Pediatric facial fractures

Maxillofacial trauma in the pediatric population presents the clinician with many challenges. While the goals of therapy are the same as in adults, the approach to the management of these injuries in children is often different, because of the emotional, anatomic, and physiologic peculiarities of childhood. After four decades of extensive literature on the subject, controversy still exists in many areas of treatment. Management must take into consideration the unique characteristics of pediatric fractures, the differences in the pediatric facial structure, the recognition that the pediatric maxillofacial skeleton is a growing entity, and the lack of literature documenting long-term follow-up. Fortunately, facial fractures in the child are uncommon because of environmental and anatomic protective factors.

INCIDENCE

Numerous studies document the incidence of maxillofacial injury in children as lower than in adults. Reasons cited include the small volume of facial mass relative to the calvarium, the relative resiliency of the immature bone, and the protected environment in which children live. Posnick et al. recently reviewed a group of pediatric facial fracture patients and found that injury was twice as common in boys and affected the 6- to 12-year-old age group most often often. Rowe found that only 1% of all facial fractures occurred in children under 6 years of age. He later reviewed 1500 facial fractures and found only 77 fractures in children under 12, an incidence of only 5%.[9] McCoy and others reviewed 1500 facial fracture patients and reported only 86 fractures in the pediatric population. Panagoupoulos reported an even lower incidence, with only 1.4% of all facial fractures involving children. However, most of these data were collected at a time when computed tomography (CT) was unavailable. There is ample documentation that conventional radiography in children underdiagnoses bony injury because of the high cancellous to cortical bone ratio and lack of developed sinuses. Additionally, isolated nasal and dentoalveolar fractures, two of the more common injuries in children, are often not included in these reviews. This oversight occurs because these injuries most often result from minor trauma and rarely warrant admission. Therefore, it is likely that the incidence of pediatric facial fractures is significantly higher than reported, a finding that is supported by more recent series. Carroll and others found a 23% incidence of pediatric facial fractures in 1044 patients over a 5-year period, 1979 to 1983.

TABLE 19-1. RELATIVE INCIDENCE OF PEDIATRIC FACIAL FRACTURES

Author	Year	No. of Patients	Incidence (%)	Comments
McCoy etal.[10]	1966	86	6	Nasal fractures treated as outpatient not Included
Rowe[6]	1968	24	5	
Rowe[9]	1969	77	5	
Dufresne and Manson[34]	1990	158	5	
Gussacketal.[1]	1987	30	15	CT used In diagnosis
Carroll et al.[6]	1987	241	23	Includes dentoalveoar fractures

DISTRIBUTION OF FRACTURES

As fractures; which of the two is more preva the two most prominent features of the pediatric face, the nose and mandible account for most of the reported fracture; which of the two is more prevalent depends on the author. McCoy et al. reported that mandibular fractures comprised 41%, whereas nasal fractures totaled 23% of all fractures. Bales et al., at the University of Pennsylvania, found that mandibular fractures comprised 65% of the total injuries.[2] On the other hand, Kaban et al. found nasal fractures more common, accounting for 45%, followed by mandibular fractures comprising 32%.[14] Other fractures of the midface are relatively uncommon. McCoy and colleagues reported an incidence of 16.3% for orbital or malar complex fractures, 5.8% for maxillary fractures, and 4.7% for zygomatic fractures.[5] Kaban and coworkers reported no midfa-cial fractures in 109 pediatric patients accumulated over a 10-year period.[14] Over the next decade of 184 fractures, Kaban found only five midface fractures, all of them Le Fort III injuries.[1]

CAUSATIVE FACTORS

The etiology of pediatric facial fractures varies depending upon the study cited. Posnick et al. found traffic-related accidents accounted for 50% of injuries, followed by falls (23%), and sports (15%).[7] Johnston and coworkers observed that a greater involvement in car accidents and less use of car restraints caused a 64% higher incidence of injury for 3-year-olds than for infants.[16] Carroll and colleagues found 42.6% of the injuries caused by falls, followed by road traffic injuries (34.4%), and sports (5.8%). Assaults occurred in 3.2% of the population, but all in the 10- to 15-year-old group. Not surprising, there was a marked seasonal variation, rising to a peak in July. Recently, all-terrain vehicles (ATVs) have become a common cause of maxillofacial trauma. De-mas and Braun reviewed the injuries incurred by juvenile ATV users and found that 37% sustained facial fractures. Fortunately, child abuse is a rare cause of pediatric facial fractures but should be considered, especially in children with recurrent injuries.

DIAGNOSIS

The diagnosis of pediatric facial fractures can be problematic. One must have a high index of suspicion, especially in the presence of other major injuries. Children are frequently uncooperative, making the history and physical examination at times impossible. It is not uncommon to utilize general anesthesia to properly examine and evaluate a pediatric trauma patient. History must often be obtained from the parents or observers, because children are frequently unable to recount the events surrounding their trauma. Photographs of the child before the injury are sometimes helpful. In addition, dental records, including any models, obtained from the child's dentist or orthodontist can be especially helpful. Examination must include a complete opthalmologic and neurologic evaluation because of the high incidence of associated injuries. As a result of the large skull to face ratio in children, there is a high incidence of associated skull fractures. McCoy et al. found a 41% incidence of associated skull fractures in their patients, whereas the incidence of other associated injuries included facial wounds in 88%, concussions in 31%, cerebrospinal fluid (CSF) rhinorrhea in 14%, extremity fractures in 10%, ocular injury in 3.6%, closed chest injury in 5.8%, and abdominal injury in 2.3%.

In today's practice of medicine, plain radiographs have been superseded by computed tomography (CT). Plain radiographs consistently underdiagnose facial fractures in the pediatric population. This is because of a combination of a higher ratio of cancellous to cortical bone, and the higher incidence of "greenstick" type fractures, as compared to adults. In addition, a child may not tolerate the varied positioning required for plain radiographs because of pain or poor cooperation. CT, on the other hand, provides detailed information on bone and soft tissue, with the capability for three-dimensional reconstruction.[20] Finally as previously discussed, with the high incidence of associated injuries in pediatric trauma, CT is indicated in even apparently trivial injuries in order fully to evaluate these often uncooperative patients.

UNIQUE CHARACTERISTICS

One of the problems in reviewing pediatric maxillofacial fractures is that many series tend to group children of all ages into one category. The pediatric facial skeleton is a dynamic, evolving structure and the face of a 1-year-old is very different from that of a teenager. What begins as a vertically short, wide, and resilient mass matures into an elongated, projecting, and less resilient structure. These facial changes, coupled with the decreasing elasticity secondary to increased mineralization of the facial skeleton, lead to differing patterns of injury as the child ages. Although increasing skeletal mineralization and hardening continue throughout life, most experienced craniofacial surgeons agree that the brittleness of facial bones increases dramatically after the age of 2 to 3 years. It has been our experience that seemingly equivalent traumatic force in the child and adult creates

injuries in the child with less comminution. There rarely are "egg-shell" type fractures in the child, whereas nondisplaced "greenstick" fractures are common.

The development of paranasal sinuses also greatly affects the pattern of fracture in the pediatric population. Maxillary sinus aeration begins after birth and is

Figure 19-1. A unilateral greenstick fracture of the right condyle In a young boy. This fracture will remodel appropriately with conservative management.

completed, reaching the nasal floor, by approximately 12 years of age. Frontal sinus aeration is not evident until age 4 to 5 and is completed in late adolescence. Sinus development and eruption of permanent dentition contribute to the evolution of an immature, solid mass into a pillared, hollow structure. Before these changes, the typical pattern of Le Fort fractures rarely occurs; more commonly fractures follow oblique patterns. Furthermore, Messinger et al. have described the unique patterns of supraorbital fractures before the development of the frontal sinuses. Thus, as sinus aeration and permanent dentition develop, there is a progression toward a more adult-type pattern of fracture.

The pediatric mixed dentition represents a unique challenge to the reconstructive surgeon. Not only does it impose limitations on the method of fixation used, but it must also be taken into account that injury to primary teeth or the surrounding bone and soft-tissue matrix may lead to future abnormalities of the teeth in succession. The differences in approach are outlined later in the chapter.

The immature, pediatric skeleton presents two other unique challenges to the reconstructive surgeon. First, because of the rapid healing of the pediatric skeleton, fractures must be treated sooner than in adults, preferably within 3 to 4 days. Later reduction can be difficult, if not nearly impossible. Second, consideration must be given to the effects injury and its treatment may have on subsequent facial growth. Unfortunately, despite appropriate treatment at the time of injury, disruption of normal development can occur. Ousterhout and Vargervik presented several patients in whom midfacial fractures resulted in halted development and midfacial hypoplasia.

CONTROVERSIES IN MANAGEMENT

Conservative versus Aggressive Management of Fractures

The development of rigid internal fixation after wide exposure and anatomic reduction has led to greatly improved results in the treatment of adult facial fractures. Unfortunately, this approach cannot be indiscriminately applied to the pediatric population. There is evidence that the pediatric skeleton has considerable ability to remodel after injury. Walker, studying a condylar fracture model in the rhesus monkey, demonstrated the potential for significant remodeling of the facial mass in the growing skeleton. His observations lend scientific support to observations made by several authors. Retrospective studies of condylar and nasal fractures in the pediatric population have demonstrated that many occult fractures go unrecognized and remodel without deformity. Therefore, conservative management of some pediatric facial injuries is warranted. The surgeon must consider the severity of the fracture and the age of the patient in deciding on a treatment modality. A young child with a minimally displaced or greenstick fracture can be treated conservatively, whereas an older patient with a severely displaced fracture requires treatment similar to an adult. The controversy arises in addressing the large gray area between these two extremes. How does one treat the moderately displaced facial fracture in the child who is skeletally immature? The best approach may be a surgically conservative one, and there is often a role for merely limited exposure and reduction without the need for rigid internal stabilization.

[1] Wide versus Limited Exposure

Complete exposure of the fracture site is one the basic tenets of maxillofacial trauma. The question remains as to whether extensive exposure is necessary or appropriate in the pediatric patient. Some authors have suggested that wide subperiosteal undermining may contribute to the restriction of bone growth from a scarred soft-tissue envelope. On the other hand, broad undermining of the fronto-orbital region, as in the treatment of plagiocephaly, is not observed to significantly restrict growth. Until more experience is accumulated, it is reasonable to limit exposure to the minimum required for treatment, in an attempt to decrease any potential for further injury.

Reduction and the Use of Rigid Internal Stabilization

Like those in the adult population, many pediatric facial fractures require reduction and fixation. In children the question remains whether modestly displaced fractures require reduction and, if reduction is required, whether internal stabilization is necessary. There is ample evidence that many fractures in the pediatric patient will remodel appropriately with litde or no intervention. As mentioned, greenstick fractures are common in children and reduction without fixation may be stable, a situation rarely seen in adults except in the nasal region.

When internal stabilization is required, single-point fixation may be suitable, again because of the tendency of greenstick-type injuries.

The use of plate-and-screw fixation in children is also unresolved. It has been demonstrated experimentally that plates and screws of the size used in the routine management of adult midface fractures may, if not removed after fracture healing, cause growth disturbances secondary to the rigid fixation. The recent development of smaller microplates may avoid this problem. We have observed anecdotally that microplates appear to function like wire fixation; that is, they provide stable, not rigid, fixation without exerting deleterious long-term effects. Another consequence of plate-and-screw fixation is the "migration" (i.e., translocation) of plates and screws in the growing skeleton. The facial mass expands by appositional and translational growth. It is observed clinically and experimentally that the plates and screws may translate inward, becoming covered with bone over time.[36] The long-term implications of this have yet to be assessed. Although plate-and-screw fixation has a definite role in complex pediatric facial fractures, consideration must be given to interval removal. Removal is strongly recommended when multiple plates have been used, or the child has a significant amount of facial growth to complete.

Use of Alloplastic Materials and Bone Grafts

Alloplastic materials have gained acceptance in primary and secondary reconstruction in adults. In the pediatric population, the long-term results of alloplastic materials for reconstruction are unpredictable. Since other accepted options exist for pediatric reconstruction, alloplastic materials are not recommended for use in children. Autogenous bone harvested from the cranium provides excellent material for reconstruction.

The timing of bone grafting in children has also created controversy. Obviously, if bone is missing, inlay grafts should be applied. The problem arises with the use of onlay grafts in the acute setting to supplement contour. First, one cannot predict whether a contour defect will remodel to a suitable appearance with development. Second, rigid fixation of a bone graft over a fracture site may cause a secondary growth disturbance. Therefore, acute bone grafting should be reserved for severe deformity and soft- tissue collapse. It is important in the setting of a severe fracture to thoroughly discuss the possibility of secondary reconstructive procedures with the parents. If after appropriate treatment a contour deformity exists, secondary reconstruction is undertaken when facial growth is complete.

Pediatric Dentition

The mixed dentition in the pediatric patient presents a unique challenge in the management of maxillofacial fractures. Primary teeth and partially erupted secondary teeth are not a stable foundation for arch bars or similar techniques utilized for intermaxillary fixation (IMF) in adults. Because of the conical shape of the teeth, it is often difficult or impossible to place the wires required for fixation. In addition, primary teeth can be avulsed by the pressure exerted in IMF.

Intermaxillary fixation can best be obtained through the use of occlusal splints, fashioned in the operating room, and secured with circummandibular or pyriform aperture wires . If arch bars are used in the young mouth, circummandibular or pyriform aperture wires securing the arch bars may decrease the chance of tooth displacement.

In the infant and throughout childhood, the mandible and maxilla are filled with tooth buds in various stages of eruption Therefore, injuries to this region can result in the maldevelop-ment of permanent dentition. Extreme care must be taken to avoid further injury by limiting debridement and manipulation. Tooth buds in the fracture line should not be discarded but should instead be carefully preserved. Finally, if internal stabilization is needed, one must take great care to avoid placement of wires or screws near or through developing teeth.

Despite these concerns, the pediatric dentition does offer the reconstructive surgeon one advantage. Minor occlusal discrepancies may be accepted because of the potential for orthodontic remodeling with growth.

MANAGEMENT OF FACIAL FRACTURES
Alveolar Fractures

Fractures of the alveolus are common in the child but are frequently underreported in the literature. Alveolar fractures occur most commonly from falls, most frequently involve the anterior maxilla, and are usually not associated with other injuries. Therefore, when present as an isolated injury, they are treated in an outpatient setting and are overlooked in retrospective studies.

Andreasen[41] first classified fractures of the dental arch into three types:

1. Fractures of the facial or lingual-palatal socket
2. Fractures of the alveolar process
3. Fractures of the mandible and maxilla

Fractures of the tooth socket occur secondary to luxation of the tooth. Fractures to the alveolar process occur when trauma is dispersed over several teeth. The survival or death of the tooth pulp in these types of injury is related to the degree of trauma inflicted upon the pulpal vascular supply, the type of luxation, the stage of root development, and the time interval from injury to permanent fixation. [42] The lowest frequency of pulp necrosis is found in the case of subluxation, and the highest in the case of intrusive luxation. The important point to remember, as the treating physician, is that the interval from injury to fixation is the one factor we can control.

Treatment of alveolar or dental fractures requires prompt attention. Any avulsed teeth should be replaced immediately into their socket, preferably at the scene of the traumatic injury. Replacement of avulsed teeth within 30 minutes of injury has a reasonable rate of success, whereas after 30 minutes root resorption invariably occurs. Bone fragments should not be debrided from surrounding soft tissues, because these often survive as long as they are attached to periosteum. Fragments are reduced and intramaxillary fixation obtained with an occlusal splint. Fixation for at least 6 weeks is required, as shorter periods of fixation lead to an

increased incidence of malocclusion. If the tooth or alveolus fracture is beyond fixation, the soft tissue should be closed over the injury to avoid bony resorption.

Dental injuries can be divided into those involving deciduous teeth and those involving permanent dentition. Deciduous teeth in small children are frequently intruded at the time of injury, and will reerupt in several weeks. As the child ages, the incidence of subsequent pulp necrosis and tooth loss unavoidably increases. Loose or avulsed teeth should be properly reoriented within the socket and fixed into place with an occlusal splint. The close anatomic relationship between the apices of primary teeth and their developing permanent successors explains why injuries to the primary teeth may involve the permanent dentition. Intruded teeth lead to a significant incidence of injury to the underlying permanent dentition. Andreasen and Rawn found disturbances in the permanent dentition in 41 % of all dentoalveo-lar trauma, and the majority occurred secondary to an intrusive injury.[45]

Luxation of permanent teeth is treated similarly, with repositioning and splinting. Splinting is completed with an acrylic overlay or orthodontic bonding and bracketing. The difference from deciduous teeth arises in the common complication of pulp necrosis and subsequent need for root canal therapy. If the crown is fractured, therapy requires capping and/or a partial pulpectomy.

Mandibular Fractures

Incidence

As a result of the relative prominence of the mandible in children, mandibular fractures are not uncommon. Following nasal fractures, injury of the mandible is the second most common injury to the craniofacial region. In previous studies the most common causal factors for mandibular fractures were motor vehicle accidents, bicycle accidents, altercations, and falls. Most large series of pediatric patients report the incidence of mandibular fractures at approximately 20% to 40% of all facial fractures. Hall found 116 mandibular fractures in 495 children (20.7%) under the age of 14, 64% involving the body of the mandible, 24% involving one condyle, and the remainder involving both condyles. McCoy et al. found a 40.8% incidence of mandibular fractures in children in their series." The incidence of mandibular fractures increases from birth through 15 years of age in a gradual progression. In children under the age of 6, a mandibular fracture is rare and its presence should alert the physician to the likelihood of other injuries. In the Kaban et al. series, patients with mandibular fractures had the highest incidence of associated injuries. Twenty-two of 29 patients had other injuries, including facial lacerations, cervical spine injuries, skull fractures, other craniofacial trauma, or extremity injuries.[14]

Distribution

The patterns of mandibular fracture vary with age. The incidence of condylar fractures decreases and the incidence of body and angle fractures increases with increasing age of the child.[4(1] In addition, the proportion of condylar fractures is

higher in children than adults. Siegal et al. reported a 43.4% incidence of condylar fractures in children under 6 years; this incidence decreased to 7% in children aged 13 to 18. Lehman and Saddawi" reported a

Diagnosis

In examination of the child, there are several physical findings that are indicative of mandibular injury. Malocclusion is usually present, although in less severe fractures it may be subtle. The physician's only evidence for malocclusion may be the child's complaint that his or her teeth do not come together normally. A bilateral condylar fracture will cause an open bite deformity. In contrast, a unilateral condylar fracture may only be evidenced by slight deviation of the mandible to the affected side upon opening. The risk of overlooking a condylar fracture has been discussed by Proffitt et al. These fractures can go undiagnosed because of few physical symptoms and lead to growth disturbances later in life. Proffitt et al. found that of 121 patients with severe mandibular asymmetry, 5% to 10% probably were caused by an unrecognized condylar injury. Examination must include a bimanual extraoral and intraoral exam. Tenderness, crepitus, and swelling may be present over a fracture. Condylar neck fractures are always displaced medially as a result of the pull of the pterygoid muscle, but a depression deformity does not result. Placing the fingers in the external auditory canal can be helpful in assessing fracture dislocations. In an isolated mandibular fracture a panoramic view is adequate. It provides a view of the entire mandible, condyles, teeth, glenoid fossa, and maxilla. Although panoramic views are usually sufficient, children can incur unusual patterns of injury (i.e., sagittal fractures) that are missed. Therefore, if any doubt in diagnosis exists or other head injury is suspected, a CT scan should be obtained.

Treatment

The goal in the treatment of mandibular fractures is the same as in the adult: Restore a normal occlusal relationship, ensure bone union, and avoid infection. Children provide an advantage of allowing minor malocclusion or malunion to be tolerated that will remodel with eruption of secondary teeth and facial growth. If the fracture is incomplete, favorable, or with minimal displacement and occlusion is normal, then a conservative approach is warranted. A regimen of rest, soft diet, and supportive care for 2 to 3 weeks is sufficient for healing. With unfavorable or moderately displaced fractures, reduction and intermaxillary fixation are required. If occlusion is obtained through closed manipulation, then intermaxillary fixation alone is indicated. Open reduction with internal stabilization is undertaken in severe fracture dislocation when normal occlusion cannot be obtained through closed manipulation and IMF.

As discussed earlier, interdental fixation is challenging in the pediatric population. In older children, arch bars and eyelet wiring may be used, but this is

possible in only one third of the pediatric population. In younger children, for reasons already discussed, an alternative method of fixation is required. An acrylic overlay mandibular splint is constructed and secured to the mandible via two circumferential wires. The splint is constructed so that the occlusal surface is in contact with the maxilla, and a normal vertical dimension is maintained.[51] In the case of a fracture to the body or symphysis, this type of monomaxillary fixation may be adequate. When interdental fixation is required, additional wires are passed through the nasal spine or lateral pyriform aperture and afixed to the circummandibular wires. In the child, fixation should not be obtained with cir-cumzygomatic wires as the wires will cut through the soft bone. A unique alternative to IMF that we have used in patients with condylar fractures involves joining circummandibular and piriform aperture wires without the use of an occlusal splint. Because of the rapid healing of children, a 2-week period of immobilization is effective. This shorter period of immobilization also avoids any subsequent functional impairment or ankylosis.

In badly displaced body or angle fractures, open reduction may be necessary. Through an intraoral approach, interosseous fixation is achieved with either miniplates and screws or figure-eight wiring. In- terval removal is recommended when miniplates are used. Occasionally, with minimally to moderately displaced greenstick-type fractures, stabilization may be achieved with microplates at the lower border and segmental wiring of the teeth. Use of such fixation will obviate the need for hardware removal but must occur when only semirigid fixation is necessary. Whichever method is used, care must be taken to place the fixator near the lower border of the mandible to avoid injuring tooth buds.

Fractures of the coronoid process either alone or in conjunction with other mandibular fractures are extremely rare. Minimally displaced fractures require only conservative care. If displacement is severe and interferes with mandibular function, the coronoid process is removed through an intraoral approach." '

Management of mandibular condyle fractures has been debated for years. The controversy arises because of the potential for growth disturbance and the complexity of the temporomandibular joint. The primary growth center of the mandible is located in the condylar head where a cartilaginous cap provides epiphyseal-like growth and endochondrial ossification. Mandibular growth, in turn, greatly influences facial growth. Severe injury to the condyles can result in ankylosis, and hypoplasia on the affected side. Rowe reported that the younger the child in which a fracture occurs, the more likely a growth disturbance will result. The eitiology of ankylosis is not completely understood, because it occurs both in patients who have been excessively immobilized and in those who have not.

Numerous authors have presented experimental and clinical data supporting the ability of the condyle to remodel without anatomic reduction. Walker and Boyne, working on rhesus monkeys, found that, despite the type and degree of fracture dislocation, conservative care resulted in appropriate remodeling of the mandibular condyle. Leake et al., in their series of 13 children with condylar fractures, found that all subsequently had normal appearance and function. This included a 2/4-year-old with a bilateral fracture dislocation treated with conservative methods and

no fixation. Lindahl and Hollender[58] provided radiologic evidence of condylar remodeling. In children aged 3 to 11, there was a complete return to normal skeletal relations in 20 of the 27 previously injured joints. Joints in teenagers (aged 12 to 19) did not normalize to the same extent, and in adults only minimal remodeling was observed. MacLennan, in a review of 180 cases of condylar fractures treated by conservative methods, found that crush injuries of the condylar cartilage before the age of 5 were most prone to maldevelop-ment. However, complications occurred with only 16% of the children experiencing deviation with motion, and none with limitation of motion. The child at greatest risk for mandibular growth disturbance is under 3 years old with a crush-type, bilateral condylar injury. It appears that the choice of treatment in this patient group does little to affect outcome. Fortunately, this is a very small subset of the patient pop-ulation. More recently Norholt et al. examined 55 patients between 5 and 20 years old who were previously treated conservatively for a fracture of the mandibular condyle, with a mean follow-up time of 10.1 years. Radiologic abnormalities could not be correlated with the severity of dysfunction. In addition, no cases of ankylosis or serious asymmetry were found, although the older age group had significantly more minor asymmetry and dysfunction.

These experiences, and many others, have led to a predominately conservative approach to the treatment of condylar fractures in preteenage children. A conservative approach implies restoration of normal occlusal relations with IMF if needed, followed by physiotherapy. In the absence of malocclusion, a regimen of analgesics, a liquid-to-soft diet, and close observation are usually sufficient. If pain and malocclusion are present, a 7- to 10-day period of immobilization followed by physiotherapy is indicated.

Although conservative management predominates, there are some unusual circumstances when open reduction is indicated; these include a failed conservative approach, a fractured condyle that interferes with normal jaw movement, a bilateral condylar fracture that results in an anterior open bite, and, rarely, a condylar fracture with dislocation into the middle cranial fossa causing a neurologic deficit. There are several surgical approaches available to the surgeon. Hoopes et al. advocated a postauricular incision and transauricular approach as providing rapid, safe access with generous exposure of the temporomandibular joint. This approach has the added advantage of avoiding the main branch of the facial nerve and a hidden surgical scar. More common approaches include a preau-ricular incision or a retromandibular approach. Once exposure is obtained, the fragments are realigned and interosseous fixation completed with 25-guage wire or a small (mini- or micro-) plate.

Maxillary and Midfacial Fractures
Incidence

Fractures to the midface in the pediatric population are rare. Kaban et al. reported no midfacial fractures in 109 consecutive children involved in facial

trauma. Rowe has estimated that midfacial fractures account for under 0.5% of all facial fractures in children under 12 years old. Because of the prominence of the cranium and mandible, these structures provide protection and absorb most of the traumatic force. This, in combination with incomplete pneumatization of the maxillary sinuses, mixed dentition, and unerupted teeth, makes the face more elastic and resistant to fracturing. Therefore, when a maxillary fracture is present a great deal of force has been delivered, and a diligent search for other injuries is warranted. The incidence of associated injuries varies from 25% to as high as 88%.

Special Considerations

In the pediatric population, the structural pillars or buttresses that determine the classic patterns of fracture in the adult have not developed. This leads to atypical patterns of fracture in the midface. In children, an oblique pattern of fracture with less comminution is routinely observed . The typical Le Fort patterns of fracture rarely exist. Le Fort I, a horizontal maxillary fracture, is uncommon because of the lack of sinus pneumatization. It is not
until age 10 that the tooth buds have developed into permanent dentition and the maxillary sinus has reached the floor of the pyriform aperture. Until skull development is complete, forces that would result in Le Fort I fractures in the adult are usually absorbed lower. This leads to avulsed teeth, and fractures of either the labial or buccal plates of alveolar bone. Le Fort II, pyramidal, fractures are slightly more common, but when these occur they are usually unilateral. Le Fort III fractures, craniofacial disjunction, rarely occur, and when present are composed of several facial fragments. As noted originally by Le Fort, fracture lines of the midface tend to travel through the path of least resistance. The palatal suture does not complete ossification until late adolescence and is weak in children. Therefore, it is common to observe palatal splits in the midline in children. In contrast, adults experience parasagittal splits on the side of the face absorbing the traumatic force.

Diagnosis

Diagnosis is confirmed with any maxillary mobility, step-off deformity, or malocclusion. Because of the lack of sinus pneumatization, plain radiographs are not useful in diagnosis. A CT scan is essential for accurate preoperative evaluation and treatment. In addition, because of the excessive force required to create midfacial fractures in children, a CT scan is usually indicated to exclude intracranial and other injuries.

Treatment

Treatment of these fractures in children requires a resourceful surgeon. The methods of fixation must be varied depending on the degree of dental maturity. Because of rapid healing and the ability to remodel, midfacial fractures with minimal displacement are best managed without surgical intervention. Again, when fixation is required, care must be taken to avoid injury of the tooth buds. When intermaxillary fixation is indicated, acrylic occlusal splints are superior to arch bars in young children without a significant number of permanent teeth. Once fabricated from dental models, the acrylic dental splints are stabilized with a combination of lateral pyriform aperture and circummandibular wires. This method avoids stress on the deciduous dentition.[87] Suspension wires to the orbital rim or zygoma are unacceptable in children because of the softness of the bone. Patients should be followed periodically to assure that the occlusal relationship is maintained. If a palatal fracture is present, care must be taken to avoid fixation that separates the palate. Often a palatal splint will be needed for adequate reduction. Healing is significantly shorter than in adults, so fixation may be removed in 2 to 4 weeks, depending on the severity of injury.

Despite appropriate and careful treatment of midfacial fractures, injury to the growth centers of the maxilla and nasal septum can alter normal bone growth, leading to facial deformity.[2] Converse and Dingman suggested that nasomaxillary fractures may explain nasal deviation and nasomaxillary hypoplasia seen in children with no other obvious causes. Ousterhout and Vargervik reported three previously normal children who developed significant midfacial hypoplasia after sustaining midfacial fractures, despite adequate treatment.[26] This risk of potential growth disturbance needs to be stressed to parents preoperatively, although, except for severe injuries, this occurrence is infrequent.

Naso-orbito-ethmoid Fractures

When disruption of the nasal bones is severe with structures pushed into the intraorbital space, open
reduction with fixation via interfragmentary wiring is required. Open reduction in severe naso-orbital fractures can avoid complications such as traumatic telecanthus, "saddle-nose" deformity, and disturbances in the lacrimal apparatus. In addition, naso-orbito-ethmoid (NOE) fractures are always associated with "blowout" fractures of the medial and inferior orbital wall and rim.

Diagnosis

Naso-orbito-ethmoid fractures are associated with significant perinasal and periorbital edema. Retru-sion, flattening of the nasal pyramid, and an increase in

the columella-tip angle are common findings. Lacerations of the frontal and nasal area should also raise suspicion. Bilateral periorbital hematoma may suggest a fracture extending into the anterior cranial fossa. A CSF leak may be present, indicated by increased nasal drainage.

Physical examination should exclude any instability, crepitus, or tenderness. Traumatic telecanthus is often not observed until several days after injury, when swelling has subsided. Examination should include measurement of the intercanthal distance. Palpebral fissure width usually approximates the pre-traumatic intercanthal width. Measurement of the points where each medial can thus bisects a horizontal line between the center of the pupils provides accurate assessment. Other indications of a displaced medial canthus are rounding of the medial canthus and horizontal shortening of the palprebral fissure. Other useful methods to demonstrate a lack of medial canthal tension are a positive "bowstring test" when the upper and lower lids are pulled laterally, or lateral movement of the medial canthal ligament when downward traction is applied to the lower lid.[78]

Any suspicion of a NOE fracture is reason to obtain a CT of the coronal and axial facial skeleton with thin cuts through the area of concern. Visualization of the fractures in both planes allows accurate assessment and optimal planning for surgical repair. Three-dimensional CT imaging is also helpful but is not necessary.

Treatment

Ideally these fractures should be reduced at 4 to 7 days postinjury, because edema has resolved and facial contour returned. Further delay in treatment results in fragments that are immobile secondary to the rapid healing in children. Fractures accessible through a large open wound, panfacial fractures that are severely displaced, or Le Fort-type fractures that include splitting of the hard palate and alveolus are best managed acutely.[79]

Management varies little from that of an adult. It requires complete exposure of the fracture site, reduction, and fixation to restore nasal height and contour, proper intercanthal distance, orbital rim continuity, and appropriate anterior-posterior globe position (Fig. 19-8). Exposure is achieved through bicoronal and subcilliary incisions. The supraorbital vessels and nerves are freed from their bony canal via a small osteotomy or burr. The entire NOE region must be exposed in a subperiosteal plane.

Several methods of interosseous fixation are available to the surgeon. Working from stable skull to unstable fragments, choices for fixation include wires, microplates, or absorbable sutures. The use of wires can lead to sharp, palpable edges, particularly with larger gauge wire. These can be a source of chronic irritation. There may also be the need for wire removal if a subsequent revision rhinoplasty is performed. An alternative method is the use of absorbable suture in place of wire. Suture placed through predrilled holes in a figure-eight configura-

tion provides good fixation without bony overlap. This method alleviates concern of chronic irritation, palpable fixation, erosion, or the need for subsequent removal.[75]

Microplates have similar disadvantages as those described for wires. Their main advantage is the ease of fixation, especially in the presence of severe comminution. Additionally, reconstruction plates can be sized and molded to aid in contour and reconstruction. Microplates provide a stable point of suture fixation for detached medial canthal ligaments and allow accurate placement of transnasal wires for reapproximation of intercanthal distance.

Accurate reduction of NOE fractures will reduce the incidence of nasolacrimal complications secondary to compression. Direct injury is uncommon, but as many as 17% with NOE fractures will have late postoperative epiphora. Injury occurs because of the location of the lacrimal fossa in the anteromedial wall of the orbit, just posterior to the medial canthal ligament. At the time of fracture reduction, no exploration or irrigation should be performed unless an obvious injury is observed. When a laceration is present, a silicone stent can be passed and left in place. If stent placement is difficult, dacryocystorhinostomy can be performed at a later date with good results.

Zigomatic fractures

Incidence

As previously mentioned, zigomatic fractures are rare in infants and young children. These fractures are more commonly seen in older children. The zigomatic bone is resilient and considerable force is required to cause a fracture. In young children, the development of the maxillary sinus is uncomplete. The relatively solid midface, compared to an adult, leads to atypical fracture lines. Frature dislocation is more commonly sen secondary to the incomplete union of the zigomaticofrontal suture. Injury at the suture line results in the entire zigomatic bone and the orbital floor being displaced downward. Thus is more common in children to see a combined zygomatico-orbital fracture rather than an isolated zygomatic fracture.

The incidence of isolated zygomatic fractures in facial trauma is reported as 4.7%, but increases to 16.3% in association with orbital fractures.[5] Other more recent series report similar findings, with the incidence of isolated zygomatic fractures ranging from 5% to 8% and combined orbitozygomatic fractures increased to 21% to 22%.[1,6,7]

Treatment

Treatment of pediatric zygomatic fractures is similar to that of adults, although children retain considerably more ability to remodel. Minimally displaced fractures should be managed conservatively. Because of the common greenstick

nature of fractures in young children, there is a role for simple reduction without fixation in modestly displaced and noncom-minuted fractures. A Gilles approach with reduction should be attempted and, if the fracture appears stable, aftercare including a soft diet and frequent follow-up may suffice. If the zygoma is unstable following this approach, open reduction with fixation should be employed. Severely displaced or comminuted fractures should be approached with open reduction and internal fixation. Surgical exposure is achieved through an intraoral upper sulcus, vertical incision for isolated fractures of the zygomatic arch, or a subcilliary incision if the zygomaticofrontal suture is involved. In general, two-point fixation provides adequate reduction if the following principles of stabilization are followed: use at least one mi-croplate and incorporate the zygomaticofrontal suture as one point of fixation.[82] With comminuted fractures one begins from superior to inferior and from lateral to medial, working from a stable to unstable fragment. Care must be taken to avoid injury to the developing tooth buds in young children. Malunion occurs secondary to an unstable reduction or a missed, unreduced fracture. Malalignment of zygomatic fractures can reach 10% and complications are more common with closed reduction.[83,84]

Orbital Fractures   Incidence

In children, isolated orbital fractures are uncommon and usually are associated with zygomatic fractures. The most common cause of orbital and malar complex fractures is automobile accidents, followed by child abuse.[5] Orbital fractures in children are most often characterized by a separation of the frontozy-gomatic suture in the lateral orbital wall, with downward displacement of the orbital floor. This is in contrast with adult orbital trauma, in which injury to the lateral wall is uncommon. Fractures of the supraorbital rim are rare but do occur with severe naso-orbital or frontal bone fractures. The "blow-out" fracture, a term first introduced by Smith and Regan,[85] does occur in young children despite the relative lack of a maxillary sinus. This type of fracture can be particularly difficult to diagnose in children. In addition, children can incur isolated fractures of the orbital roof. Before age 7 there is no frontal sinus to dissipate traumatic energy to the frontal region, and this energy is transmitted to the orbital roof.[24]

Diagnosis

Physical findings suggestive of an orbital fracture are periorbital and subconjunctival hematomas. If there is bleeding into the maxillary sinus, unilateral epistaxis may be present. The infraorbital nerve is frequently entrapped and leads to hypoesthesia in its distribution. Tenderness, as well as a step-off discrepancy, may be present. The lateral can thus may be displaced inferiorly, creating an antimongoloid slant of the palpebral fissure. If a "blow-out fracture" is present, there may be entrapment of one or more orbital soft-tissue structures (Fig. 19-9). This can lead to ocular muscle dysfunction, unequal pupil height, diplopia, and enophthalmos. In the case of supraorbital fractures hypoesthesia of the supraorbital

nerve, exophthalmos, and inferior globe displacement may be present. Examination must also include an ophthalmologic evaluation of the globe. The incidence of ocular injury can exceed 60% in nasal, mid-facial, and frontal fractures.[86]

The radiologic evaluation, however, is essential in the examination of children with orbital trauma. The most valuable plain films, to assess injury in this region, are the Waters and Caldwell views. The Waters view demonstrates the infraorbital rim, maxillary sinus, zygoma, and nasal pyramid. The Caldwell view is used to define the frontal bone, frontal sinuses, and more importantly the frontozygomatic suture. Unfortunately, because of a higher ratio of cancellous to cortical bone in comparison to adults, plain films are difficult to interpret in children.[8] Therefore, CT should routinely be performed if suspicion of injury is high. The resolution is superior to plain radiographs and allows assessment of soft tissues, orbital contents, and the brain.[12] Axial and coronal views with thin cuts through the region of concern also should be obtained.

Treatment

Patients with radiographic and physical findings should be reconstructed as soon as their overall condition permits.[88] Complete exposure of the involved craniofacial skeleton is required using a combination of existing lacerations and coronal, subciliary, and intraoral upper sulcus incisions. The periorbital tissues and orbital contents are elevated subpe-riosteally, with attention given to freeing the orbital contents circumferentially to the apex of the involved orbital cone. Associated injuries such as dural tears and optic or olfactory nerve injuries need to be addressed by neurosurgical consultants. If required, cranial bone graft harvest is performed.[89,90]

The goal, as in adults, is to restore the anatomic structure of the orbit and to preserve function. Fragments of the orbital rim are accurately reduced. Rigid internal fixation is accomplished with either titanium microplates or interfragmentary wires. Once the orbital rim is intact, linear cracks within the orbit will realign. Restoration of orbital floor defects is completed as with adults. The exact area of the orbital floor defect must be covered to prevent postoperative complications such as enophthalmos, adhesions, and impairment of muscle function. After reduction of orbital contents, autogenous cranial bone grafts are placed over the defect. These can be secured to solid portions of the existing orbit via small-gauge wires or anchored with a lag screw.[91,92]

Rigid fixation with microplates or lag screws is preferable to wire fixation in that retention of graft volume is greater with the former.[9]" Although allo-plastic materials and titanium mesh are used in adults, these materials are not recommended for use in children. Autogenous bone graft is superior to al-loplastic materials in children for reconstruction of the orbit. Alloplastic implants have a higher rate of infection and displacement, as well as lacking growth potential. '

Fractures to the orbital roof that are nondis-placed or superiorly displaced may be treated conservatively. Inferior displacement of the orbital roof will result in a significant incidence of late en-cephalocele formation if treated conservatively. Therefore, this group of orbital roof fractures is explored and continuity reestablished.

Diplopia and ocular movement abnomalities typically resolve in children following surgical repair. Loss of vision is rare if care is taken when retracting the globe and implant materials are kept clear of the optic nerve.

Frontal Sinus and Cranial Base Fractures
Incidence

The incidence of frontal sinus fractures and associated injuries is debated in the literature. There are several factors unique to children that lead to a differing incidence than that found in the adult population. First, the young child has a larger cranium to face ratio, and a relative prominence of the frontal skull. This is countered by the more elastic nature of pediatric bone and the lack of developed sinuses. The frontal sinuses begin as outgrowths of the nasal chamber in utero, infiltrate the frontal bone by age 4, and reach adult pneumatization by 20 years of age.[97] Gussack et al. found cranial injury to be significantly more common in the pediatric trauma patient (55%) when compared to adults (39%).' In addition, the likelihood of associated injuries (68%) was found to be significantly higher than in the adult population (33%). In contrast, Wright et al. recently reviewed 209 patients with frontal sinus fractures, and found that only 40 patients (19%) were below the age of 19. None of the injuries occurred in children below 6 years of age. They found the incidence of associated injuries to be more frequent and simi-lar for adults and children, approximately 93% and 96%, respectively.[98] Because of the lack of developed frontal sinuses in young children, when significant force is sustained by the pediatric skull, the fracture that results often extends to the cranial base.

Mann et al., in a retrospective analysis of 12 072 pediatric head injuries resulting in 1297 skull fractures, found that the incidence of associated intracranial injuries was directly related to age. Children under the age of 2, with open skull sutures, had a negligible chance of developing intracranial hematomas. As the child ages, with the fusion of metopic and squamosal sutures, the risk of developing intracranial hematomas rises, matching adults at 15 years of age.[99] Chan et al., in reviewing the same patient population, found impairment of consciousness at the time of admission and the presence of a skull fracture to be predictive factors of intracranial complications. Analysis revealed that the combination of impaired consciousness and skull fracture carried the highest risk of intracranial complication, approximately 75%. However, the presence of a skull fracture alone carried a risk of only 2%.[100] The survival of children suffering head injury is better than in adults, but children suffer more long-term sequelae of decreased memory and intellect.[1 1]

Skull fractures in the pediatric population most often involve a vertical, linear fracture of the frontal bone that may extend into the supraorbital foramen. Automobile and motorcycle accidents appear to be the most common causes, followed by falls and fights.[1,98] Although child abuse is an infrequent cause of pediatric facial fractures, it should always be in the clinician's differential. When osseous injury is present secondary to child abuse, skull fractures account for 20%.

Diagnosis

Complete evaluation of children with cranial trauma must include an initial Glasgow Coma Scale score, a neurologic assessment, and a CT scan. Radiologic evaluation is required, because of the high incidence of associated injury and the common lack of physical evidence of a skull fracture at the initial examination. Physical findings include laceration, hematoma, palpable deformity, and CSF leak. The CSF may drain from the wound or the nose. Cerebrospinal fluid leaks were found to be twice as common in children.[98] In the case of a basilar skull fracture, eyelid hematoma, hearing loss, hemotympanum, or cranial nerve palsy may be present.

Treatment

Goals in the treatment of frontal sinus and cranial base fractures are similar to those in adults: isolation of intracranial structures, cessation of CSF leakage, prevention of posttraumatic infection, and restoration of facial contour.[103] Criteria for operative intervention and open reduction of a skull fracture include displaced bony fragments, intracranial or extracranial hematoma, evidence of a dural tear, a persistent CSF leak (4 to 7 days), and pneumo-cephalus. In the absence of other findings, pneumo-cephalus or a dural tear without CSF leak are relative indications for exploration. Whereas intracranial injury requires neurosurgical expertise and is beyond the scope of this chapter, skull fractures fall into the realm of the reconstructive surgeon. Appropriate treatment requires a combined neurosurgical and plastic surgical approach. Nondisplaced fractures are best treated conservatively, whereas displaced fractures require fixation with either interosseous wires or microplates (Fig. 19-10). The neurosurgeon provides access via the craniotomy, repairs dural tears, and evacuates hematoma. The reconstructive surgeon then begins repair by reestablishing the supraorbital bar and working upward. In the case of posterior wall fractures or nasofrontal duct involvement, the sinus is either cranialized or obliterated to the nasofrontal duct. The sinus mucosa is thoroughly removed with loupe magnification and a burr. Inadequate removal is the direct cause of mucocele formation postoperatively. The incidence of meningitis is approximately 5% and is similar to the incidence seen in adults.[104] Late infectious complications, including mucocele, mucopyocele, and

brain abscess, can occur up to several years after the injury. These complications require operative intervention and cranialization.

SUMMARY AND CONCLUSIONS

Fortunately, pediatric facial fractures are relatively uncommon because of environmental and anatomic protective factors. Whereas the goals in the treatment of facial fractures in children are similar to those in adults, it is important to emphasize that the approach many times varies. The emotional, anatomic, and physiologic differences in children challenge the clinician to diagnose and treat the injury accurately, while at the same time avoiding interference with subsequent maxillofacial growth. The following principles are a guideline for the assessment and treatment of pediatric facial fractures. Modification may be necessary as further experience in treatment and documentation of long-term follow-up accumulates.

1. Physical examination is often difficult and the surgeon must maintain a high index of suspicion for a maxillofacial injury in the presence of multitrauma.
2. Because of the nature of pediatric bone, plain radiographs are often inadequate. In addition, with maxillofacial trauma there is a high incidence of associated injuries. Therefore, CT imaging should be obtained routinely, even for seemingly minor trauma.
3. Pediatric facial fractures need to be addressed earlier than in adults, because of the rapid healing of pediatric bone.
4. Because greenstick and minimally displaced fractures are common in children, fractures can often be treated with observation and conservative care.
5. When internal fixation is required, wires or microplates provide adequate stability and obviate the need for interval removal.
6. If conventional miniplates and screws are used in the very young child, interval removal is strongly urged.
7. Alloplastic materials should not be used in the pediatric patient.
8. Cranial bone provides good material when bone grafts are required. Replace lost bone in kind, and add adequate onlay bone to maintain a normal soft-tissue envelope.
9. Be familiar with the alternatives for IMF in the child with mixed dentition.
10. Avoid iatrogenic injury to developing tooth buds by proper application of reduction and fixation methods.