlled tracheotomy performed under general anesthesia in the operating room.

Blood loss from the highly vascular broken face of a child can rapidly result in hypovolemic shock. This blood loss may be a double threat if it is lost into the airway. Immediate volume expansion with crystalloid solution via large bore intravenous lines is necessary. With severe hemorrhage, transfusion with type specific red blood cells and other blood products, such as plasma and platelets, may be appropriate.

The secondary survey of the head and neck proceeds in an orderly fashion beginning with the neurologic assessment, evaluation of the neck and cervical spine, inspection of the eyes, otoscopy, rhinoscopy, and finally examination of the face and oral cavity. Important to the neurologic assessment of facial fractures are the sensory function of the fifth nerve and the motor function of the seventh nerve. Ophthalmologic evaluation is important to rule out intraocular trauma, and should include ophthalmoscopy as well as tests for range of motion, diplopia, and pupillary reflexes. Otoscopy is necessary since anterior canal wall injuries usually indicate a condylar fracture and a hematotympanum may suggest a temporal bone fracture. Anterior rhinoscopy is essential for the evaluation of septal injury, septal hematoma, or CSF rhinorrhea.

Examination of the facial skeleton should begin with inspection followed by manual palpation. Suggestive signs of facial fracture may include facial asymmetry with edema, ecchymoses, periorbital swelling, trismus, and malocclusion. Bimanual examination of the facial skeleton begins over the zygomatic arches and systemically proceeds down the face. The examiner feels for asymmetry, tenderness, and crepitation - all indications of underlying facial fractures. The malar eminences, the orbital rims, and the nasal bones are palpated. The stability of the maxilla is assessed by holding the head steady with one hand and rocking the premaxilla with the other, while observing for movement of the middle third of the face. Further information can be obtained by intraoral digital examination of the maxillary buttresses.

The manual examination of the mandible begins with the palpation of the temporomandibular joints and of the external auditory canals with opening and closing of the jaw. Fingers are swept acoss the skin covering the ramus, angle, and body of the mandible. Intra- and extraoral bimanual palpation of the body and symphysis completes the examination.

Radiologic Examination

Historically, pediatric facial fractures have been difficult to document radiographically. Much has changed with the advent of computerized tomography (CT), which has revolutionized the imaging of facial fractures. A CT scan in an axial plane is indicated for orbital and maxillary fractures. Direct coronal projections add substantive information especially in complex nasoethmoid and orbital fractures, but can be difficult to obtain in an injured, uncooperative child. Nevertheless, every effort should be made to obtain both projections for major injuries since the combined scans accurately define the aberrant anatomy in anticipation of correction. Three-dimensional CT reconstructions have also proved to be a valuable adjunct to two-dimensional CT for preoperative assessment and the surgical planning of facial fractures.

For mandible fractures, the most useful diagnostic radiograph is the panoramic view, which displays the total anatomy of the mandible including the condyles and the upper and lower teeth. Its proper performance requires that the child be seated and stably positioned. This is not always possible with severely injured or very young children, and alternate views may be required for documentation of their fractures. The posteroanterior projection demonstrates the entire mandible including displaced fractures. The anteroposterior projection, also known as the modified Towne's view, is specific for the condyles. The lateral oblique projection displays the condyle, coronoid, ramus, angle, and body. Intraoral projections can be helpful for the symphyseal and parasymphyseal area and with dentoalveolar fractures as well.

Axial CT scans are also useful for documenting mandible fractures, especially in a multiply injured child who cannot be readily positioned for routine mandibular radiographs. For those children who may require cranial and upper facial CT scanning, it is advantageous to get additional images that include the mandible.

The imaging of nasal fractures remains controversial because of the inaccuracy of standard nasal radiographs in isolated nasal trauma. This is especially true in children whose nasal bones are not fully fused, making radiographic interpretation difficult. Nevertheless, children being referred from the emergency department for clinical examination have routinely been x-rayed. Perhaps there is a medicolegal justification or psychological benefit; however, they are generally not useful. On the other hand, a significant nasal fracture in a child that results in flattening of the nasal dorsum warrants proper imaging with axial and coronal CT scan.

Facial Growth

Alterations of facial growth as a consequence of childhood facial fractures are well recognized. However, malformations attributable to early trauma are not inevitable. Normal development of the face results from the absolute growth of the face and the relative proportional modifications that distinguish the shape of child's face from that of an adulgt. It is the disturbance of the differential growth rates attributable to the injury that will result in anomalies at maturity. A detailed accounting of the morphology of facial growth is beyond the scope of this chapter. However, an understanding of facial development, particularly from a pathologic and a physiologic perspective, may aid in the differentiation of injuries most likely to interfere with facial growth and facilitate the identification of reconstructive techniques that will best promote normal facial maturation.

Pathologic changes caused by accidental and experimental trauma to different parts of the facial skeleton are documented in the literature. Grymer et al studied 47 adult patients who had sustained nasal fracture during childhood and compared them to a control group of adults who did not have a history of nasal trauma. They also analyzed the effects of these fractures based on the period of facial development during which the injury had occurred. This was premised on observations that there are three periods of nasal growth: from the age of 1 to the age of 6 years, when there is rapid growth; from 6 to 11 years, when there is a period of slow growth; and from 12 to 16 years, when there is a second period of rapid growth. They found a significant increase of bony and cartilaginous deformities in the fracture group. However, they found that nasal deformities as a consequence of trauma during specific developmental periods were equally distributed among all their patients.

Rock and Brain did a cephalometric analysis of 29 adults with a history of nasal fractures and compared these to a control group without a history of trauma. They found significant reduction in the size of the midface, reduced projection of the nose, and an increase in vertical height.

Sarnat and Wexler did a series of experimental resections of septal cartilage and bone in the septovomerine angle of growing rabbits. This caused a deceleration of the growth of the snout, which resulted in a reduction in the size of the nasal and premaxillary bones, the nasal cavity, and the piriform aperture. The extent of the deformity varied with the amount of tissue resected. He concluded that the relationship of the septum to the growth of the face is comparable to the relationship of the eye to the growth of the orbit, and the brain to the growth of the skull. In a similar vein, Siegel resected the nasal septum in growting baboons and noted diminished upper facial growth.

Osterhout and Veargervic described three patients who sustained midfacial trauma in early childhood and were found during adolescence to have midfacial hypoplasia requiring Le Fort III maxillary advancements.

Precious et al described three patients, victims of child abuse, with a history of nasomaxillary fractures, who were studied with cephalometrics during adolescence. The children were found to have an elevation of the anterior palatal plane, a reduction in the length of the premaxilla and nasal spine, decreased nasal projection, and modifications in the occlusal plane of the mandible.

Bachmayer et al demonstrated that Le Fort III advancements in children with Crouzon's, Apert's, and Pfeiffer's syndromes result in a cessation of any further forward growth of the maxilla. Although they noted that these patients already had diminished maxillary growth due to premature fusion of some facial sutures, they concluded that the combination of traumatic osteotomies and periosteal stripping stopped further growth.

Shapiro et al did Le Fort I advancements in monkeys and followed the animals for 2 years with serial cephalometrics. They found that the animals had diminished anterior maxillary growth, which they attributed to the formation of scar tissue.

Munro studied the effects of total maxillary advancement in pigs, varied with other factors including periosteal elevation, simple osteotomies, fixated osteotomies, and bone grafts. He found that growth in the areas adjacent to osteotomies was reduced, but by no more than the reduction caused by periosteal elevation. He concluded that periosteal elevation decreased local blood supply, increased periosteal adherence, and changed local bone growth.

Hellquist did an extensive study on the effect of periosteal resection on the facial growth of rodents. He found that the periosteum quickly regenerated from the denuded bone surface. Although this new periosteum appeared normal, the underlying bone showed altered morphology extending beyond the area of resection. When periosteal stripping was confined to the premaxilla, growth was not altered; however, when it involved the maxilla, growth was significantly diminished.

Lindahl and Hollender radiographically studied the process of condylar remodeling in children and adults after fracture. They found that among children between 3 and 11 years of age, extensive remodeling of the condylar processes resulted in normal anatomy. In 12- to 19-year-olds, remodeling occurred but to a lesser extent. In adults, only minimal remodeling took place.

MacLennan reviewed 180 cases of condylar fractures of which five were in children under the age of 10. He found that the great majority of these injuries healed without functional impairment. However, he did note that crush injuries of the condylar head before the age of 5 predisposed to ankylosis and growth disturbances.

Walker, in a study of the treatment of condylar fracture dislocations in monkeys, found that condylar reformation was comparable whether management was conservative immobilization, early mobilization, or direct surgical wiring.

Anderson and Alling studied subcondylar fractures in young dogs and found that there was no difference in the mature mandible if the fractures were untreated or repaired by wire fixation. They also performed a condylectomy in one animal and found complete regeneration of the condyle with normal symmetry of the mature skull.

Studies of the normal processes of facial growth date back to John Hunter, who in 1835 described the normal development of the mandible. He fed madder, the root of a plant that has the property of staining growing bone a red color, to two young pigs for a month. He sacrificed one pig after a month, whereas the other pig was fed a regular diet for an additional month before sacrifice. He then studied the pattern of madder staining on the mandibles and found that the bone that had been the condyle during the staining diet had been incorporated into the ramus, whereas unstained bone, which had grown after the madder diet had been stopped, was now the condyle. He also noted that what had been the madder-stained anterior border of the mandible in the first animal had nearly disappeared in the second animal.

Clinical experience with the pathologic influence of trauma and experimental observations such as Hunter's provide an insight into the basic concepts of the processes of facial growth. These have been extensively reviewed by Enlow and are briefly summarized here.

Bones grow by the deposition of bony tissue on one surface and absorption on the opposite surface. This combines to produce growth movement or "drift" in a specific direction. Bones of the face are covered on the outside by periosteum and on the inside by endosteum. These osteoactive membranes cover the bone in a jigsaw-like pattern of growth fields, which are responsible for both bone deposition and resorption. This growth is not thought to be programmed within the bone itself, but in its covering osteogenic membranes and functioning soft tissues such as tendons, muscle, mucosa, and brain. The rate of activity in differential growth fields vary according to the specific function and growth of the surrounding soft tissues. Certain growth fields, such as the mandibular condyle, have special significance in the growth process. Nevertheless, it is a misconception to view them as isolated "growth centers", since all of the surrounding bone participates in the remodeling and enlargement that produces the mature facial form.

The process of remodeling and enlargement results in the relocation of the component parts to allow for overall growth and to provide structure for the changing physiologic conditions of the encapsulating soft tissues. It also results in each component bone being carried away from its adjacent neighbors, a process called primary displacement. Primary displacement occurs as a result of a bone's own growth, and its direction is generally in the opposite direction of bone deposition. For example, as the mandible ios carried forward by its growing soft tissues, it is displaced anteriorly and inferiorly from the temporal mandibular joint. In response, the condyle and the ramus grow by deposition in a posterosuperior direction, in effect filling the space caused by the displacement. Similarly, as the nasomaxillary complex is displaced anteriorly and inferiorly, bone deposition occurs at the multiple sutural interfaces between the maxilla and the adjacent bones of the face. In other words, bone growth at the sutures is not responsible for the projection of the maxilla, but is the result of it. Furthermore, the bones of the face are also secondarily displaced by the enlargement of the adjacent bones, such as occurs with the downward and forward displacement of the maxilla as a result of cranial enlargement.

It is clear from the foregoing discussion that facial growth is a complex process of multiple anatomical and functional interrelationships, no part of which is independent of others. What is not obvious is the mechanism of control and coordination responsible for the overall pattern of growth. Although many possible explanations have been proposed, none completely explains how the morphogenetic process works and what occurs during facial development. A short overview of the major concepts of facial growth follows; for a detailed discussion the reader is referred to the works of Scott, Moss, and Enlow.

One need only see a parent and child who look alike to understand the genetic influence on facial growth. Nevertheless, there remains deep uncertainty in attributing all facial skeletal development to an intrinsic blueprint within the bone-producing cells of the face. Rather, contemporary thought holds that growth is controlled by the genetic program within the enveloping soft tissues and regional growth sites. The nasal septum has received much attention for its role in nasomaxillary development. It has been proposed as the structure responsible for the dramatic anterior and inferior displacement of the growing maxilla. Although it is doubtful that the septum is the only pacemaker of midfacial development, both experimental and clinical data support its role as an important regional growth site.

Moss has proposed a broader conceptual framework to explain facial growth and osteogenic regulation. Known as the "functional matrix" theory, it holds that the predeterminants of bony morphology reside in the encapsulating soft tissues. The brain, the nasal and pharyngeal mucosa, the facial musculature, the tongue, and the teeth form a functional matrix that surrounds the bone and directs its growth and form. Direct and indirect stimuli produced by the growth and action of these functioning tissues switches on the osetoactive cells to deposit and absorb bony tissue, thus displacing, remodeling, and enlarging the facial skeleton in order to accommodate the physiologic activities of the face.

Based on analysis of the known effects of trauma in the growing face as well as on an understanding of the operational mechanics of facial growth, certain practical concepts for the repair of facial fractures in children emerge. The mandible appears to be generally resistant to abnormalities of growth as a result of trauma, unless there is alteration of its function due to injury in or near the temporomandibular joint. Early restoration of mandibular mobility is desirable in order to facilitate the restorative bony changes that result from normal function.

The nose, nasoethmoid complex, and maxilla are more prone to growth abnormalities as a result of trauma. This probably occurs because of the minor restorative functional movement that these bones are subject to, the physiologic derangements that result from the fractures, the importance of the septum as a regional growth site, and the vulnerability of the multiple suture sites to scar formation. All these factors suggest specific interventive strategies that include:

1. careful restoration of injured soft tissue, particularly the periosteum;

2. close attention to septal injuries with an emphasis on realignment rather than resection;

3. reduction of fractures into their stable anatomic locations;

4. correct realignment of suture lines;

5. minimal periosteal elevation;

6. three-dimensional, stable fixation of complex fractures;

7. use of rigidly fixed bone grafts as a substrate for growth in areas of bone loss.

The issue of rigid plate fixation in children warrants additional consideration because of the conceptual implications of its use with regard to facial growth. There is only one study that has investigated the effect of plate fixation in growing animals. Lin et al did frontoorbital craniotomies on an expanding portion of the craniofacial skeleton in two groups of kittens. After removal, the cranial segment was replaced into its anatomically correct position. In the first group, fixation was accomplished with wire and in the second group fixation was obtained with a mini-compression plate. As controls, a third group of kittens had straight plate fixation across the coronal suture without osteotomy, and a fourth group had incision and periosteal elevation alone. Growth analysis was accomplished with volumetric determination by three-dimensional CT and cephalometrics after sacrifice. The results showed significant growth restriction in both the osteotomized groups but not in the group with the plate across a coronal suture. Moreover, the unoperated side showed a significant compensatory growth in the osteotomized kittens. It is difficult to draw any firm conclusions from this study, but it does suggest some measure of safety with the use of plate fixation.

Nevertheless, plate fixation with our current state of knowledge should be considered only for children with complex three-dimensional injuries that cannot be repaired by simpler means. There are several reasons for such caution. Access for plating often requires surgical trauma to facial soft tissues and extensive periosteal elevation, both important factors in alteration of facial growth. Bone is deposited at facial sutures as a result of tension fields across them. Plating across a suture line could potentially convert the sites to compressive fields, resulting in bony resorption. Plate and screw fixation also risks injury to the maxillary tooth buds. The circulation of the injured facial bones, already compromised by fracture and the extra trauma of exposure, is further jeopardized by the plates and screws, in that immediately after placement no circulation is seen around the drill holes and under the implant for several weeks. There is also the question of whether plates can be indefinitely left in place or should be removed after the facial bones have healed. Since the effect of plates on facial growth remains unknown, consideration of removal is valid and must be weighed against the additional injury to facial soft tissues required for their removal.

Despite these reservations, recognizing that each reconstructive technique has its strengths and its weaknesses, the use of rigid fixation is highly desirable in complex fractures where the original features are difficult to restore. The alternative of no correction is unacceptable, and the use of interfragmentary wires is tedious and may lead to reconstruction of uncertain stability. As Rahn has written, "open reduction of a fracture may sometimes appear to be an aggressive approach. It can be justified when late reconstruction and secondary surgery is avoided. Thus an approach that appears initially to be more aggressive, may be more conservative."

Nasal Fractures

The proportionate nasal anatomy of the child differs substantially from that of an adult, and this results in a different pattern of injuries in response to trauma. The primary projecting component of a child's nose is cartilaginous and readily deforms during a blow to the midface. The impacting force is dispersed across the maxillary soft tissues, resulting in a broad area of edema with a loss of anatomical specificity of the nose on examination.

The anatomy, orientation, and compliance of the lower and upper lateral cartilages allow for a ready rebound from a traumatic deformity, and these cartilages rarely sustain permanent injury, except for dislocations of the upper lateral cartilages from the bony framework. However, the more rigid septum, within its tight perichondrial covering and surrounding bony encasement, is much more prone to long-term damage.

Three types of injury can affect the septum. The first results from the detachment of its perichondrial covering in response to the deformation of the cartilage during impact. This creates a potential space between septum and its perichondrial leaflet and allows the formation of a septal hematoma. The second type of injury tears the anchorage of the septum inferiorly from the maxillary crest and posteriorly from the perpendicular plate of the ethmoid and vomer. The resulting septal dislocation can be an immediate cause of nasal obstruction. Moreover, since the vomerine region of the septum is its most actively growing part, growth disturbances, generally of the hypertrophic variety, are a common late sequela. The third type of injury is a fracture of the septum, which can occur either vertically, horizontally, or in stellate fashion. This can result in immediate or subsequent obstruction, delayed twisting deformities, and growth disturbances. A mixed picture of the septal injuries is typically encountered.

The nasal bones are not very prominent in young children and thus uncommonly injured. They are surrounded by the nasomaxillary and the nasofrontal sutures and divided by a midline suture. Injuries will often result in "greenstick"-type sutural dislocations, commonly just on one side. When the blow is directly to the midline an "open book"-type fracture can occur resulting in central depression, lateral flaring, and dislocation of the nasal bones over the frontal process. With fractures of the nasal skeleton, one must have a high index of suspicion about more extensive but occult nasoethmoid and orbital injuries.

The initial examination of a child with a nasal fracture may be of limited value with regard to the external deformity. However, immediate intranasal examination is essential to evaluate for septal hematoma. Suspicion should be greatest in a child who has difficulty breathing through the nose following injury. The clinical appearance of septal hematoma is that of a purple bulge in one side of the nasal vestibule with contralateral deflection of the septum. The area will be compressible to palpation with a cotton tip applicator and not responsive to topical vasoconstriction.

Septal hematoma is a serious complication when left untreated and can result in a thick fibrotic and obstructive septum. It may also become infected, resulting in cartilage necrosis and subsequent saddle deformity of the nose. Stucker et al suggest that abscess formation is not always necessary for there to be cartilage dissolution and collapse from an untreated septal hematoma.

The treatment of septal hematoma should begin with needle aspiration of the suspicious area after topical anesthesia. Since this is not always possible in a child, a general anesthetic may be necessary in order to evaluate and evacuate the hematoma via a hemitransfixion incision. This can also provide an opportunity to explore the entirety of the septal injury with suture reduction of the displaced fragments. Following exploration, the mucoperichondrial leaflet is sewn back to the cartilage with continuous through and through chromic sutures with a mini-Keith needle. If necessary, the septum can be further supported with Silastic splints. The nose is always packed with antibiotic-impregnated gauze for 2 to 3 days. Postoperatively the child is kept on broad-spectrum antibiotics.

During the anesthetic the bony nasal pyramid is examined, and if there are displaced fragments, these are manipulated into place with closed-reduction techniques. Unfortunately, severe facial edema may preclude precise examination and reduction, necessitating later reevaluation and possible rereduction.

If septal hematoma has been ruled out and there remains concern about the possibility of nasal fracture, the child is asked to return in 3 to 4 days. This waiting period will have allowed the subsidence of a majority of the facial edema and will allow for a more accurate examination. Crockett et al suggest that this is also a good time for the parents to find a pretrauma photograph for use as an additional guide to the child's normal anatomy.

Definitive management is initiated if there are demonstrable bony and septal fractures resulting in cosmetic deformity and/or airway obstruction. In most circumstances, closed reduction of the bony component is accomplished with intranasal instrumentation and external manual manipulation. However, "greenstick" fractures may not always readily reduce into the desired position. For these, open reduction with completion of the fracture with a small osteotome will allow for proper alignment of the fragments. Once the bone have been relocated, they will require support with intranasal packing and an external cast for several postoperative days.

Septal injuries are more difficult to control with closed techniques. Attempts should be made to reduce the dislocations and realign fracture segments with instrumentation, Silastic splinting, and packing. However, if it becomes obvious intraoperatively that conservative measures are inadequate, then perichondrial elevation and cartilage exposure is necessary. Care is taken to preserve the integrity of the mucoperichondrial leaflets and the emphasis of the open technique should be toward suture realignment of the septal fragments with minimal resection of cartilage.

Newborns

An occasional problem is asymmetrical tip deformities in newborns. These infants typically present with a flattening of the nasal tip to one side with the septum tilted in the same direction. The bony dorsum is invariably straight. It is difficult to know whether this type of deformity is an acute traumatic birth injury or due to prolonged intrauterine positional pressure.

There are some nasal surgeons who advocate immediate surgical reduction of these deformities by straightening and relocating the septum. However, experience has shown that these deformities self-straighten over time without late sequelae. Treatment for these children is to reassure the parents that the nose in time will straighten out. Although it is hypothetically possible for such a deformity to cause airway obstruction in the nasally obligate neonate, this has not been a problem even with severe deformities.

Mandible Fractures

The goal of mandibular fracture management in children and adults is correct alignment with proper fixation in centric occlusion. However, the techniques required to achieve this goal vary with age and the quality of dentition. Before the age of 2 the eruption of the deciduous teeth is incomplete; hence, it is difficult to achieve adequate anchorage for immobilization. On the other hand, inaccurate alignment is generally compensated for by later growth. Between 2 and 5 years of age the deciduous incisors have firm roots, and if the deciduous molars have formed, both of these can be utilized for cap splints or arch bars. Between 5 and 9 years of age, when the deciduous incisors fall out and the deciduous molar roots are resorbed, is the period that presents the toughest problems for the establishment of occlusion. Reliance on circummandibular and circummaxillary stabilization with Gunning-type splints is often necessary during this time. After 10 years of age, the development of permanent teeth provides safe anchorts for fixation.

Condylar Fractures

Condylar fractures can be classified into three anatomically distinct types. The first two are intracapsular and include crush-type fractures of the condylar head and high condylar fractures through the neck above the sigmoid notch. The third type, which is also the most common, is a low or subcondylar fracture often of the "greenstick" variety. It is extracapsular and is from the sigmoit notch back toward the posterior ramus.

There are those who advocate open surgical treatment of condylar fractures in children; however, clinical and experimental observations overwhelmingly support a conservative, closed approach to the management of most of these injuries. For the majority of condylar fractures, the primary decision is whether to immobilize or not. In most cases, unilateral condylar fractures present with normal occlusion and normal mandibular movement. A soft diet and movement exercises are all that is necessary. This may also apply to bilateral condylar fractures where there is normal function. Condylar fractures presenting with an anterior open-bite deformity, retrusion of the mandible, or movement limitation indicate a brief period of immobilization lasting 2 to 3 weeks.

In children under 2 years of age and in children between 5 and 9 years of age, whose dentition does not allow for the application of arch bars, immobilization requires unconventional fixation techniques. An overlay acrylic mandibular splint is constructed and is held in place by circummandibular wires. Its occlusal surface is placed in normocentric relation to the maxilla and immobilization is accomplished by suspending a wire from the piriform aperture and tightening it around the midline wire, which is holding the splint to the mandible.

In children with stable deciduous or permanent teeth, conventional arch bars are the preferred technique for immobilization. These can be fixed in place with 26- or 28-gauge stainless steel wire. Rubber bands will suffice to provide traction for intermaxillary fixation. Arch bars can be further reinforced with circummandibular wires and suspension wires from the nasal spine or piriform aperture.

The indications for an open surgical approach of pediatric condylar fractures are quite limited and are reserved for situations where there is a mechanical obstruction to normal movement or in the extremely rare cases of dislocation of the condyle into the middle cranial fossa. The preauricular exposure gives excellent access to the condylar head and temporomandibular joint. This approach unfortunately risks injury to the facial nerve. The submandibular technique of Risdon is safer to the upper branches of the facial nerve, but provides exposure primarily for subcondylar fractures.

Symphyseal and Parasymphyseal Fractures

Condylar fractures are most commonly associated with fractures of the anterior arch of the mandible, either at the symphyseal or parasymphyseal regions. The submental musculature exerts a downward and retrusive force to these areas; hence, fragments may often be displaced accordingly and may complicate reduction. Symphyseal or parasymphyseal fractures with minimal to moderate displacement can often be realigned with careful manual manipulation under anesthesia and immobilized with a cap splint, arch bar, or interdental wiring. In younger children under 3 years of age, an acrylic splint held in place by circummandibular wires is most useful.

The problem with these simple techniques is that reducing the fracture with an arch bar or interdental wires on the side of the dentition (tension surface) will result in distraction of the lower border (compression surface). In order to better reduce serious misalignment, open reduction with internal fixation of the fragments is required. These midline areas are readily exposed via an intraoral degloving approach. The lower border can then be reduced by wire fixation or by monocortical reconstruction with miniplates. With both techniques, great care must be exercised in drill hole placement in order to prevent injury to the developing tooth buds. With both miniplate reconstruction and with interosseous wiring, a brief period of intermaxillary fixation of 2 to 3 weeks is required. In children with full, permanent dentition the principles of bicortical, compression-plate reduction are applicable.

Body and Angle Fractures

As with condylar fractures, body and angle fractures are often of the "greenstick" variety presenting as monocortical cracks. These children will typically present with normal occlusion and movement and thus are best treated with a soft diet and symptomatic therapy. When the fractures are displaced, treatment will depend on the availability of the dentition, direction of muscle pull, and the degree of distraction. For distracted body fractures, intermaxillary fixation with elastic traction is usually adequate. However, if misalignment of the lower border cannot be controlled in a conservative manner, then open reduction with internal fixation with interosseous wiring or monocortical minicompression plating is necessary. Although both of these can usually be accomplished intraorally, the open reduction of posteriorly placed body fractures may require an external approach in some children.

The difficulty with angle fractures is that they lie beyond the dentition and thus may not be amenable to reduction with splints or intermaxillary fixation when the fracture is displaced and under unfavorable muscle tension. Under such circumstances extraoral open reduction with wire or plate fixation is required.

Dentoalveolar Fractures

Dentoalveolar fractures constitute a dental emergency because salvage of the traumatized teeth requires prompt reimplantation, generally within an hour of the injury. Although loss of the deciduous teeth is not a problem, identification of tooth type, whether primary or permanent, especially during the period of mixed dentition is difficult for the physician unfamiliar with pediatric dentitition. The typical injury is to the mandibular or maxillary incisiors and canines, due to their prominent anterior position. The fractures can involve the crown and the deep pulp, or there can be partial or complete avulsion with loss of the surrounding cortex. Treatment is directed at getting the child seen immediately by a dentist for definitive therapy. In the interim, the tooth is gently cleansed in saline, handled by the crown, and if the child is cooperative, replaced in the socket. If the child cannot cooperate, then the tooth is kept in salive-sauked gauze or a bowl of milk until such time as a dentist can reimplant and stabilize the tooth with either a splint or an arch bar.

Maxillary Fractures

Fractures of the maxilla in children are classified as in adults. Le Fort I fractures separate the palate from the maxilla, extending through the floor of the nose, maxillary sinus, and the pterygoid plates. Le Fort II fractures separate the midface from the cranium, extending through the pterygoid plates, along the lateral and anterior maxillary walls, the medial orbital wall, and the nasofrontal suture. Le Fort III fractures separate the entire face from the cranium extending through the zygomatic arch, frontozygomatic suture, lateral orbital wall, medial orbital wall, nasofrontal suture, septum, and the pterygoid plates.

These rare fractures present with severe facial edema, prominent orbital ecchymoses, anterior open bite, and other occlusal deformities. Associated injuries such as basilar skull fractures and dural tears with cerebrospinal fluid fistulae are common, since a force great enough to fracture the face will often be transmitted to the cranial vault.

The goals of therapy are to reestablish facial symmetry, appropriate occlusion, and normal vertical dimension. Significant fracture displacement must be reduced in 4 to 8 days or as soon as the condition of the child permits, since rapid interfragmentaly healing makes adequate correction extremely difficult after 10 days. Acute reduction should be considered when fractures are accessible through open wounds.

Injuries with minimal or no displacement do not require correction. Active intervention is necessary when displacement has altered form or function. Reestablishing occlusion by intermaxillary fixation with splints, arch bars, or interdental wiring is generally the first maneuver in the repair of these injuries. Intermaxillary fixation techniques utilized to overcome the unique problems of pediatric dentition are those previously described for mandible fractures. Additional simple intervention such as the suspension of Le Fort I fractures with piriform aperture wires and suspension of Le Fort II fractures from circumzygomatic wires remain time-tested alternatives to open reduction and internal fixation.

Historically, complicated Le Fort II and Le Fort III fractures, as well as panfacial fractures, have required craniomaxillary and craniomandibular fixation. This is based on the concept that the solid foundation of the cranium and correct occlusion are required for accurate reconstruction of the face. Traditionally this was accomplished with a plaster head cap with outrigger suspension wires, which supported the fragments by external traction. Later, halo-type external fixateurs with direct pinning or fragmentary suspension were developed for the management of complicated fractures. Although these techniques were often successful, they presented problems of patient incompatibility, particularly in young children.

Over the last decade, the availability of miniplate and microplate screw fixation systems have made internal, three-dimensional, rigid fixation a preferable alternative to external suspension. The injuries are approached via hidden facial degloving incisions, inferiorly via the maxillary gingivobuccal sulcus and superiorly through a bicoronal incision.

The inferior approach provides access to the entire maxilla, lateraly to the masal bone and zygoma, anteriorly to the infraorbital nerve, and medially up to the lacrimal fossa. The exposure provides for the reestablishment with individually contoured plates of both the lateral zygomaticomaxillary buttress and the medial nasomaxillary buttress. It also allows for rigid interfragmentaly fixation of the entire midface below the level of the orbital rim. Additional exposure of the inferior orbital rim and floor can be obtained by subciliary or transconjunctival techniques.

The superior approach, which is subperiosteal over the cranium and subfascial over the temporalis muscle, provides access to the superior and medial orbital rims. Orbital roof and nasoethmoid exposure can be obtained by drilling the bone from around the supraorbital nerves. Detachment of the temporalis fascia from the lateral orbital rim and zygomatic arch reveals the bones of the entire upper face from the zygomatic root on one side completely around to the other. Access to the lateral orbital can be obtained by reflecting the temporalis muscle posteroinferiorly. The exposure provides a means to realign and rigidly fix the frontozygomatic suture, the entire zygomatic arch, and the nasal bones. It also allows for harvesting of cranial bone grafts for orbital reconstruction and cantilever nasal reconstruction in complex nasoethmoid fractures. Intracranial access for neurosurgical intervention or basicranial fracture reduction is also possible via this technique.

Orbital and Nasoethmoid Fractures

The orbit and its contents occupy a prominent position in the face of a child, and injuries to this area can have serious functional and cosmetic consequences. The scope of these injuries are related to the magnitude of the impacting force and can vary from relatively minor fractures, such as "blow-out" of the orbital floor, to complex fractures involving the rim, multiple walls, and the apex, with alteration of orbital volume, ocular mobility, and visual acuity. Management depends on the extent of the injury, ranging from observation to surgical intervention requiring craniofacial exposure, rigid fixation, and bone grafting.

Appropriate treatment requires accurate diagnosis best accomplished by physical examination and CT scanning. The first priority is an assessment of visual acuity. Periorbital edema, ecchymoses, and subconjunctival hemorrhage are indicative of orbital trauma. The position of the globe, often obscured by edema, is inspected for exophthalmos, enophthalmos, and vertical dystopia. Intraocular pressure is measured. The extraocular musculature is tested for voluntary range of motion and if necessarily with forced ductions under anesthesia. Intercanthal distance and the length of the palpebral fissures are measured, and the locations of the medial canthal ligaments are identified. The rims are palpated for disruption. The supraorbital and infraorbital nerves are tested for sensitivity.

Classified by its pattern of fractures, the orbit has three anatomically distinct regions. The anterior component is the hard bone of the orbital rim, which divides into three subsections. The first is the supraorbital rim, which is a portion of the frontal bone. The second is the infralateral rim, which is part of the zygomaticomalar complex. The third is the medial rim, part of the nasoethmoid complex, and to which attach the medial canthal tendons. The middle component consists of thin lamellae of bone forming the roof, the floor, and the medial and lateral walls. The posterior component consists of the orbital apex, including the orbital fissures and the optic foramen.

Orbital Rim Fractures

Zygomaticomalar Fractures

Paskert et al have suggested a useful classification system of three types of zygomaticomalar fractures based on patterns of fracture seen on CT scan. Type 1 is incurred with low-impact trauma and results in separation of the frontozygomatic suture, infraorbital rim disruption with separation through the zygomaticomaxillary suture, fracture of the zygomatic arch, and cracks along the lateral orbital wall and floor. Type 2 fractures result from more forceful impacts and present with comminution of the inferior rim, the zygomaticomalar buttress and the orbital floor, along with separation of the frontozygomatic suture. Type 3 injuries are the most severe and often associated with Le Fort-type fractures. These result in total disruption of the zygomaticomalar complex. Typically, there is marked retrodisplacement of the malar fragment, comminution of the infraorbital rim, zygomatic arch, lateral orbital wall, orbital floor, and loss of both buttresses.

The surgical correction of type 1 and 2 injuries requires exposure of the infraorbital rim, frontozygomatic suture, and zygomaticomaxillary buttress. This can be accomplished via the combination of a brow and subciliary incision or a transconjunctival incision with lateral canthotomy in conjunction with an upper buccal sulcus incision. The bony fragments are manipulated into alignment utilizing the contralateral side as a guide to correct positioning. Type 1 injuries can be fixed with interosseous wires or microplates at the frontozygomatic suture and infraorbital rim. Type 2 injuries will often require additional plating of the zygomaticomaxillary buttress. Exploration of the orbital floor may reveal prolapsed orbital contents and the need for additional support with alloplastic implants or bone grafts. The zygomatic arch can be repositioned by elevation through the brow incision or the lateral canthotomy. Type 3 injuries may require a bicoronal craniofacial approach to reconstruct the zygomatic arch and lateral orbit.

Supraorbital Rim Fractures

In young children the stout bone of the supraorbital rim is not affected by the expansion of the frontal sinus and is thus resistant to injury. However, when high forces impact this area the consequences are serious, since fracture of this portion of the rim will often extend into a frontal skull fracture with intercranial injury. Moreover, without the protection of the frontal sinus, large forces will also be transmitted into the inner bone of the orbital roof, resulting in orbital "blow-out" fractures.

When these injuries occur they are often associated with overlying lacerations that allow for direct repair with either interosseous wiring or plating. If there is no ready access via an existing laceration, a bicoronal craniofacial exposure is appropriate. A brow incision may be sufficient when the need for exposure is limited.

Older children, in whom the frontal sinus has developed, and who have sustained supraorbital rim fractures must be evaluated and treated as adults with frontal sinus fractures. Isolated anterior wall injuries can be managed with appropriate interfragmentary reconstructions with wire or plates. Complex injuries requires basicranial exploration for evaluation and repair of dural tears, assessment of the nasofrontal ducts, and reconstruction of the anterior wall. With supraorbital fractures, the injury is typically above the nasofrontal duct, so sinus obliteration is generally unnecessary. Should obliteration be required, the standard techniques of stripping of sinus mucosa, burring of the walls, muscle, or bone pate obstruction of the ducts, and filling the cavity with homologous fat can be performed.

Nasoethmoid Fractures

The three-dimensional saddle shape of the nasoethmoid region, with its strongly defined vertical and horizontal axes, subtle curves, careful proportions, and prominent symmetries, make injuries of this region the most difficult to reconstruct. Nasoethmoid fractures can vary from simple dislocations of a fragment of the orbital rim, to comminuted compound fractures with bilaterally shattered medal orbital rims, medial orbital walls, nasal bones, and complete disruption of the ethmoid labyrinth. Various classifications have been described, but all try to differentiate between simple medial rim injuries as opposed to extended complex injuries seen in conjunction with other midface fractures. Anatomically, a nasoethmoid fracture is defined by fractures of the nasofrontal suture, nasal bones, medial orbital rim, and inferior orbital rim. Such a four-sided fracture yields a core of bony pieces that Paskert et al call "the central fragment", the appropriate reconstruction of which will provide the optimal function and cosmetic results. The varying displacement and mobility of this central fragment also provides the physical clues for accurate diagnosis.

Measurement of intercanthal distances is mandatory but poses some difficulty. The bony intercanthal distance is often obscured by edema and there is no well-documented data about soft tissue intercanthal distances as a consequence of trauma in children. Nevertheless, some quidelines are available. Recognizing ethnic, gender, and normal anatomic variations, the mean bony interorbital width by 4 years of age is 19.5 mm, by 8 years of age it is 22 mm, by 12 years of age it is 23 mm, and at adulthood it is 25 mm. Experience suggests that the soft tissue intercanthal distance is about 5 mm wider than the bony interorbital width. An additional 5 mm of soft tissue intercanthal distance is indicative of, and 10 mm diagnostic of, displaced nasoethmoid fractures.

The contemporary management of nasoethmoid fractures requires adequate exposure to facilitate optimal correction. Existing lacerations can be utilized and, if necessary, extended into camouflaged areas such as the brow. Coronal exposure is the aesthetically superior choice when lacerations are asbent. The major fragments and the medial canthal ligaments are identified. Great care is taken to preserve the attachment of the ligament to its bony insertion. The central fragment is mobilized in order to facilitate interfragmentary reduction and transnasal wiring.

The maneuver of greatest importance in the successful correction of nasoethmoid fractures is the correct setting of the medial canthal ligaments by transnasal wiring. Conversely, the easiest mistake in children is to set this intercanthal distance too widely, since interorbital growth is nearly complete by 8 years of age. A drill hole is made into the anterior lacrimal crest just above the insertion of the anterior limb of the ligament. A second drill hole is made in the posterior lacrimal crest just behind the insertion of the posterior limb. Contralateral drill holes are similarly placed and 28-gauge stainless steel wire is passed transnasally between the two fragments and tightened in an effort to overcorrect the deformity. An alternative technique is to use a small screw as the anchor for the transnasal wires. Interfragmentary wiring is complete and, if unstable, further supported by plate fixation of the medial orbital rim.

Another detrimental aesthetic feature of nasoethmoid fractures is the loss of nasal dorsal support secondary to combined fractures of the septum, ascending nasal process of the maxilla, and the nasofrontal suture. Under such circumstances bone grafts should be used to correct the deformity. These must be rigidly fixed to prevent reabsorption and this is best accomplished by lag screw fixation of the graft to the remaining nasal dorsum or by plate fixation of the graft to the frontal process in a cantilever fashion.

Orbital Floor Fractures

Orbital floor fractures are the most common injuries of the middle component of the orbit. They occur as isolated "blow-out" fractures or in conjunction with zygomaticomalar or Le Fort-type fractures. In children the occurrence of these injuries parallels the pneumatization of the maxillary sinus and are generally not seen before 5 years of age.

The clinical findings suggestive of an isolated fracture are diplopia, infraorbital hypoesthesia, periorbital ecchymoses, and edema. Several "blow-out" configurations occur. In a "trapdoor" fractue, the "blow-out" is hinged on one surface with the orbital contents herniated past it and trapped by the fragment of bone. In a "saucer" fracture, there is a depressed fracture of the floor with an increase in orbital volume resulting in enophthalmos.

The surgical treatment of isolated "blow-out" fractures has been the subject of controversy. Putterman suggests observation alone, whereas Converse and Smith advocate early exploration and reconstruction. Although these opposing perspecitves remain unresolved, a generally accepted approach in children is to observe them for 1 week. If at that point they continue to have enophthalmos, restriction or pain on movement, and ptosis of the globe on upward gaze, then exploration is undertaken. Large fractures are routinely explored as are fractures that on CT have muscle entrapment. Orbital floor fractures concurrent with other maxillary fractures are reconstructed as part of the overall facial fracture repair.

The surgical approach to isolated orbital fractures is via a transconjunctival or subciliary incision. The orbital septum is exposed and followed to the rim where the periosteum is incised, the entire orbital floor exposed, and the fracture site identified. Herniated orbital tissue is carefully teased back into the orbit and the bony fragments are elevated into position if possible and occasionally removed. If a defect or weakness persists, an implant of two layers of saline-soaked Gelfilm is usually adequate in children. In more severe multiple fractures with large defects, calvarial bone implants secured to the rim by 28-gauge wire may be necessary.

Orbital Roof Fractures

Orbital roof fractures in young children have traditionally been considered a rare injury. However, several recent reports suggest that these are more common than previously suspected. They all attribute this to the availability of direct, coronal CT evaluation in conjunction with an increased awareness of the clinical presentation of these injuries.

Characteristically, isolated orbital roof fractures occur in children under 7 years of age prior to the pneumatization of the frontal sinus. There is usually a history of a blow to the brow from a fall or a blunt object often associated with a late-developing periorbital hematoma. This delayed swelling can be an important clue in differentiating roof fractures from other orbital injuries. Proptosis or dystopia can occur but may not be immediately evident. Concomitant intracranial injury is present in a substantial proportion of cases. Although permanent morbidity is an ever-present concern, usually as a consequence of neurologic damage, the orbit and the globe do not frequently sustain long-term damage. Orbital encephaloceles have been reported as a late sequela, presenting with vertical dystopia, axial proptosis, and pulsation of the globe.

Pediatric orbital roof fractures also occur as a component of more extensive craniofacial fractures. These tend to be seen in older children and are associated with greater impacts such as high falls and motor vehicle accidents. These children have a much higher incidence of acute neurologic injury as well.

Messinger et al have suggested a classification system for orbital roof fractures based on the pattern of injuries seen on coronal CT. In type 1 fracture, there is comminution of the orbital roof but no displacement of fragments. In type 2, the fracture fragments are superiorly displaced toward the anterior cranial fossa. In type 3, the fracture fragments are inferiorly displaced into the orbit. Type 1 and type 2 injuries do not need surgical repair; however, large type 3 fractures will require combined intracranial and extracranial exploration with cranial bone graft reconstruction of the deficit to correct dystopia and exophthalmos and to prevent encephaloceles. For more extensive craniofacial injuries, where there is orbital roof fracture, neurosurgical intervention takes priority. However, surgical management may in fact require concurrent reconstruction.

Medial Orbital Wall Fractures

Medial orbital wall fractures in children are typically associated with nasoethmoid fractures. Isolated fractures of the lamina papyracea are relatively uncommon, occurring usually as a consequence of blunt trauma to the nose, rim, or eye. Orbital emphysema is commonly seen on CT. Enophthalmos and entrapment may occur with isolated injuries and, under these circumstances, surgical correction is necessary. This can be accomplished by an external ethmoidectomy-type incision, which exposes the medial orbital wall. Soft tissue reduction and bone grafting, if necessary, can then be performed.

Orbital Apex Fractures

Fortunately, orbital apex fractures are rare injuries. Although there are no reports in the literature of these injuries specific to children, it is doubtful whether the mechanism, pattern, and consequence of trauma to this vital area varies with age. Fractures of the apex are usually due to posterior extensions of complex craniofacial injuries. Blindness is the greatest concern, occurring as a result of optic nerve injury and vascular injury to the ophthalmic artery. Treatment with steroids or optic nerve decompression via either a transsphenoidal or intracranial approach should be considered; however, reversal of blindness is unusual. Injury to the neurovascular structures entering the superior orbital fissure can result in ophthalmoplegia, ptosis, and fifth nerve hypoesthesia. Treatment is expectant but long-term deficits are common.

Temporal Bone Fractures

Temporal bone fractures are not traditionally considered within the realm of maxillofacial trauma. Because of frequent association between these two types of injuries in children, as well as the profound aesthetic and functional facial changes that can be the result of temporal bone fractures, a brief review of the topic is presented.

Temporal bone fractures are classified by their anatomic pattern of injuries into three types: longitudinal, transverse, and mixed. Longitudinal fractures are the most common and account for 70% to 85% of temporal bone fractures. The mechanism of injury is generally trauma to the temporal or parietal areas. These injuries are parallel to the long axis of the petrous bone, typically starting at the posterior half of the squamosa, extending medially, and slightly anteriorly. Along its course, the fracture runs through the posterosuperior wall of the external auditory canal, the epitympanum, and the carotid canal, ending in the middle cranial fossa near the foramen lacerum. Classically, the fracture is lateral and then anterior to the inner ear. Although the cochlea and vestibule are not directly injured, sensorineural hearing loss is reported in 5% to 35% of longitudinal fractures. Conductive hearing loss is much more common, occurring in about 50% of cases as a result of hemotympanum, tympanic membrane tears, and ossicular chain disruptions. Hemorrhage from the external auditory canal is also a common feature resulting from tears of the canal skin. Facial nerve dysfunction occurs in about 10% to 20% of longitudinal fractures, generally as the consequence of a physiologic block secondary to stretching, ischemia, or edema in the tympanic segment of the nerve. CSF otorrhea is rare in longitudinal fractures and is due to medial extension of the fracture to the tegmen. Bilateral longitudinal fractures are seen in 10% to 30% of cases.

Transverse fractures account for 10% to 20% of temporal bone fractures. The mechanism of injury is usually from severe blows to the occipital or frontal areas of the skull. These injuries are perpendicular to the long axis of the petrous bone, typically starting at the foramen magnum, crossing the petrous pyramid, and ending in the middle cranial fossa at or near the foramen lacerum. As the fracture passes across the petrous pyramid it inolves the cochlea and the vestibule, resulting in universal sensorineural hearing loss and vertigo. Facial nerve injury occurs in 50% of cases, generally due to a tear within the labyrinthine segment. If the fracture line involves the medial wall of the middle ear then hematotympanum is seen. Middle ear involvement can also result in CSF otorrhea.

Mixed fractures account for 10% to 20% of temporal bone fractures. The mechanism of injury is usually from crushing blows to the side of the head. There is no generic fracture pattern as in longitudinal and transverse types, but a variety of fracture lines involving the petrous pyramid, cochlea, vestibule, and middle ear are seen. There is thus a variable clinical picture of conductive and sensorineural hearing loss, vertigo, facial nerve paralysis, hematotympanum, canal hemorrhage, and CSF otorrhea.

In children, these types of injuries are due to pedestrian-motor vehicle accidents (40%), falls (30%), passenger-motor vehicle accidents (25%), and blows to the head (5%). Hence, the temporal bone fracture is only considered after the more life-threatening injuries have been taken care of. Important diagnostic studies include axial and coronal CT and early audiologic evaluation. Facial nerve testing is indicated when paralysis is present.

Management of temporal bone fractures depends on the deficits incurred. The most common problem is conductive hearing loss. When this is due to hematotympanum alone it generally resolves without intervention. In most cases, tympanic membrane tears will also heal on their own. This can be facilitated with paper patching, if the child allows, or concurrently with a general anaesthetic for another problem. Persistent perforations have a potential for cholesteatoma formation and should be repaired with standard tympanoplasty techniques within 3 to 6 months of the injury.

Ossicular disruptions account for 15% to 20% of conductive hearing loss in temporal bone fractures. The two most common injuries are incudostapedial separation and incus dislocation. Fractures of the stapedial crura occur less frequently. An air bone gap of 35 dB or greater 3 months after the injury suggests ossicular disruption and is an indication for exploratory tympanotomy. Incudostapedial separation or incus dislocation warrants ossicular reconstruction with the homograft incus. This can be accomplished either as a "mushroom cap" interposition between the tympanic membrane and the stapes or as a Y strut between the malleus and stapes. Crural fracture is best treated with stapedectomy in older children. In younger children, the footplate should be left intact.

Sensorineural hearing loss can occur with all types of temporal bone trauma and is seen in 5% to 10% of children with head injury. Recovery rates are reported between 10% and 50%. With longitudinal injuries, where there is no fracture of the cochlea, sensorineural hearing loss may be a consequence of hydraulic trauma to the inner ear membranes or to disruption of central auditory pathways. With transverse fracture there is direct cochlear injury resulting in a 90% to 100% incidence of sensorineural hearing loss. When there is anakusis or flat hearing loss, little recovery can be expected; however, there may be some with fluctuating or low-frequency losses. If there is serviceable hearing in the involved ear, amplification can be provided. Suspicion of perilymphatic fistulae, as evidenced by fluctuating sensorineural hearing loss and positive fistula tests, indicates immediate exploratory tympanotomy.

Vertigo can also occur with all types of temporal bone injuries. It is more likely with transverse and mixed fractures, where there is direct vestibular injury. Both post-concussive vertigo and cupulolithiasis can be seen with longitudinal fractures. Vestibular testing is difficult in children and may not add much to the outcome. Due to the plasticity of a child's brain, dizziness and disequilibrium will extinguish as compensation occurs.

Facial nerve paralysis is more likely with transverse and mixed fractures. Longitudinal injuries are much more common; hence, they account for a higher incidence of facial paralysis as a consequence of all temporal bone trauma. With longitudinal fractures, facial paralysis will often have a delayed onset. This is an important clue since it suggests subsequent recovery. Unfortunately, this information is not always available and prognostic insight must await facial nerve testing. Electroneurography is the diagnostic procedure of choice and can be done as soon as 3 days after the injury, the time required for denervation to occur. Fisch has published guidelines regarding the prognostic value of electroneuronography along with indications for surgical intervention. If there is 90% or greater denervation within 6 days of the injury, the likelihood of recovery is small and facial nerve exploration and decompression is indicated. Denervation of a lesser degree, occurring over a longer period of time, is associated with a greater likelihood of spontaneous recovery and surgical intervention is not necessary. The surgical approaches for facial nerve exposure are via the transmastoid, translabyrinthine, and middle cranial fossa routes. Each approach has its advocates, but all agree that decompression of the geniculate ganglion is desirable for optimal results. For cases with loss of nerve tissue, cable grafting or hypoglossal facial anastomosis can be utilized.

Cerebrospinal fluid leaks presenting as clear otorrhea or rhinorrhea can be the one life-threatening consequence of temporal bone fractures because of the potential for meningitis. They occur in 5% of basilar skull fractures and will spontaneously seal more than 90% of the time. In the first 2 weeks, treatment is directed toward promoting natural closure by bed rest, head elevation, and spinal drainage. If the leak persists, an attempt should be made to diagnose its source with metrizamide-contrasted CT or radionuclide studies. Unfortunately, these are not universally successful in identifying the site of leakage. Surgical closure by either a transmastoid or craniotomy approach is necessary for persistent leaks, late-onset leaks, recurrent meningitis, or brain herniation.

Conclusion

In our highly mechanized society children sustain serious maxillofacial injuries that require appropriate repair. The primary factor that differentiates the treatment of pediatric facial fractures from those of adults is facial growth. The anticipation of growth of the mandible simplifies fracture repair, since most of these injuries can be managed with intermaxillary fixation. On the other hand, inadequate treatment of upper facial injuries will result in serious alterations of facial growth. The techniques of three-dimensional reconstruction of complex fractures have been revolutionized over the past decade with the use of rigid plating systems, craniofacial exposure, and bone grafting. There are solid theoretical grounds for the application of these techniques and short-term results of their use appear promising. Only time and careful study will prove their long-term value.