Int. J. Oral Maxillofac. Surg. 2006; 35: 2–13
doi:10.1016/j.ijom.2005.09.014, available online at http://www.sciencedirect.com

International Journal of
Oral & Maxillofacial Surgery

Invited Review Paper
Trauma

Pediatric facial fractures: recent advances in prevention, diagnosis and management

C. E. Zimmermann, M. J. Troulis, L. B. Kaban*
Department of Oral and Maxillofacial Surgery, Massachusetts General Hospital, 55 Fruit Street, Boston, MA 02114, USA

C. E. Zimmermann, M. J. Troulis, L. B. Kaban: Pediatric facial fractures: recent advances in prevention, diagnosis and management. Int. J. Oral Maxillofac. Surg. 2006; 35: 2–13.

Abstract. During the last 25 years, there have been considerable advances in the prevention, diagnosis and management of craniomaxillofacial injuries in children. When compared to adults, the pattern of fractures and frequency of associated injuries are similar but the overall incidence is much lower. Diagnosis is more difficult than in adults and fractures are easily overlooked. Clinical diagnosis is best confirmed by computed tomographic (CT) scans. Treatment is usually performed without delay and can be limited to observation or closed reduction in non-displaced or minimally displaced fractures. Operative management should involve minimal manipulation and may be modified by the stage of skeletal and dental development. Open reduction and rigid internal fixation is indicated for severely displaced fractures. Primary bone grafting is preferred over secondary reconstruction and alloplastic materials should be avoided when possible. Children require long-term follow-up to monitor potential growth abnormalities. This article is a review of the epidemiology, diagnosis and management of facial fractures in children.

During the past three decades, there have been considerable advances in the prevention, diagnosis and treatment of craniomaxillofacial (CMF) injuries. Preventive legislation (speed limits, alcohol restriction, use of helmets, shoulder and seat restraints), improved road construction measures and vehicle safety modifications (safety glass, padded dash boards, stronger frames, collapsible steering columns, airbags) have led to a significant decrease in the incidence and severity of road traffic accidents (RTA) in some countries[2,97,129,122]. There has also been a corresponding decrease in the incidence and severity of CMF injuries, particularly in children below the age of 10 years[4,51,66,105,122–124].

Imaging techniques such as computed tomographic (CT) scanning with three-dimensional reconstruction have been developed and improved. They provide the fine, unobstructed anatomic detail required to guide surgeons in achieving accurate reduction of fractures, especially in the midface region[47,61,65,86,90].

The introduction of rigid internal fixation into CMF surgery has revolutionized the treatment of facial fractures by allowing accurate reduction and fixation of bone fragments, stable three-dimensional reconstruction and by reducing the need for prolonged maxillomandibular fixation. Finally, improvements in airway, meta-

DOI of original articles: 10.1016/j.ijom.2005.06.015, 10.1016/j.ijom.2005.11.001.

bolic and anesthesia management have also helped to improve the outcomes for pediatric patients who suffer CMF injuries. This article reviews the current principles and recent advances in the management of facial fractures in children. This material was presented in greater detail in three recent book chapters on pediatric facial trauma[11,12,135].

Unique features of the pediatric patient

Children have a higher surface-to-body volume ratio, metabolic rate, oxygen demand and cardiac output than adults. They also have lower total blood and stroke volumes than adults. Therefore, the risk for hypothermia, hypotension and hypoxia after blood loss is higher in pediatric patients. Even mild airway swelling or mechanical airway obstruction can quickly compromise the airway. For these reasons, maintenance of the airway and breathing, control of hemorrhage and early resuscitation are even more critical and time dependent in children than in adults.

At birth, the ratio between cranial volume and facial volume is approximately 8:1. By the completion of growth, this ratio becomes 2.5:1[37]. The retruded position of the face relative to the ''protecting'' skull is an important reason for the lower incidence of midface and mandibular fractures and higher incidence of cranial injuries in young children (less than 5 years of age)[69,72]. With increasing age and facial growth, in a downward and forward direction, the midface and mandible become more prominent and the incidence of facial fractures increases, while cranial injuries decrease[69].

Facial fractures in children occur less frequently than in adults and they are more often minimally displaced. This is because a thicker layer of adipose tissue covers the more elastic bones and the suture lines are flexible. In addition, stability is increased by the presence of tooth buds within the jaws and the lack of sinus pneumatization[65,90,132].

The possibility of adverse post-injury growth disturbances, particularly after severe nasal septal and condylar injuries should be considered when planning treatment. Growth potential, on the other hand, may serve to improve long-term results as with compensatory condylar growth after condylar fractures[63]. In addition, children in the deciduous and mixed dentition stages demonstrate some capacity for spontaneous occlusal readjustment, after injury and treatment, as deciduous teeth are shed and permanent teeth erupt.

Epidemiology of facial fractures in children

Incidence

Social, cultural and environmental factors vary from one country to another and influence the incidence and etiology of CMF trauma. In children, the incidence and etiology of CMF trauma are also affected by age-related activities. Overall, facial fractures in the pediatric population comprise less than 15% of all facial fractures[3,10,41,42,133]. They are rare below age 5 (0.6–1.4%)[3,8,10,21,45,49,64,68,83,88,96,99] and their incidence rises as children begin school[7,83,90]. Another peak in incidence occurs during puberty and adolescence with increased unsupervised physical activity and sports[3,8,48,96,107,108,117,133]. Seasonal variations are reported with peak frequencies during summer months (except for skiing injuries) when outdoor activity is greatest[21,33,48,90].

Gender

The incidence of facial fractures is higher in boys than in girls worldwide and in all age groups. This male preponderance, which has remained constant over time[123], ranges from 1.1:1 to 8.5:1[3,7,9,10,20,21,29,34,36,41,42,47–49,55,57,62,69,71,76,83,88,90,104,108,110,116,117,119,133,134] and has been attributed to greater and more dangerous physical activities among boys[19,90–92,134]. In younger age groups, gender differences are less significant and the etiologies are similar in both sexes.

Etiology

Falls, sports-related injuries and RTA constitute the most frequent causes of facial fractures in children[7,21,49,52,55,62,83,88,90,96,133]. The percentage of the various etiologies reported depends on the age groups examined and on the types of fractures included (e.g. children below age 18 years versus those below 6 years; inclusion or exclusion of dentoalveolar and/or nasal fractures). While young children usually sustain injuries from low-velocity forces (e.g. falls), older children are more likely to be exposed to high-velocity forces (e.g. in RTA, sports-related trauma). High-velocity maxillofacial injuries in infants and young children may be under reported because of their high mortality from concomitant neurocranial injuries.

In infants and preschool children (up to age 6 years), falls in the home environment are the most common etiology of facial fractures[17,21,48,49,55,57,109,134]. With increasing age and outdoor exposure, falls tend to occur outside the protected area of the home and parental supervision[83]. As motor skills improve, sporting injuries become more common. Most sports-related facial fractures occur in children 10–14 years of age[20,39,48,91,110,111,113].

Motor vehicle accidents (MVA) are the leading cause of death in children after the perinatal period[115] and the incidence of MVA-related maxillofacial injuries increases with age[79]. Similarly, involvement in a RTA as a pedestrian or bicyclist is also a common cause of facial fractures in children 6 years of age and above[21,29,44, 55,71,88,90,116]. In contrast to adults, interpersonal violence is a rare cause of facial fractures in children. These injuries occur more commonly in adolescents[9,21,52,90, 134].

Facial fractures are seen in 2.3% of victims of child abuse[82]. Overall, the head, neck, face and mouth are involved in 50–75%[6,15,130] of such cases. Victims of child abuse can be found in all age groups, but the groups most prone are newborns, infants and preschool children[26,50,82], particularly boys. The perpetrators are parents or caretakers in 90% of the cases, especially in young children[82]. Repeated injuries and multiple injury sites with inadequate history or delayed presentation should raise suspicion of possible abuse. In most developed countries, the law requires that emergency room personnel, surgeons and other caregivers report the suspicion of child abuse to the authorities.

Site and pattern

The site and pattern of a fracture depend on the inter-relationship between etiology and force of the injury, and the unique anatomic features of the child's stage of development. While infants (below age 2) are more likely to sustain injuries of the frontal region, older children are more prone to injuries of the chin/lip region[109]. Children below age 3 usually sustain isolated, non-displaced fractures[90]caused by low-impact/low-velocity forces.

Dentoalveolar and nasal fractures are both very common in children and are often treated in the outpatient setting. Mandibular fractures are the most common facial fractures seen in hospitalized children[1,11,12,21,32,53,55,70,88,90,96,107,117,134]. Their incidence increases with age [28,45,90,96]. The condylar region is the most frequently fractured site[19,21,28,36,45,55,83,96,133,134], being affected bilaterally in about 20% of pediatric patients [60,63,96,119]. Fractures of the condyle are more common in children than in adults (50% of mandibular fractures versus 30%)[55], because the highly vascularized pediatric condyle and thin neck are poorly resistant to impact forces during falls. In children below 6 years of age, condylar fractures are more often intra- than extra-capsular in location. Above this age, most condylar fractures occur in the neck region[119]. Fractures in the condylar region are followed in number by symphysis, angle and body fractures, respectively[21,83,96]. While body fractures are less common than in adults, symphysis and parasymphysis fractures of the mandible occur more often[53].

Midface fractures in children, usually resulting from high-impact and/or high-velocity forces (e.g. MVA), are rare[52,55,64,69,83,96,99,103]. Zygomatic complex fractures are the most frequent, after maxillary alveolar and nasal injuries[48,52,102]. Le Fort fractures (at all levels) are uncommon and are almost never seen before age 2. Children below age 6 sustain mostly alveolar fractures, acquired in low-impact falls and sports[48]. Above the age of 5, as the maxillary sinuses continue to expand and the permanent teeth erupt, the incidence of midface fractures increases[48,90,96]. The highest incidence occurs in children 13–15 years of age[48].

Orbital injuries constitute approximately 20% of pediatric facial fractures[36,41,55,69,90]. They result from transmission of forces directly from a blow to the bony orbital ring to the thin orbital walls and/or indirect forces from a hydraulic pressure effect of displaced orbital soft tissues[56,95]. Orbital roof fractures occur in young children, in whom the frontal sinus is still underdeveloped. These fractures are often associated with skull injuries.

Orbital floor fractures are more common in older children[56,73,90], in whom the maxillary sinus has expanded beyond the equator of the globe. The age at which the probability of an orbital floor fracture exceeds the probability of an orbital roof fracture is 7 years[57].

Fractures of the cranial vault in children are uncommon. The most commonly involved site is the frontal bone[90] (children below age 6) because of its relatively prominent position[69]. At age 6, the frontal sinus measures less than cherry-size and has not yet reached the orbital roof[126]. Thus, involvement of the frontal sinus is not seen below this age[131]. With increasing frontal sinus pneumatization during pubertal development[131], the incidence of frontal sinus fractures increases. Frontal bone fractures are often associated with other facial fractures and significant injury of the central nervous system[131].

The nasal bones are the least resistant of the facial skeleton[81]. This, combined with the relative prominence of the nose, which increases with growth, makes it most likely to sustain injury in older children[7,22,55,62,78]. Yet, nasal fractures are not listed among the most common pediatric facial fractures[9,21,69,88] in studies from large trauma centers, because the majority of these children are seen and treated in an office setting, or because nasal fractures are grouped among midface[52,62,90,134] or fronto-naso-ethmoid[107] fractures. When evaluated separately, nasal fractures make up approximately 50% of all facial fractures in children[7,55].

Concomitant injuries

Patients with multiple trauma often have facial fractures and conversely patients with facial fractures often have other concomitant injuries[98]. Associated injuries are seen in 25–75% of children with facial fractures[36,41,43,47,48,57,68,69,72,76,90]. These include closed head trauma, neuro-cranial injuries, temporal bone fractures, extremity fractures, abdominal, thoracic and spine injuries as well as dental injuries and soft tissue lacerations.

Children who sustain facial injuries in high-impact MVA are at increased risk for associated injuries[48]. Those with mandibular[55,77] or midface[36,41,43,47,48,90] fractures have a higher incidence of associated injuries (chest, abdomen, extremity and cervical spine)[59,69,71,132] than children with nasal or orbital fractures. The high energy required to produce fractures of the mandible and midface is probably responsible for this phenomenon. Finally, the more comminuted a facial fracture, the greater the likelihood of an associated systemic injury[90].

Preventive measures

Preventive measures are geared to reducing the number of accidents and/or minimizing the severity of injuries. The incidence, severity and mortality of CMF injuries in adults and children can be reduced significantly by using seat restraints[4,51,66,105,120,122,124]. However, compliance varies and is usually low[10,31,47,79,125], particularly among young males, who are in the population most at risk. Approximately 50–70% of all children sustaining injuries in MVA and up to 70% of children sustaining facial fractures are unrestrained[4,79,105,123,124].

Conventional seat belts may not offer proper protection for the pediatric passenger, because the anterior superior iliac spine is incompletely developed and the center of gravity is located higher in children than adults. There is a greater body mass above the waist and therefore conventional seat belts may cause abdominal and thoracic injury in a child[106]. With age-appropriate restraints, protection is improved and restraint-related injury patterns do not occur[122].

In sports, the use of preventive measures is less frequent than in motor vehicles. Most children with head injuries in bicycle-related accidents were not wearing protective helmets at the time of injury[83,91,92]. The design of currently available helmets may reduce the risk of head and midface injury. However, they may not provide enough protection against mandibular fractures[1,118].

The importance of preventive measures should be emphasized. Supervising adults, i.e. coaches, administrators, teachers and parents should be educated. Children should be encouraged to develop appropriate habits (e.g. related to wearing a helmet) at an early age, because incidence and severity of sports-related injuries are inversely related to skill level and age[13,110].

Diagnosis of facial fractures in children

Pediatric facial fractures are sometimes not suspected or overlooked in the emergency room. The injuries are uncommon so the index of suspicion may be low. Sometimes the history is difficult to obtain from a child and the accompanying caretakers may not have witnessed the accident. Clinical signs and symptoms are the same as in adults. Thorough clinical examination, however, may be impossible in the uncooperative young trauma patient. Wide suture lines and the elasticity of the bone may mimic fracture gaps on palpation. Plain radiographs are less helpful than in adults, particularly in the midface region where poorly developed sinuses and tooth buds occupy space and obscure skeletal anatomic landmarks[61,65,86]. CT scans greatly increase diagnostic accuracy and have become the standard of care for imaging pediatric MF trauma victims[47,90].

Management of facial fractures in children

General considerations in the young trauma patient include maintenance of the airway, balance of fluid and electrolyte levels and adequate nutritional intake during treatment. Children are often as cooperative as adult patients, when treated with respect to their developmental age[54].

As in adults, the pre-injury skeletal and dentoalveolar anatomy and function are re-established by anatomic reduction of fractures based on the occlusion[23,30]. Children have greater osteogenic potential and faster healing rates than adults[52,65]. Therefore, anatomic reduction in children must be accomplished earlier[46,73] and immobilization times should be shorter (2 weeks versus 4–6 weeks in adults)[3,41,83].

Fracture immobilization and fixation, when required, can be achieved with maxillomandibular fixation (MMF) or internal skeletal fixation or a combination of these, depending on the type of fracture and the patient's stage of development. MMF, using the teeth, may be more difficult than in adults. Fewer teeth may be available, roots of deciduous teeth may be resorbed, the surfaces are not retentive for etching-techniques and the crowns of deciduous incisors and canines and partially erupted permanent teeth may be unfavorably shaped for the fixation of interdental wires and arch bars[101]. On the other hand, intraosseous tooth buds and (erupting) teeth in the line of fracture should not be traumatized during placement of screws and plates.

While non-displaced fractures can be treated by observation, combined with a liquid to soft diet and analgesics as needed, displaced fractures often require closed or open reduction and fixation[21,69,90]. Generally, the need for surgical intervention is more likely in older children[69].

Rigid internal fixation in children

Until the mid-1970s, closed reduction and immobilization with MMF was used for all types of pediatric fractures[40,100,103]. Today, open reduction and rigid internal fixation (ORIF) has become the standard of care for management of displaced fractures. ORIF provides stable three-dimensional reconstruction, promotes primary bone healing, shortens treatment time and eliminates the need for or permits early release of MMF. Decreased dependence on MMF improves postoperative respiratory care, nutritional intake and oral hygiene measures[90].

Controversy regarding the use of rigid internal fixation in growing children arose because of cost, potential artifacts on CT scans or magnetic resonance images, palpability or visibility of plates through the child's thin skin, pain and early or late infection. Particularly in children, tooth buds or erupting teeth may be traumatized, plates or screws may migrate with risk of dural penetration, cerebrospinal fluid leak, meningitis or even brain injury after translocation through the inner cortex of the skull, and finally, growth may be disturbed[14,18,25].

The effects of rigid fixation on craniofacial growth are incompletely understood. Animal experiments in dogs[67] and rabbits[35,87,129] have shown adverse effects, which may be overcome by compensatory regional bone growth[35,75,129]. It has been difficult to determine whether the initial trauma, the surgical procedures for reduction and fixation, or hardware removal, have had the greatest adverse effect on growth[24,58]. Although in humans, adverse effects have not been reported[46,102], it is recommended that plates should not traverse suture lines or the midline of the mandible. Furthermore, plates and screws should be removed as early as 2–3 months after placement[18,45]. In the future, resorbable implants might offer an alternative to metal devices in the growing skeleton[38,74,127].

Mandibular fractures

As in adults, clinical signs of mandibular fractures may include displacement of the fragments, mobility, crepitus, hematoma, swelling, mucosal tears, limited mouth opening, malocclusion, pain and sensory deficits in the distribution of the inferior alveolar nerve. In children, clinical suspicion of a fractured mandible is confirmed by panoramic, supplemented by posterior–anterior, lateral oblique and occlusal radiographic views. CT scans may be indicated in condylar fractures to help determine three-dimensional displacement of the condyles. Treatment of mandibular fractures in children depends on the fracture site and the stage of skeletal and dental development[54,65].

Fractures of the mandible limited to the alveolar process are treated by open or closed reduction and immobilization by splints and arch bars for 2–3 weeks. Rarely, long-term mono-maxillary immobilization (via splinting) for up to 2 months is indicated to prevent malocclusion[117].

Mandibular fractures without displacement and malocclusion are managed by close observation, a liquid to soft diet, avoidance of physical activities (e.g. sports) and analgesics.

Displaced mandibular fractures need to be reduced and immobilized. When tooth buds within the mandible do not allow internal fixation with plates and screws [77], this can be achieved with a mandibular splint fixed to the teeth, to the mandible (with circum-mandibular wires, Gunning splint) or a splint with MMF (Fig. 1).

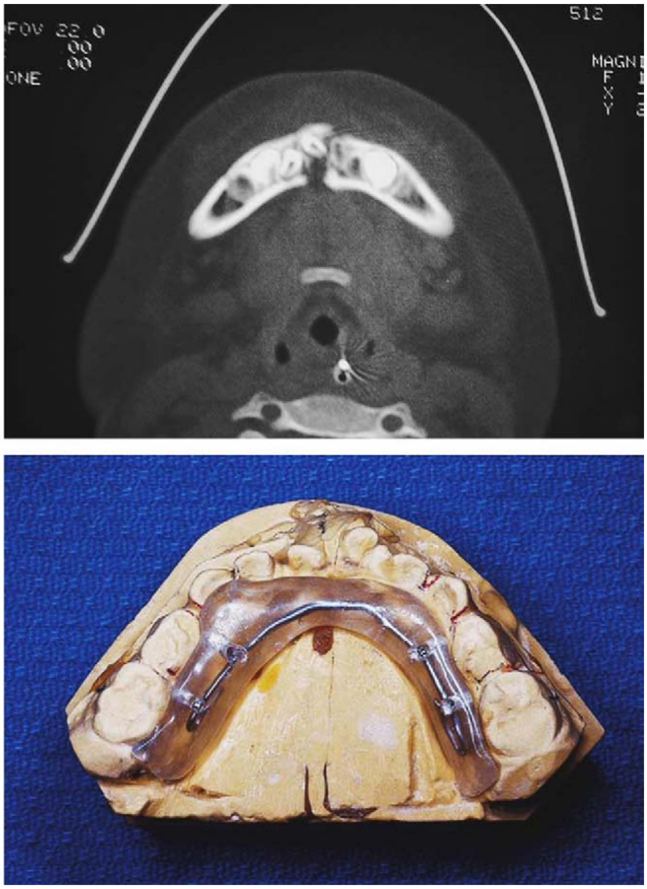
Displaced symphysis fractures can be treated by ORIF through an intraoral incision after age 6, when the permanent incisors have erupted. ORIF in parasymphysis fractures in feasible, when the buds of the canines have moved up from their inferior position at the mandibular border after age 9. Similarly, in body fractures, the inferior mandibular border can be plated, when the buds of the permanent premolar and molar have migrated superiorly toward the alveolus[54] (Fig. 2). Growth abnormalities in fractures of the mandibular body are rare[104].

Most condylar fractures are treated with observation or closed reduction and a short period of MMF for no more than 7–10 days. MMF is usually followed by a period of physical therapy consisting of mandibular opening exercises guided by elastics to promote remodeling of the condylar stump and prevent ankylosis. Although open reduction of condylar fractures avoids MMF and may improve functional outcome[27], most authors recommend closed reduction. Minimally invasive techniques like ORIF of condylar fractures under endoscopic visualization may gain acceptance[121] (Fig. 3).

Frequent postoperative follow-up is recommended to detect and treat early complications such as infection, malocclusion, malunion or nonunion which are fortunately rare in children. However, children must be monitored longitudinally for late complications such as damage to permanent teeth, which may occur in 50% of mandibular fractures, temporomandibular joint (TMJ) dysfunction (recurrent subluxation, noise and pain, limited condylar translation, deviation on opening, ankylosis) and growth disturbances (e.g. secondary midface deformity, mandibular hypoplasia or asymmetry)[104].

Midface fractures

The diagnosis of pediatric midfacial fractures is based on the history, physical examination and imaging techniques. Physical findings may include: pain on palpation, facial asymmetry, particularly when the patient is examined from below or behind, periorbital swelling, monocular or binocular ecchymosis or hematoma, chemosis, enophthalamos, decreased and painful ocular mobility, diplopia, blurred vision, and sensory abnormalities in the distribution of the infraorbital nerve (V_2). Abnormalities of extraocular muscle movement should be confirmed by a forced duction test and all patients with orbital injuries should be examined by an ophthalmologist to rule out injuries to the globe and retina. Patients may also exhibit painful limitation of mouth opening due to



(A) (B)

Fig. 1. (A) Occlusal radiograph of symphyseal fracture, (B) treated using a lingual splint. The splint can be wired to the teeth (preferably) or stabilized with circumamandibular wires (from BAUMANN et al., p. 451[12]).

impingement of the zygomatic arch on the coronoid process and pain upon forced occlusion (zygoma fractures). When the nose, nasoethmoidal complex and maxilla are injured there may be telecanthus, epistaxis, nasal airway obstruction, nasal swelling and deviation, septal deviation and hematoma, malocclusion and elongation of the middle third of the face (Le Fort injuries). Mobility of the maxilla at the dentoalveolar arch (Le Fort I level), at the infraorbital rim and nasofrontal suture (Le Fort II level), or at the frontozygomatic and nasofrontal sutures (Le Fort III level) may be palpable.

CT imaging has become the standard of care in the diagnosis of pediatric midface fractures[47]. Plain radiographs are not useful because midface fractures are easily overlooked[65] and obscured by lack of pneumatization of the sinuses and the presence of tooth buds in the maxilla[61,65,86]. Diagnosis of zygomatic arch fractures on a typical submental vertex view is impeded by the superimposition of the skull[61].

Zygomatic complex fractures

Zygomatic complex fractures without displacement and functional deficits such as diplopia or sensory deficits may be treated by observation[90]. Open reduction and internal fixation is indicated in comminuted fractures[89] and in cases of esthetic and functional impairment. The most common problems associated with zygomatic complex fractures include: facial asymmetry, enophthalmos, anesthesia or paresthesia in the distribution of the infraorbital nerve (V_2), orbital floor defects with entrapment of orbital soft tissues with or without limitation of eye movement[33,85] (Fig. 4).

Treatment should be performed as soon as the initial edema has resolved, i.e. after 3–5 days. Delay of orbital repair may result in higher rates of posttraumatic enophthalmos and the need for additional orbital or muscle surgery[33].

Access to the lines of fracture should be achieved in children via the lateral upper eyelid incision (frontozygomatic suture line), the lower eyelid, infraciliary, or transconjuctival incision (infraorbital rim and orbital floor), and the transoral buccal sulcus approach (zygomatic buttress). Contrary to adults, one-point fixation at the frontozygomatic suture may suffice in children, because of shorter lever arm forces from the frontozygomatic suture to the infraorbital rim[77].

Reduction may be achieved via a transoral approach at the zygomatic buttress. Plating at the zygomatic buttress may carry the risk of traumatizing maxillary tooth buds, particularly in children below age 6[16]. Therefore, exposure of the frontozygomatic suture and/or infraorbital rim may be indicated to apply plate and screw fixation. Microplates are often sufficient in children. When soft tissue is entrapped at the orbital floor, or when sensory deficits suggest involvement of the infraorbital nerve, exploration of the orbital floor is required.

Primary reconstruction of the orbital floor is indicated, when unretrievable bony fragments have disappeared into the maxillary sinus leaving a defect. Autologous bone grafts are preferred over alloplastic materials in children.

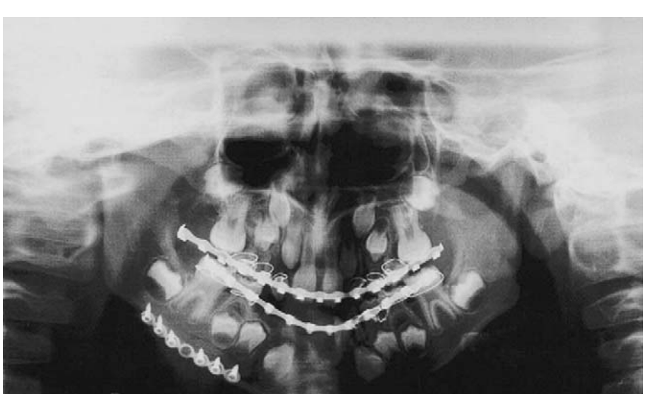


Fig. 2. Panoramic radiograph shows miniplate fixation of a mandibular fracture at the inferior border. The arch bars were used for stabilization of the dentoalveolar segments (photographs courtesy of Dr. Meredith August) (from BAUMANN et al., p. 453[12]).

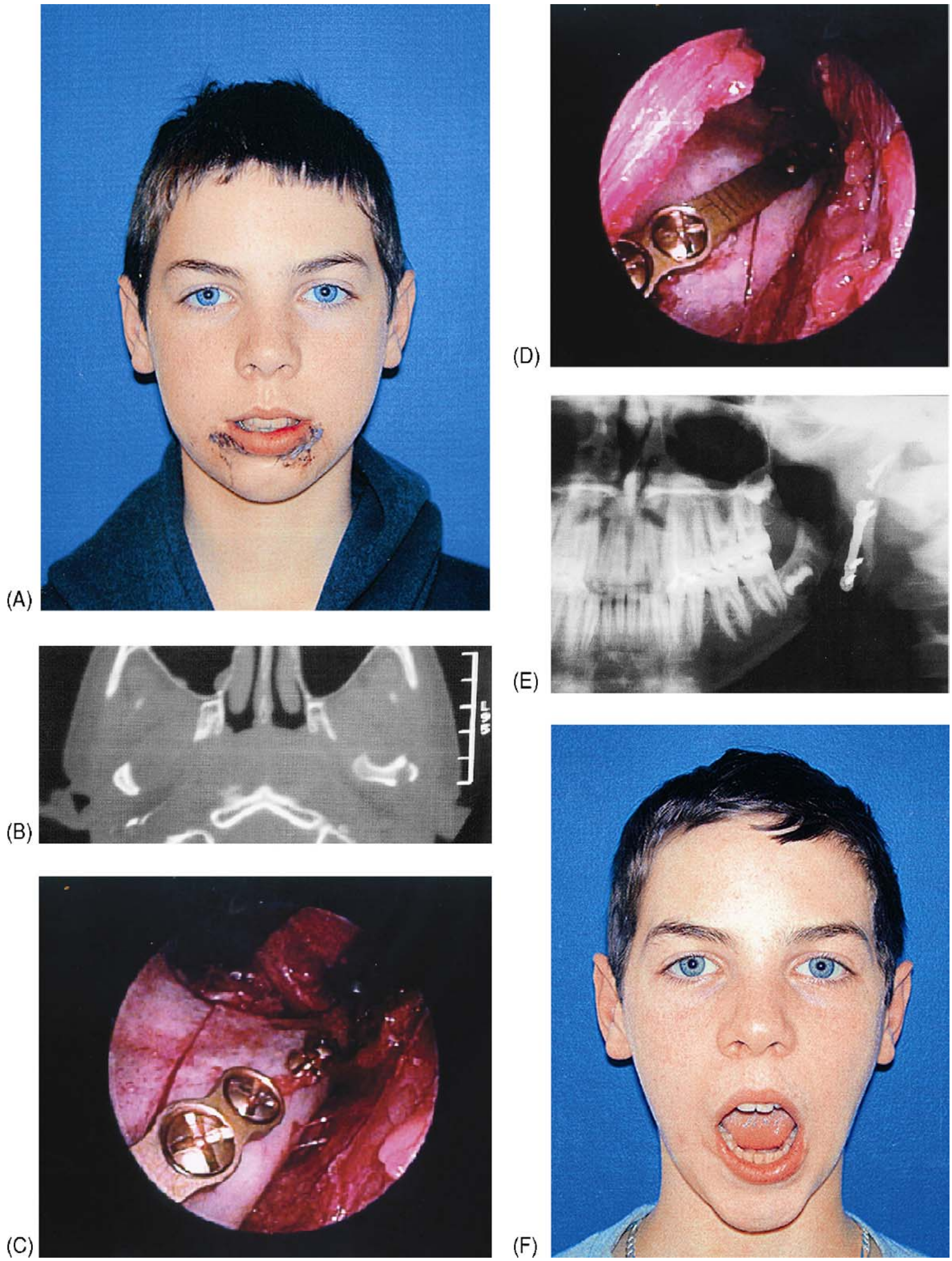


Fig. 3. (A) Frontal photograph of 15-year-old boy who suffered a left subcondylar fracture while snowboarding. He was treated with a 7-day course of maxillomandibular fixation. On attempt to remove the wire fixation he had a severe contralateral open bite and severe pain (requiring replacement of the MMF). He was referred to the MGH OMFS clinic. (B) Axial CT scan confirms that the left condyle was dislocated out of the fossa. Endoscopic views (C and D) show the condylar stump well-reduced and fixed with 2, 2.0 screws. The proximal ramus was then fixed to the mandible with a 2.0 plate. The postoperative panoramic radiograph (E) shows the proper alignment of the ramus/condyle unit. Postoperative frontal photograph (F) shows good symmetry and a normal interincisal opening with no deflection (from BAUMANN et al., p. 458–459[12]).

For isolated zygomatic arch fractures, a Gillies temporal approach can be used to elevate the arch and reduce the fracture. Zygomatic arch fractures are usually stable without further fixation[52]. In frontonasoethmoid or Le Fort III fractures, the zygomatic arch is usually approached via a coronal incision. The arch is rigidly fixed to restore the proper bitemporal skull width.

Orbital fractures

Indications for early open reduction via a transconjunctival[77], infraciliary[52], or infraorbital incision are, identical to zygomatic complex fractures. The overall goal is to restore orbital volume and to free incarcerated soft tissues. Primary orbital floor reconstruction with autogenous calvarial bone or split rib may be necessary in large orbital floor defects. Severely displaced orbital roof fractures may need an interdisciplinary neurosurgical (transcranial) approach[90].

Frontal skull and frontonasoethmoid fractures

Most patients require operative treatment to reestablish sinus anatomy and ventilation. A coronal approach offers wide exposure including the orbital rims, zygomatic arches and nasal root for reduction and microplate fixation of comminuted fractures. When severely disrupted, the sinus mucosa should be ablated and drainage via the natural ostium and nasofrontal duct should be ensured by means of a tracheal spiral catheter for several weeks to prevent mucocele formation[114]. In posterior frontal sinus wall involvement, an interdisciplinary neurosurgical approach is necessary.

In frontonasoethmoid fractures the medial canthal ligament, usually still attached to a bony fragment at its insertion, must be repositioned and fixed with[128] or without[89] microplates or transnasal wires to avoid telecanthus. Calvarial bone grafts and primary stenting of the nasolacrimal duct may be necessary in severely comminuted fractures.

Fig. 4. Young boy who sustained a blow to the left cheek. (A) Frontal and (B) submental photographs illustrate the typical findings of a zygomatic complex fracture: periorbital ecchymosis (mild in this case), antimongoloid slant of the lateral canthus, depression of the cheek. (B) Submental view better illustrates the marked cheek depression. (C) Computed tomographic image demonstrates fracture at anterior maxillary wall and a fluid-filed antrum. (D) Intraoperative photograph shows the access via an intraoral, vestibular incision, the good reduction (achieved in this case with a Carroll–Gerard screw) and rigid internal fixation using 2.0 mm plates (Synthes Maxillofacial, Paoli PA). (E) Frontal and (F) Submental photographs, 1 year postoperatively, demonstrate symmetry of the zygomas. (G) Postoperative Water's view confirms the proper reduction and symmetry (from BAUMANN et al., p. 431[11]).

Fig. 4. (*Continued*).

Le Fort fractures

Displaced midface fractures are treated by open reduction and rigid internal fixation with plates and screws (when damage to the tooth germs or erupting teeth can be avoided[90]) utilizing coronal, infraciliary or transconjunctival, and intraoral incisions. Intermaxillary fixation and suspension from the zygomatic arches or piriform aperture for 2–3 weeks[52,77] may be used in very young children.

Nasal fractures

The diagnosis of a nasal fracture is based on the history and physical examination. In children, these fractures are easily missed; because physical examination (e.g. intranasal exam with a speculum) may be difficult, crepitation of the resilient bones may be missing and edema may conceal deviation of the nasal dorsum.

Septal hematoma, although extremely rare, constitutes an emergency, because it requires immediate drainage to prevent septal cartilage necrosis with subsequent saddle nose deformity and potential midface growth retardation.

In a displaced fracture, accurate anatomic reduction should be carried out within 7 days[52]. However, unlike in adults, surgical reconstruction is contraindicated in the growing child[41]. In most cases, anatomic realignment, hemostasis and fixation are achieved under general anesthesia by closed reduction[90], bilateral intranasal packing or splinting for 2–3 days and an external splint for 10–12 days. In newborns, who are obligatory nasal breathers, the use of bilateral nasal packing should be avoided. As facial swelling decreases, the external splint may loosen and have to be renewed for sufficient stabilization. Rarely, open reduction is required. Tissue injury must be kept to a minimum[70].

Complications

Postoperative infection, malunion or non-union are rare in children because of the child's greater osteogenic potential, faster healing rates, and the less frequent requirement for open reduction and rigid internal fixation. Furthermore, a greater number of fractures are minimally to non-displaced. The complications listed previously usually occur only in pediatric patients with severely comminuted fractures[40,41,68,116].

Malocclusion as a complication of pediatric facial fractures is rare[41]. It has been attributed to short fixation times in alveolar fractures[117] and may be caused by growth abnormalities after condylar fracture[40,69]. Spontaneous correction of malocclusion is seen as deciduous teeth shed and permanent teeth erupt[112]. Growth disturbances are reported in 15% of TMJ fractures[104]. They are more likely to occur in intracapsular condylar crush injuries, particularly below 2.5 years of age[64]. In these cases, mandibular asymmetry by compensatory growth with overgrowth (in 30%) or dysplastic (under-)growth (in 22%) are more common than a symmetric mandible (in 48%) resulting from compensatory overgrowth on the affected side[63,94].

The incidence of TMJ ankylosis with or without growth retardation is reported in 1–7% of condylar fractures[5,55,83]. The risk for ankylosis is higher with bilateral condylar fractures, in children between age 2 and 5, if treatment is delayed[3], or MMF is prolonged[83]. At an early age (e.g. before age 3), the cumulative effects of continued abnormal or asymmetric growth due to TMJ ankylosis are particularly high[100]. When developing after age 12, ankylosis-related abnormalities in facial growth rarely require surgical correction[28]. TMJ ankylosis is best prevented by short immobilization and consecutive active mobilization of the TMJ in condylar fractures[60,63].

Overall, complications of midface fractures are rare. They include interorbital widening, nasolacrimal obstruction, telecanthus and nasal collapse in nasoethmoidal fractures; encephalocele and globe protrusion in orbital roof fractures; enophthalmos, persistent diplopia from orbital soft tissue entrapment or scar cicatrisation of herniated orbital contents in orbital floor fractures. With early and adequate surgical treatment, midfacial growth disturbances are rare[46,48,68].

Among the potential complications after nasal trauma are nasal deformity, stubby nose, septal deviation, nasal airway obstruction, and growth disturbances due to involvement of the nasoethmoid and/or septovomerine sutures[80,84,93]. Secondary rhinoplasty may be required for esthetic and/or functional reasons[55]. Strictly cosmetic rhinoplasty may be delayed until after completion of growth.

Acknowledgement. This work was funded by the AO-Synthes-MGH Pediatric Oral and Maxillofacial Surgery fellowship (C2), the MGH Department of OMFS Education and Research Fund and the National Institutes of Health (K-23, MJT).

References

1. Acton CH, Nixon JW, Clark RC. Bicycle riding and oral/maxillofacial trauma in young children. Med J Aust 1996: **165**: 249–251.
2. Adams CD, Januszkiewcz JS, Judson J. Changing patterns of severe craniomaxillofacial trauma in Auckland over eight years. Aust N Z J Surg 2000: **70**: 401–404.
3. Adekeye EO. Pediatric fractures of the facial skeleton: a survey of 85 cases from Kaduna, Nigeria. J Oral Surg 1980: **38**: 355–358.
4. Agran PF, Dunkle DE, Winn DG. Effects of legislation on motor vehicle injuries to children. Am J Dis Child 1987: **141**: 959–964.
5. Amaratunga NA. Mandibular fractures in children—a study of clinical aspects, treatment needs, and complications. J Oral Maxillofac Surg 1988: **46**: 637–640.
6. Ambrose JB. Orofacial signs of child abuse and neglect: a dental perspective. Pediatrician 1989: **16**: 188–192.
7. Anderson PJ. Fractures of the facial skeleton in children. Injury 1995: **26**: 47–50.
8. Bamjee Y. Paediatric maxillofacial trauma. J Dent Assoc S Afr 1996: **51**: 750–753.
9. Bamjee Y, Lownie JF, Cleaton-Jones PE, Lownie MA. Maxillofacial injuries in a group of South Africans under 18 years of age. Br J Oral Maxillofac Surg 1996: **34**: 298–302.
10. Bataineh AB. Etiology and incidence of maxillofacial fractures in the north of Jordan. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998: **86**: 31–35.
11. Baumann A, Troulis MJ, Kaban LB. Facial trauma I: midfacial fractures. In: Kaban LB, Troulis MJ, eds: Pediatric Oral Maxillofacial Surgery. USA: Elsevier Science 2004: 425–440.
12. Baumann A, Troulis MJ, Kaban LB. Facial trauma II: dentoalveolar injuries and mandibular fractures. In: Kaban LB, Troulis MJ, eds: Pediatric Oral Maxillofacial Surgery. USA: Elsevier Science 2004: 441–460.
13. Bayliss T, Bedi R. Oral, maxillofacial and general injuries in gymnasts. Injury 1996: **27**: 353–354.
14. Becelli R, Renzi G, Frati R, Iannetti G. Maxillofacial fractures in children. Minerva Pediatr 1998: **50**: 121–126.
15. Becker DB, Needleman HL, Kotelchuck M. Child abuse and dentistry: orofacial trauma and its recognition by dentists. J Am Dent Assoc 1978: **97**: 24–28.
16. Beirne OR, Myall RWT, Rigid internal fixation in children. In: Kaban LB, ed: Oral and Maxillofacial Surgery in Children and Adolescents, Vol 6. Philadelphia, MD: W.B. Saunders 1994 153–167.
17. Benoit R, Watts DD, Dwyer K, Kaufmann C, Fakhry S. Windows 99: a source of suburban pediatric trauma. J Trauma 2000: **49**: 477–481 (discussion 481–472).
18. Berryhill WE, Rimell FL, Ness J, Marentette L, Haines SJ. Fate of rigid fixation in pediatric craniofacial surgery. Otolaryngol Head Neck Surg 1999: **121**: 269–273.
19. Berthouze E, Sagne D, Momege B, Achard R. Treatment of mandibular fractures in children. Our therapeutic approach (author's translation). Rev Stomatol Chir Maxillofac 1980: **81**: 285–288.
20. Brudvik C. Child injuries in Bergen, Norway. Injury 2000: **31**: 761–767.
21. Carroll MJ, Mason DA, Hill CM. Facial fractures in children. Br Dent J 1987: **163**: 289.
22. Carroll SM, O'Connor TP. Trends in the aetiology of facial fractures in the south of Ireland. Ir Med J 1996: **89**: 188–189.
23. Cawood JI, Stoelinga PJ. Facial trauma. Int J Oral Maxillofac Surg 1990: **19**: 193.
24. Connelly SM, Smith RJ. Effects of rigid plate fixation and subsequent removal on craniofacial growth in rabbits. Arch Otolaryngol Head Neck Surg 1998: **124**: 444–447.
25. Costantino P, Wolpoe ME. Short- and long-term outcome of facial plating following trauma in the pediatric population. Facial Plast Surg 1999: **7**: 231–242.
26. da Fonseca MA, Feigal RJ, ten Bensel RW. Dental aspects of 1248 cases of child maltreatment on file at a major county hospital. Pediatr Dent 1992: **14**: 152–157.
27. Dahlstrom L, Kahnberg KE, Lindahl L. 15 years follow-up on condylar fractures. Int J Oral Maxillofac Surg 1989: **18**: 18–23.
28. Demianczuk AN, Verchere C, Phillips JH. The effect on facial growth of pediatric mandibular fractures. J Craniofac Surg 1999: **10**: 323–328.
29. Denloye OO, Fasola AO, Arotiba JT. Dental emergencies in children seen at University College Hospital (UCH), Ibadan, Nigeria—5 year review. Afr J Med Med Sci 1998: **27**: 197–199.
30. Denny AD, Rosenberg MW, Larson DL. Immediate reconstruction of complex cranioorbital fractures in children. J Craniofac Surg 1993: **4**: 8–20.
31. Dodson TB, Kaban LB. California mandatory seat belt law: the effect of recent legislation on motor vehicle accident related maxillofacial injuries. J Oral Maxillofac Surg 1988: **46**: 875–880.
32. Down KE, Boot DA, Gorman DF. Maxillofacial and associated injuries in severely traumatized patients: implications of a regional survey. Int J Oral Maxillofac Surg 1995: **24**: 409–412.
33. Dulley B, Fells P. Long-term follow-up of orbital blow-out fractures with and without surgery. Mod Probl Ophthalmol 1975: **14**: 467–470.
34. Emshoff R, Schoning H, Rothler G, Waldhart E. Trends in the incidence

and cause of sport-related mandibular fractures: a retrospective analysis. J Oral Maxillofac Surg 1997: **55**: 585–592.

35. Eppley BL, Platis JM, Sadove AM. Experimental effects of bone plating in infancy on craniomaxillofacial skeletal growth. Cleft Palate Craniofac J 1993: **30**: 164–169.
36. Fortunato MA, Fielding AF, Guernsey LH. Facial bone fractures in children. Oral Surg Oral Med Oral Pathol 1982: **53**: 225–230.
37. Frazer JE. The skull: general account. In: Breathnach AS, ed: Anatomy of the Human Skeleton. London: J. & A. Churchill Ltd 1965: 161–181.
38. Gerlach KL. Resorbable polymers as osteosynthesis material. Mund Kiefer Gesichtschir 2000: **4**(Suppl 1):91–102.
39. Ghosh A, Di Scala C, Drew C, Lessin M, Feins N. Horse-related injuries in pediatric patients. J Pediatr Surg 2000: **35**: 1766–1770.
40. Graham GG. The management of mandibular fractures in children. J Oral Surg Anesth Hosp D Serv 1960: **18**: 416–423.
41. Gussack GS, Luterman A, Powell RW, Rodgers K, Ramenofsky ML. Pediatric maxillofacial trauma: unique features in diagnosis and treatment. Laryngoscope 1987: **97**: 925–930.
42. Härtel J. Facial bone fractures and their accompanying injuries during growth. Stomatol DDR 1985: **35**: 247–253.
43. Hartel J, Pohl A, Greve JW. Fractures of the facial skull in the growth period and concomitant injuries. Unfallchirurg 1994: **97**: 991–993.
44. Hartel J, Sonnenburg I. Fractures in childhood. Zahntechnik (Berl) 1982: **23**: 81–84.
45. Haug RH, Foss J. Maxillofacial injuries in the pediatric patient. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000: **90**: 126–134.
46. Heitsch M, Mohr C, Schettler D. Indications for the surgical treatment of midfacial fractures in children. Dtsch Zahnarztl Z 1990: **45**: 803–805.
47. Holland AJ, Broome C, Steinberg A, Cass DT. Facial fractures in children. Pediatr Emerg Care 2001: **17**: 157–160.
48. Iizuka T, Thoren H, Annino Jr DJ, Hallikainen D, Lindqvist C. Midfacial fractures in pediatric patients. Frequency, characteristics, and causes. Arch Otolaryngol Head Neck Surg 1995: **121**: 1366–1371.
49. Jaber MA, Porter SR. Maxillofacial injuries in 209 Libyan children under 13 years of age. Int J Paediatr Dent 1997: **7**: 39–40.
50. Jessee SA. Physical manifestations of child abuse to the head, face and mouth: a hospital survey. ASDC J Dent Child 1995: **62**: 245–249.
51. Johnston C, Rivara FP, Soderberg R. Children in car crashes: analysis of data for injury and use of restraints. Pediatrics 1994: **93**: 960–965.
52. Kaban LB. Facial trauma I: midface fractures. In: Kaban LB, ed: Pediatric Oral and Maxillofacial Surgery. Philadelphia, PA: W.B. Saunders 1990: 209–232.
53. Kaban LB. Facial trauma II: dentoalveolar injuries and mandibular fractures. In: Kaban LB, ed: Pediatric Oral and Maxillofacial Surgery. Philadelphia, PA: W.B. Saunders 1990 : 233–260.
54. Kaban LB. Diagnosis and treatment of fractures of the facial bones in children. J Oral Maxillofac Surg 1993: **51**: 722–729.
55. Kaban LB, Mulliken JB, Murray JE. Facial fractures in children: an analysis of 122 fractures in 109 patients. Plast Reconstr Surg 1977: **59**: 15–20.
56. Koltai PJ, Amjad I, Meyer D, Feustel PJ. Orbital fractures in children. Arch Otolaryngol Head Neck Surg 1995: **121**: 1375–1379.
57. Kotilainen R, Karja J, Kullaa-Mikkonen A. Jaw fractures in children. Int J Pediatr Otorhinolaryngol 1990: **19**: 57–61.
58. Laurenzo JF, Canady JW, Zimmerman MB, Smith RJ. Craniofacial growth in rabbits. Effects of midfacial surgical trauma and rigid plate fixation. Arch Otolaryngol Head Neck Surg 1995: **121**: 556–561.
59. Lee D, Honrado C, Har-El G, Goldsmith A. Pediatric temporal bone fractures. Laryngoscope 1998: **108**: 816–821.
60. Lindahl L, Hollender L. Condylar fractures of the mandible. II. A radiographic study of remodeling processes in the temporomandibular joint. Int J Oral Surg 1977: **6**: 153–165.
61. Litwan M, Fliegel C. Roentgen diagnosis of midfacial fractures. Radiologe 1986: **26**: 421–426.
62. Lukas J, Rambousek P. Injuries of the upper and middle thirds of the face. Analysis of the cause of injury. Cas Lek Cesk 2001: **140**: 47–50.
63. Lund K. Mandibular growth and remodelling processes after condylar fracture. A longitudinal roentgencephalometric study. Acta Odontol Scand Suppl 1974: **32**: 3–117.
64. MacLennan WD. Consideration of 180 cases of typical fractures of the mandibular condylar process. Br J Plast Surg 1952: **5**: 122–128.
65. Maniglia AJ, Kline SN. Maxillofacial trauma in the pediatric age group. Otolaryngol Clin North Am 1983: **16**: 717–730.
66. Margolis LH, Wagenaar AC, Liu W. The effects of a mandatory child restraint law on injuries requiring hospitalization. Am J Dis Child 1988: **142**: 1099–1103.
67. Marschall MA, Chidyllo SA, Figueroa AA, Cohen M. Long-term effects of rigid fixation on the growing craniomaxillofacial skeleton. J Craniofac Surg 1991: **2**: 63–68 (discussion 69–70).
68. McCoy FJ, Chandler RA, Crow ML. Facial fractures in children. Plast Reconstr Surg 1966: **37**: 209–215.
69. McGraw BL, Cole RR. Pediatric maxillofacial trauma. Age-related variations in injury. Arch Otolaryngol Head Neck Surg 1990: **116**: 41–45.
70. McGraw-Wall BL. Facial fractures in children. Facial Plast Surg 1990: **7**: 198–205.
71. Meier K, Barsekow F. Fractures of the facial skull in multiple injuries in childhood. Z Kinderchir 1988: **43**: 11–14.
72. Meier K, Barsekow F, Hausamen JE. Problems associated with fractures of the visceral cranium involving multiple injuries in children. Dtsch Zahnarztl Z 1990: **45**: 806–807.
73. Messinger A, Radkowski MA, Greenwald MJ, Pensler JM. Orbital roof fractures in the pediatric population. Plast Reconstr Surg 1989: **84**: 213–216 (discussion 217–218).
74. Montag ME, Morales Jr L, Daane S. Bioabsorbables: their use in pediatric craniofacial surgery. J Craniofac Surg 1997: **8**: 100–102.
75. Mooney MP, Losken HW, Siegel MI, Tsachakaloff A, Losken A, Janosky J. Plate fixation of premaxillomaxillary suture and compensatory midfacial growth changes in the rabbit. J Craniofac Surg 1992: **3**: 197–202.
76. Morgan WC. Pediatric mandibular fractures. Oral Surg Oral Med Oral Pathol 1975: **40**: 320–326.
77. Mulliken JB, Kaban LB, Murray JE. Management of facial fractures in children. Clin Plast Surg 1977: **4**: 491–502.
78. Muraoka M, Nakai Y, Nakagawa K, Yoshioka N, Nakaki Y, Yabe T, Hyodo T, Kamo R, Wakami S. Fifteen-year statistics and observation of facial bone fracture. Osaka City Med J 1995: **41**: 49–61.
79. Murphy Jr RX, Birmingham KL, Okunski WJ, Wasser TE. Influence of restraining devices on patterns of pediatric facial trauma in motor vehicle collisions. Plast Reconstr Surg 2001: **107**: 34–37.
80. Mustoe TA, Kaban LB, Mulliken JB. Nasal Fractures in Children. Eur J Plast Surg 1987: **10**: 135–138.
81. Nahum AM. The biomechanics of maxillofacial trauma. Clin Plast Surg 1975: **2**: 59–64.
82. Naidoo S. A profile of the oro-facial injuries in child physical abuse at a children's hospital. Child Abuse Negl 2000: **24**: 521–534.
83. Oji C. Fractures of the facial skeleton in children: a survey of patients under the

age of 11 years. J Craniomaxillofac Surg 1998: **26**: 322–325.
84. Ousterhout DK, Vargervik K. Maxillary hypoplasia secondary to midfacial trauma in childhood. Plast Reconstr Surg 1987: **80**: 491–499.
85. Perrott DH. Controversies in the management of orbital floor fractures. In: Worthington P, Evans JR, eds: Controversies in Oral & Maxillofacial Surgery. Philadelphia, MD: W.B. Saunders Company 1994: 258–266.
86. Pogrel MA, Podlesh SW, Goldman KE. Efficacy of a single occipitomental radiograph to screen for midfacial fractures. J Oral Maxillofac Surg 2000: **58**: 24–26.
87. Polley JW, Figueroa A, Hung KF, Cohen M, Lakars T. Effect of rigid microfixation on the craniomaxillofacial skeleton. J Craniofac Surg 1995: **6**: 132–138.
88. Porter SR. Facial fractures in children. Br Dent J 1987: **163**: 144.
89. Posnick JC. Craniomaxillofacial fractures in children. In: Kaban LB, ed: Oral and Maxillofacial Surgery in Children and Adolescents. Philadelphia, MD: W.B. Saunders Company 1994: 169–185.
90. Posnick JC, Wells M, Pron GE. Pediatric facial fractures: evolving patterns of treatment. J Oral Maxillofac Surg 1993: **51**: 836–844 (discussion 844–835).
91. Powell EC, Tanz RR. Cycling injuries treated in emergency departments: need for bicycle helmets among preschoolers. Arch Pediatr Adolesc Med 2000: **154**: 1096–1100.
92. Powell EC, Tanz RR, DiScala C. Bicycle-related injuries among preschool children. Ann Emerg Med 1997: **30**: 260–265.
93. Precious DS, Delaire J, Hoffman CD. The effects of nasomaxillary injury on future facial growth. Oral Surg Oral Med Oral Pathol 1988: **66**: 525–530.
94. Proffit WR, Vig KW, Turvey TA. Early fracture of the mandibular condyles: frequently an unsuspected cause of growth disturbances. Am J Orthod 1980: **78**: 1–24.
95. Raflo GT. Blow-in and blow-out fractures of the orbit: clinical correlations and proposed mechanisms. Ophthalmic Surg 1984: **15**: 114–119.
96. Ramba J. Fractures of facial bones in children. Int J Oral Surg 1985: **14**: 472–478.
97. Reath DB, Kirby J, Lynch M, Maull KI. Injury and cost comparison of restrained and unrestrained motor vehicle crash victims. J Trauma 1989: **29**: 1173–1176 (discussion 1176–1177).
98. Regel G, Tscherne H. Fractures of the facial bones—second most frequent concomitant injury in polytrauma. Unfallchirurg 1997: **100**: 329.
99. Rowe NL. Fractures of the facial skeleton in children. J Oral Surg 1968: **26**: 505–515.
100. Rowe NL. Fractures of the jaws in children. J Oral Surg 1969: **27**: 497–507.
101. Rowe NL, Killey HC. *Fractures of the Mandible in Children. Fractures of the Facial Skeleton*. Edinburgh, London: E. & S. Livingstone Ltd 1968: 173–179.
102. Schliephake H, Berten JL, Neukam FW, Bothe KJ, Hausamen JE. Growth disorders following fractures of the midface in children. Dtsch Zahnarztl Z 1990: **45**: 819–822.
103. Schuchardt K, Schwenzer N, Rottke B, Lentrodt J. Causes, frequency, and localization of craniofacial fractures. Fortschr Kiefer Gesichtschir 1966: **11**: 1–6.
104. Selle A, Thieme V. Injuries to the facial portion of the skull and their late effects in children and juveniles—a 10-year analysis (author's translation). Zahn Mund Kieferheilkd Zentralbl 1979: **67**: 377–385.
105. Sewell CM, Hull HF, Fenner J, Graff H, Pine J. Child restraint law effects on motor vehicle accident fatalities and injuries: the New Mexico experience. Pediatrics 1986: **78**: 1079–1084.
106. Shelness A, Charles S. Children as passengers in automobiles: the neglected minority on the nation's highways. Pediatrics 1975: **56**: 271–284.
107. Sherick DG, Buchman SR, Patel PP. Pediatric facial fractures: a demographic analysis outside an urban environment. Ann Plast Surg 1997: **38**: 578–584 (discussion 584–575).
108. Sherick DG, Buchman SR, Patel PP. Pediatric facial fractures: analysis of differences in subspecialty care. Plast Reconstr Surg 1998: **102**: 28–31.
109. Shinya K, Taira T, Sawada M, Isshiki N. Facial injuries from falling: age-dependent characteristics. Ann Plast Surg 1993: **30**: 417–423.
110. Shorter NA, Jensen PE, Harmon BJ, Mooney DP. Skiing injuries in children and adolescents. J Trauma 1996: **40**: 997–1001.
111. Shorter NA, Mooney DP, Harmon BJ. Snowboarding injuries in children and adolescents. Am J Emerg Med 1999: **17**: 261–263.
112. Siegel MB, Wetmore RF, Potsic WP, Handler SD, Tom LW. Mandibular fractures in the pediatric patient. Arch Otolaryngol Head Neck Surg 1991: **117**: 533–536.
113. Smith GA. Injuries to children in the United States related to trampolines, 1990–1995: a national epidemic. Pediatrics 1998: **101**: 406–412.
114. Smoot III EC, Bowen DG, Lappert P, Ruiz JA. Delayed development of an ectopic frontal sinus mucocele after pediatric cranial trauma. J Craniofac Surg 1995: **6**: 327–331.
115. Statistics NCfH. National Vital Statistics Report. Vol 49: 2001: 16–29.
116. Stylogianni L, Arsenopoulos A, Patrikiou A. Fractures of the facial skeleton in children. Br J Oral Maxillofac Surg 1991: **29**: 9–11.
117. Tanaka N, Uchide N, Suzuki K, Tashiro T, Tomitsuka K, Kimijima Y, Amagasa T. Maxillofacial fractures in children. J Craniomaxillofac Surg 1993: **21**: 289–293.
118. Thompson DC, Nunn ME, Thompson RS, Rivara FP. Effectiveness of bicycle safety helmets in preventing serious facial injury. JAMA 1996: **276**: 1974–1975.
119. Thoren H, Iizuka T, Hallikainen D, Nurminen M, Lindqvist C. An epidemiological study of patterns of condylar fractures in children. Br J Oral Maxillofac Surg 1997: **35**: 306–311.
120. Transportation USDo. Status of Occupant Protection in America: National Highway Traffic Safety Administration. 2001.
121. Troulis MJ, Kaban LB. Endoscopic approach to the ramus/condyle unit: clinical applications. J Oral Maxillofac Surg 2001: **59**: 503–509.
122. Tyroch AH, Kaups KL, Sue LP, O'Donnell-Nicol S. Pediatric restraint use in motor vehicle collisions: reduction of deaths without contribution to injury. Arch Surg 2000: **135**: 1173–1176.
123. van Beek GJ, Merkx CA. Changes in the pattern of fractures of the maxillofacial skeleton. Int J Oral Maxillofac Surg 1999: **28**: 424–428.
124. Wagenaar AC, Webster DW. Preventing injuries to children through compulsory automobile safety seat use. Pediatrics 1986: **78**: 662–672.
125. Wagenaar AC, Wiviott MB. Effects of mandating seatbelt use: a series of surveys on compliance in Michigan. Public Health Rep 1986: **101**: 505–513.
126. Weiglein AH. Development of the paranasal sinuses in humans. In: Koppe T, Nagai H, Alt KW, eds: The Paranasal Sinuses of Higher Primates. Development, Function, and Evolution. Chicago, Berlin, London, Tokyo, Paris, Barcelona, Sao Paulo, Moscow, Prague, Warsaw: Quintessence Publishing Co., Inc. 1999: 35–50.
127. Wiltfang J, Merten HA, Schultze-Mosgau S, Schrell U, Wenzel D, Kessler P. Biodegradable miniplates (LactoSorb): long-term results in infant minipigs and clinical results. J Craniofac Surg 2000: **11**: 239–243 (discussion 244–235).
128. Winzenburg SM, Imola MJ. Internal fixation in pediatric maxillofacial fractures. Facial Plast Surg 1998: **14**: 45–58.
129. Wong L, Richtsmeier JT, Manson PN. Craniofacial growth following rigid fixation: suture excision, miniplating,

and microplating. J Craniofac Surg 1993: **4**: 234–244 (discussion 245–236).

130. Worlock P, Stower M, Barbor P. Patterns of fractures in accidental and non-accidental injury in children: a comparative study. Br Med J (Clin Res Ed) 1986: **293**: 100–102.
131. Wright DL, Hoffman HT, Hoyt DB. Frontal sinus fractures in the pediatric population. Laryngoscope 1992: **102**: 1215–1219.
132. Yarington Jr CT. Maxillofacial trauma in children. Otolaryngol Clin North Am 1977: **10**: 25–32.
133. Zachariades N, Papavassiliou D, Koumoura F. Fractures of the facial skeleton in children. J Craniomaxillofac Surg 1990: **18**: 151–153.
134. Zerfowski M, Bremerich A. Facial trauma in children and adolescents. Clin Oral Investig 1998: **2**: 120–124.
135. Zimmerman CE, Troulis MJ, Kaban LB. Diagnosis and management of facial fractures in children. In: Thaller SR, McDonald WS, eds: Facial Trauma. New York: Marcel Dekker 2004: 415–437.

Address:
Leonard B. Kaban
Department of Oral and Maxillofacial Surgery
Massachusetts General Hospital
55 Fruit Street
Boston
MA 02114
USA.
E-mail: LKaban@partners.org