Facial skeletal fractures are common, potentially serious, and frequently associated with other life-threatening conditions, such as traumatic brain injuries. Facial fractures can be simple or complex and sometimes involve serious complications. Computed tomography has revolutionized the rapid and precise assessment ofcraniofacial and neck fractures in patients with severe facial trauma. This article introduces readers to the epidemiology, skeletal anatomy and biomechanics, complications, and diagnostic imaging of facial fractures. In addition, this article describes efforts to develop and validate a quantitative scoring system for facial fracture severity and reviews treatment strategies for facial skeletal fractures.

After completing this article, the reader should be able to:

- Summarize the skeletal anatomy of the face.
- List some leading causes of facial fractures.
- Explain the differences between children’s and adults’ facial skeletons and how facial fracture patterns change with age.
- Describe the role of CT imaging in patient assessment.
- Identify various types of facial fractures, including complex facial skeletal trauma and associated complications.
- Compare systems for classifying the severity of facial fractures.
- Discuss treatment techniques.

Facial skeletal fractures are common, and severe cases usually result from motor vehicle accidents, interpersonal violence, sports, or accidental falls. Precise visualization of the location, magnitude, and extent of fractures provides clinicians with a clearer picture of likely complications and associated soft-tissue or sensory system damage, as well as details needed to plan surgical interventions.\(^1\) There are alternative imaging modalities for assessing facial trauma, but multidetector computed tomography (MDCT) imaging has become the standard choice for quick and accurate assessment of head and face trauma. This modality has revolutionized the detection and assessment of complex fracture patterns and the prediction of complications associated with specific types, locations, and patterns of fractures. CT or MDCT of the face, head, and neck are now routine imaging examinations for patients with severe facial trauma.\(^1-4\)

Although MDCT offers superior visualization of fractures and other trauma associated with high-velocity impact injuries to the face and head, it is not superior to other imaging modalities for assessing minor damage to bones such as minimally displaced nasal bone fractures. In such cases, and particularly for children, MDCT is not recommended because of its relatively high radiation doses.

The bones of children are not just smaller versions of the adult bones. Because of differences in the biology of bones, craniofacial morphology, and risk behaviors throughout the human lifespan, the patterns and associations of facial fractures vary importantly with age.

Epidemiology

Facial fractures account for more than 407,000 emergency department visits per year, representing nearly $1 billion a year in medical costs, with
an average hospital stay of 6 days and hospitalization costs of $62,414, according to a nationwide database study published in 2011. Advances in diagnostic imaging—particularly the widespread adoption of MDCT capable of visualizing occult injuries to facial bones, sinuses, and soft tissues—have improved detection of injuries that are frequently not apparent on clinical examination.

The average age of facial fracture patients is 38 years, and men represent 68% of cases. Advances in automobile safety, including laminated windshields, seatbelts, and airbags, have reduced vehicular accident mortality rates and injuries to the eyes, the bones around the eyes, and the temporomandibular joints (TMJs). Particularly among adolescent boys and young men, interpersonal violence is a common cause of facial fractures. Alcohol consumption plays a major role in interpersonal violence resulting in facial fractures. Alcohol-involved interpersonal violence also is associated with more severe facial skeletal injuries than nonalcohol-associated violence. The relative risk of required surgical treatment was 60% higher when alcohol was involved in violence, according to a 2012 prospective British study.

Midface fractures are commonly associated with accidental falls, particularly among elderly people. Horseback riding falls also are associated with midface fractures. Dog-bite injuries, especially among young children, can result in fractures of the nasal bones, orbital bones, cheek bones, and mandible; any dog attack involving bites to the face is an indication for diagnostic imaging to detect facial fractures.

Workplace accidents resulting in facial fractures are more common among men and tend to be associated with construction jobs; falling objects at construction sites are associated with skeletal fractures in the midface and mandible.

Facial fractures frequently are associated with soft-tissue and other skeletal trauma. When this trauma involves regions other than the face and head, it typically reflects complex external blunt forces related to the cause of the injury, such as high-velocity automobile accidents or falls from heights that can cause multiple and widespread potentially life-threatening injuries, a condition called polytrauma. For example, patients with facial fractures sometimes also present with pulmonary and limb bone injuries.

Not surprisingly, the same external blunt forces that fracture facial bones also frequently cause serious soft-tissue damage elsewhere in the face and head, either directly or indirectly. Associations have been identified that follow predictable patterns, reflecting the transmission of external forces throughout the body during certain types of impacts. Knowing about such associations can help clinicians look for injuries that are not initially obvious. For example, facial fractures in severe trauma patients frequently are associated with other traumatic head, brain, and upper cervical spinal injuries. Cervical spinal fractures accompanying upper midface fractures typically occur at lower levels of the cervical spine than cervical injuries that accompany mandibular fractures, which tend to be higher on the cervical spine.

Dental injuries are another common association, affecting 15% of adult patients with facial fractures. Tooth trauma is most frequently seen in association with mandibular fractures.

Despite the widespread belief that patients with facial fractures but no clinically obvious neurological abnormalities do not have severe intracranial hemorrhaging, a 2008 case-control study in Austria found that normal neurological examination findings cannot independently rule out intracranial hemorrhage among patients with facial fractures. This is especially true in the presence of vomiting, nausea, or seizures. “In many cases, facial fractures distract attention from more critical, often life-threatening injuries,” the study’s authors warned.

Complications arising directly from facial fractures also are common. Even simple nasal and mandible fractures, as well as complex midface trauma, can lead to significant blood loss. TMJ damage can make it painful and difficult to open one’s mouth or to chew. Fracturing or displacement of bones can cause shearing, herniation, or displacement of nerves, the eyes, and other soft tissues. Lateral blows to the face can, in rare cases, cause blindness or severe visual impairment. Extensive facial trauma and associated bleeding and swelling can compromise airways. Fractures to the bones that make up the orbital cavities can result in damage to the optic nerves or blood vessels, causing blindness or herniation of the globe (eye); zygomatic bone fractures can cause fractures to the orbital floor, displacing the globe. Infection also can result from facial fractures and associated trauma.
Epidemiology of Pediatric vs Adult Facial Fractures

Overall, facial fractures are less frequent among children than adults. However, they tend to be more severe in children when they do occur. Head trauma in general is the leading cause of death from injury among children in the United States. According to a 2008 analysis of data from 277,000 pediatric patients from the National Trauma Data Bank, the leading causes of facial fractures among children were automobile accidents (55%), violence (12%), and falls (9%).

Half of injuries resulting from child physical abuse involve the head and neck, although facial fractures are rare in abuse cases, representing less than 3% of cases. Physical trauma to the head and neck should be considered evidence of possible chronic child abuse when accompanied by signs of malnutrition, missing or broken teeth, fractures at different stages of healing, bruises, hand and object imprints, abrasions, or burns.

The greater plasticity of children’s bones means they are more resistant to fracture than are adult bones, on average. Facial fracture–associated dental injuries are more severe, extensive, and common among children than among adults, affecting 29.5% of children with facial fractures due to automobile accidents or falls from heights. This is likely related to the greater forces necessary to cause facial fractures in children than adults. When researchers study children with facial fractures, they are almost by definition studying a patient population that experienced high-magnitude forces. Nearly one-third of children who receive a facial fracture diagnosis simultaneously receive a concussion diagnosis, and a concomitant cranial fracture more than doubles the risk of concussion.

Facial Skeletal Anatomy

The skeleton of the head consists of 44 bony elements that fuse during early development to form the cranium (also known as the vault or braincase), the skull base, and the facial skeleton. The mandible connects to the skull at the TMJs. The rest of the bones of the head are fused or sutured together. During early development, the bones of the cranium and face emerge from 2 distinct embryonic tissues and are referred to as the neurocranium (vault) and viscerocranium (facial skeleton). The vault consists of 8 sutured bones that contain and protect the brain and brain stem from external blunt forces. The skull base separates the brain from facial anatomies; its 5 bones are subdivided into anterior, middle, and posterior zones or regions.

The human facial skeleton is composed of at least 14 interconnecting bones, not including the teeth, depending on how these fused bones and their sutures are delineated and counted. These include the frontal bone, nasal bones, temporals, sphenoidals, lacrimals, zygomatics, ethmoides, maxilla, vomer, and mandible (see Figure 1). These bones and their sutures represent more than 180 anatomic contours and features, including crests, plates, spines, canals, arches, processes, and other structures. Together the structures form a complex scaffolding for muscle attachments and the functional units of the face, namely the eyes, upper respiratory airways (e.g., the nasal cavity), the teeth, and the mouth.

Interconnecting facial skeletal buttresses connect the face to the skull base, transferring and withstanding chewing and biting forces and external compressive forces to protect soft tissues, nerves, and the underlying sinus structures (see Figure 2). Within the network of buttresses are very thin bony sinus cavities. The surfaces of these intricately contoured air-containing skeletal cavities are covered with respiratory epithelial tissue. Among other functions, they moisten air inhaled through the nose.

Unlike facial skeletal buttresses, the delicate sinuses are not resistant to external blunt forces and have been

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Figure 1. Bones of the human face.

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Frontal bone
Nasal bone
Sphenoid bone
Temporal bone
Zygomatic bone
Maxilla
Mandible
Lacrimal bone
Ethmoid bone
Vomer
likened to a “crumple zone.” Once crushed, they distort the shape and function of the face. The hypothesis that sinuses might function to reduce or prevent the transmission of external forces through the face to the brain, similar to engineered vehicle crumple zones, is controversial. For example, little evidence demonstrates that patients with only facial fractures experience less severe brain injuries than patients who have only skull injuries.

The normal skeletal anatomy of the face frequently is classified into upper, middle, and lower partitions (see Figure 3). The upper facial skeleton includes the frontal bone and the frontal sinuses, encompassing the forehead down to the upper edges of the orbital cavity rims. The mandible or jawbone represents the lower facial skeleton. Between the 2 is the midface skeleton, which extends downward from the superior orbital rims and orbits and includes the nasal cavity and associated sinuses.

The Midfacial Skeleton

The skeletal middle face includes the orbital cavities; nasal cavity; and the maxillary, ethmoid, and sphenoid—or midface—sinuses.

The midface’s orbital cavities, or orbits, are conical spaces that contain the eyes and associated vasculature and nerves. The bony roof of the orbits includes the thick frontal bone. The curved inner medial and lateral walls of the orbits join the walls of adjacent sinuses. The thin bones of the maxillary sinus roof also function as a floor for the orbits; blood vessels and nerves are situated in canals and grooves that pass through the orbital floor. Whereas the bone of the maxillary sinus roof is thin and relatively weak, other portions of the orbital walls and external rims, which are made up of thicker maxillary and zygomatic bones, are strong and more protective of the eyes. Between the orbits, the nasal
skeleton is made up of symmetrically paired nasal bones and the bony nasal septum situated between the maxilla and frontal bone and anterior to the nasal cavity.28

The curved zygomatic arches or processes are symmetrically paired bones on the right and left halves of the face. The name of these bones was derived from zygoma, the Greek word for yoke, alluding to their function in keeping the eyes contained within the orbits.

Attached to the zygomatic processes are paired right and left maxillae, each of which represents 2 fused bones that create the palate or roof of the mouth, the nasal floor and lateral walls, and orbital walls.25,27 The maxillae cover the region between the lower base of the nostrils and the upper teeth and extend upward between the nose and the lower and inner edges of the orbits.

The Facial Skeletal Buttresses

The 8 paired skeletal buttresses of the face are regions of increased bone thickness that support muscles, eyes, teeth, and the uppermost airways (see Figure 4).1,2 There are 4 paired vertical facial skeletal buttresses and 4 transverse buttresses, creating a cagelike array of thickened facial bones. All of the buttresses are linked, directly or indirectly, to the other buttresses, influencing the transmission of external forces throughout the facial skeleton.2

Not surprisingly, the buttresses’ anatomy often is an important factor in treatment planning for facial fractures.2 For example, because of their increased bone thickness, buttresses are frequently sites of metal screw fixation during surgery for facial fractures.2

Sometimes, because the right- and left-face transverse buttresses meet in the midface to create a continuous buttress, they are referred to in the singular (eg, upper transverse mandibular buttress), whereas vertical buttresses usually are referred to in the plural (eg, right and left buttresses). However, because all buttresses,
whether vertical or transverse, are in reality paired and symmetrical features, the plural is used throughout this article.

**Pediatric Facial Skeletal Anatomy**

There are marked differences in the neuroanatomy and facial skeletons of adults and children that affect patterns of facial skeletal trauma in these 2 populations.20 Children’s underdeveloped facial skeletons are composed of less ossified, more flexible bones than adult bones, with lower ratios of rigid cortical bone to interior cancellous (“spongy”) marrow-containing bone.20,29 This can lead to so-called green-stick or incomplete fractures in children. Although unerupted teeth in young children’s maxillae and mandibles might give those structures somewhat greater resistance to external compressive forces compared with older patients, the mandibles and other bones of children have a thinner cortex, leaving them less resistant, overall, to fracture.20

In addition, the morphology of children’s skeletons is very different from adults; children have a larger cranium-to-face ratio and smaller, flatter midfaces and mandibles.21,29 The bony orbits represent a much larger proportion of children’s faces than adults’ faces, and children’s midfaces are relatively smaller. As a result, the midface fractures common among adolescents and adults are relatively rare among children.29 Children’s sinuses have fewer air cavities than those of adults.29 The sinuses mature slowly throughout childhood and adolescence. Maxillary sinuses mature first, at tooth eruption. Ethmoid sinuses mature next, at puberty. The frontal sinuses mature in adulthood (see Figure 5).29

**Facial Skeletal Trauma and Fracture Types**

Facial fracture patterns reflect the location, direction, and magnitude of traumatic forces.27 When forces are severe, the extent of underlying facial skeletal trauma is not always readily discernable from a visual assessment of external facial trauma.27 Midface fractures are common and frequently involve occult, serious soft-tissue damage; their management requires careful diagnostic imaging of the facial skeletal buttresses and soft tissues.2

Figure 5. Illustration depicting the development of the frontal and maxillary sinuses according to age in years. Increasing development of the paranasal sinuses is positively correlated with the prevalence of midfacial fractures in children. The sinuses reach their full size after puberty is complete. Reprinted with permission from Alcalá-Galiano A, Arribas-García IJ, Martín-Pérez MA, Romance A, Montalvo-Moreno JJ, Juncos JM. Pediatric facial fractures: children are not just small adults. Radiographics. 2008;28(2):441-461.

CT imaging allows reconstruction of 2-D and 3-D images from multiple angles, thus allowing visualization of even subtle fractures that would be missed with traditional radiography.2 Predicting clinical complications and planning treatment and surgery require a complete set of images and an understanding of the clinical associations of common facial fracture patterns.2

**Pediatric Facial Fractures**

A common refrain in the facial fracture literature is that “children are not just little adults.”21,30 The anatomic and biological differences between the facial skeletons of adults and children of different ages lead to distinct patterns of fractures, associated trauma, and brain involvement. These differing patterns create distinct management challenges.

Overall, pediatric fractures most frequently involve nasal trauma (50% of cases) and mandibular fractures (≤ 49% of cases).21 However, facial fracture patterns vary with the stage of craniofacial development and maturity.21 Children’s facial fractures are associated with higher mortality and morbidity rates.2,20 Children who sustain
Facial fractures are significantly more likely to experience traumatic brain injury, skull base fractures, cranial vault fractures, cervical spinal fractures, eye injuries, and facial soft-tissue injuries than are children who have traumatic injuries without facial fractures.\textsuperscript{20} Approximately 32% of children with facial fractures have a concomitant concussion, and the risk of concussion is doubled among children who sustain both facial and cranial fractures.\textsuperscript{23} Pediatric facial fractures are therefore an indication for concussion screening and neuroimaging.\textsuperscript{23}

The nature of facial fractures changes with age throughout childhood.\textsuperscript{20} For example, midface fractures are more common among toddlers and infants than adolescents, while mandibular fractures are more common among teens than young children.\textsuperscript{17} The orbits represent a larger proportion of children’s faces than adults’ faces, and the frontal sinuses are immature. Together, these factors mean that the bony orbits are a common site of pediatric facial fractures.\textsuperscript{29} Blow-in superior orbital fractures are seen more often among younger children, whereas in later years, children are more likely to sustain fractures to the bones that make up the orbital floors.\textsuperscript{29} Green-stick “trap-door” facial fractures of the bony orbits can leave a bone fragment connected by a “hinge” to the orbital floor, with the fragment initially protruding into the sinus (leading the eye to prolapse into the gap), and subsequently snapping back into place in a manner that entraps eye tissue in a prolapsed position (see Figure 6).\textsuperscript{21}

Because children’s immature sinuses have fewer air cavities, frontal sinus fractures are relatively rare in children and tend to be associated with higher-velocity forces than the forces necessary to fracture adults’ frontal sinuses.\textsuperscript{29} When frontal sinus fractures do occur in children, they are frequently associated with severe and serious soft-tissue trauma, such as cerebrospinal fluid leaks and traumatic brain injuries.\textsuperscript{29}

**Sinus Fractures**

Frontal sinus fractures result from high-velocity blunt trauma to the upper face. These fractures have become less frequent with the advent of automobile airbags.\textsuperscript{3} However, they still represent up to 15% of all facial fractures, are frequently accompanied by other craniofacial fractures, and can be fatal.\textsuperscript{32} The presence of frontal sinus fractures calls for careful neuroimaging assessment for traumatic brain injury, pneumocephalus

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**Figure 6.** A-C. Computed tomographic diagnosis of nasofrontal outflow tract injury as noted by frontal sinus floor fractures (arrows). This is one criterion used in the diagnosis of outflow tract injury. When outflow tract injuries allow access to the brain vault, meningitis or brain infection can occur. C. A trap-door facial fracture (arrow). Reprinted with permission from Stanweix MG, Nam AJ, Manson PN, Mirvis S, Rodriguez ED. Critical computed tomographic diagnostic criteria for frontal sinus fractures. J Oral Maxillofac Surg. 2010;68(11):2714-2722.
(the presence of air in the cranial vault), and facial imaging for other facial fractures.\cite{3,32}

Because of MDCT’s precision, surgical interventions have become less frequent while monitoring with diagnostic imaging has become more common.\cite{3,32}

Nevertheless, frontal sinus fractures can require quick surgical intervention, especially when they involve trauma to the nasofrontal outflow tract, which can become a conduit for infectious agents into the brain (see Figure 7). Closing this conduit to the brain in some cases requires surgical obliteration of the nasofrontal outflow tract, in addition to internal fixation of the fractured sinus.\cite{3,32} Pneumocephalus is an indication of severe injury and requires surgical intervention.\cite{3}

Criteria for CT-based diagnosis of nasofrontal outflow tract injuries include fractures of the sinus floor or the anterior or posterior table or obstruction of the outflow tract. Fractures of the anterior or posterior table are present in up to 91% of patients with outflow tract injuries.\cite{3,32} Fractures of the sinus floor are identified in only 9% of patients with this type of injury.\cite{32} The presence of any one of these criteria carries up to a 300% increased likelihood of brain injury or other facial fractures.\cite{3,32}

Anterior and posterior assessments include the degree of displacement associated with any fractures.\cite{3}

**Nasal Fractures**

Nasal bones are more exposed than other facial bones, and nasal fractures are the most common form of facial trauma, although in most cases these fractures result in minor displacements that can be readily reduced without open surgery or even radiography.\cite{28}

Nasal bone fractures result from external blunt forces that impact the nose anteriorly or laterally.\cite{1} Type 1 nasal fractures involve trauma to, and displacement of, the anterior spine and bridge of the nose but do not involve the nasal septum; type 2 fractures also involve the septum.\cite{1} Type 3 nasal fractures are more serious and involve the bony orbits and other bone in addition to the nasal structures affected by type 1 and type 2 nasal fractures.\cite{1} Complications associated with type 1 fractures usually are merely aesthetic, but type 2 and 3 nasal fractures can lead to impaired nasal breathing. Clinical assessment is the norm for type 1 and 2 trauma, whereas imaging is indicated to evaluate suspected type 3 fractures.\cite{28}

**Orbital Fractures**

The orbits and orbital rims are complex skeletal structures composed of surrounding bones and buttresses.\cite{28} Fractures of the orbital walls can be localized and simple, or they can be complex fractures extending beyond the orbits, such as those extending into or through the orbital rims. Both simple and complex orbital fractures can affect the position and integrity of the eyes, eye muscles,
or optic nerves. As the name implies, simple blowout fractures occur when fractures in the orbital wall extend outward into the sinuses. Blow-in fractures are less frequent and occur when fractured bone intrudes into the orbital space inhabited by the eye. Blowout fractures affecting more than half of the orbital floor increase the risk of enophthalmos, or the sinking of the eye from its normal anatomic position.

Orbital blowout fractures are sometimes classified into 3 categories:
- **Type I** – trap-door fractures.
- **Type II** – separated bone fragments surrounding displaced soft tissue.
- **Type III** – displaced bone surrounding displaced soft tissue.

**Mandibular Fractures**

More frequently seen among children than adults, simple mandibular fractures usually are condylar or subcondylar, affecting the TMJ region (see Figure 8). Children typically sustain a single mandibular fracture, whereas adults more frequently sustain multiple fractures to the jawbone. Condylar fractures occur bilaterally 20% of the time. Mandibular fractures, like facial trauma in general, frequently involve dental trauma. This can be particularly severe among children. Jaw injuries are a common type of facial fracture in automobile accidents.

**Complex Facial Fractures**

Complex facial fractures frequently occur in predictable patterns and can result when the midface is subjected to high-velocity external blunt forces. Complex facial fractures are uncommon in children, representing less than 10% of all pediatric facial fractures. Complex fractures involving damage to multiple facial skeletal buttresses can partly or completely dissociate the midfacial skeleton from the skull and frequently require rapid assessment and surgical intervention to reduce and fix fractured bones in place. Common complex patterns of facial fractures frequently involve orbital walls and rims.

**Le Fort Fractures**

These fractures are named for the French surgeon René Le Fort, who first described them in 1901 based on experiments involving numerous cadaverous human heads and wooden clubs. There are 3 types of Le Fort fracture patterns, elements of which can overlap (see Figure 9). Le Fort fractures are classified by the site and extent of fractures, using coronal and axial 2-D CT images and 3-D surface renderings.

**Nasoorbitoethmoid Fractures**

Nasoorbitoethmoid (NOE) fractures result from high-velocity blunt forces to the nose or the upper midface, causing fractures in the region where the transverse maxillary buttresses meet the medial maxillary buttresses. Patients with NOE fractures typically present with reduced nose projection from the face and abnormal protrusion of the eye or eyes. NOE fractures are differentiated from simple nasal fractures by confirmation of involvement of the orbital walls and ethmoid sinuses.

The Manson classification system identifies 3 types of NOE fractures:
- **Type I** – a large single-segment fracture in the medial orbital rim.
- **Type II** – comminution (severe, complex fracturing into multiple small fragments) of the medial orbital rim but without damage to the tendon.
- **Type III** – comminution, as in type II, but with damage to the tendon.
Zygomaticomaxillary Complex Fractures

Direct blunt trauma to a zygomatic arch or upper transverse maxillary buttress can cause simple fractures limited to the zygomatic bone. 1 Fractures that extend into the orbital wall, in contrast, are termed zygomaticomaxillary complex (ZMC) fractures.

The zygomatic and maxillary sinus bones represent much of the floors and lateral walls of the bony orbits. 2 These ZMCs involve the upper transverse maxillary buttresses and the lateral maxillary vertical buttresses. ZMC fractures, also known as tetrapod 1 or quadrupod fractures, extend through 4 zygomatic bone sutures: the zygomaticofrontal, zygomaticomaxillary, zygomaticotemporal, and, posteriorly, the zygomaticosphenoid sutures (see Figure 10). 1

However, ZMC fractures represent a class of fracture patterns, and not all ZMC fractures involve all 4 of these sutures. 28

Complications

The fracturing and displacement of facial bones can cause nerve damage and compress or damage soft tissues, frequently in ways that can be predicted by visualization of skeletal trauma. 1,27 For example, cerebrospinal fluid leaks frequently accompany fractures of the central sinus walls. 27 Because of the anatomic location of the frontal sinuses, sinus fractures can provide infectious organisms access to the brain, potentially causing brain abscess or meningitis. 32

Fractures in the orbital wall can have profound implications for patients’ visual acuity and quality of life. Lateral orbital wall fractures can injure the eye, eye muscles, and optic nerves. 1 Superior orbital fissure syndrome and orbital apex syndrome (also known as Jacod syndrome) sometimes result, albeit very rarely, when lateral maxillary buttress fractures extend into or through the superior orbital fissure or the adjacent orbital apex. 1,36 Signs of these syndromes include ophthalmoplegia (eye muscle paralysis), eye muscle weakness, drooping of the upper eyelid, fixed dilation of the eye, bulging of the eyes, and hypoesthesia (loss of touch sensation) in the face, upper eyelids, or forehead. 36

Large orbital floor blowout fractures can cause enophthalmos, or the downward displacement of the eye. 28 Eye muscle or globe tissue can herniate into blowout fractures. Soft-tissue herniation associated with orbital floor fractures can contribute to diplopia (bilateral eye misalignment and resulting double vision) and can cause intraorbital edema and hemorrhage in the days following traumatic injury. 33 However, when diplopia persists longer than a few days after an injury, soft-tissue herniation is a more likely culprit than edema or hemorrhage. 33 Fractures near the orbital apex are uncommon but potentially serious when involving the optic nerve. 24

Soft-tissue damage resulting from facial bone fractures can include hematoma and herniation, which can complicate visualization of focal injuries. 27 Type 2 and 3
nasal fractures can sometimes cause septal hematomas, which are more common among children. They also can cause abscesses or perforation, which can complicate breathing. Accumulations of mucus in the lacrimal sac or paranasal sinuses, called mucoceles, are a common complication of nasofrontal and frontal sinus trauma. Preventing mucocele formation is an indication for frontal sinus surgery following NOE fractures.

Because of their thicker bone, facial skeletal buttresses are more resistant to fracturing. Although greater force is required to fracture buttresses than other components of the facial skeleton, such fractures do commonly result from high-velocity impact injuries due to sports, interpersonal violence, and, particularly, automobile accidents. When they do occur, buttress fractures commonly are associated with soft-tissue injuries, which frequently are serious. For example, fractures of one or both of the posterior maxillary vertical buttresses can cause TMJ dislocation. Fractures of the upper and lower transverse mandibular buttresses can cause nerve damage that results in loss of touch sensation in the lower lip, chin, or the tip or anterior portion of the tongue.

Upper transverse maxillary buttress fractures are associated with the orbital complications described previously, such as displacement or herniation of the eye or associated soft tissues, as well as potentially devastating ruptures of the globe, orbital hematoma, tears in the optic muscle, and superior orbital fissure syndrome. Deformities of the globe's overall shape (eg, the "flat tire" sign) are visible on CT images and indicate globe rupture and trauma to the entire eye, including the cornea and retina, which can cause blindness (see Figure 11). Medial maxillary buttress fractures, which can be either solitary fractures or complex Le Fort or NOE fractures, require careful CT image analysis for assessment and surgical planning because these injuries can endanger the eyes; vasculature associated with the eyes, such as the ethmoid arteries; and supporting soft tissue, such as the canthal tendons. Cerebrospinal leaks also can result from medial maxillary buttress fractures, and as with frontal sinus fractures, these injuries carry the risk of infection when fractures affect the paranasal sinuses. Meningitis and cerebral or epidural abscess can result. Damaged lacrimal (tear) ducts and sacs are surgically repaired to correct their inflammation.

Figure 10. Zygomaticomaxillary complex (ZMC) fracture pattern before and after internal fixation. A. Three-dimensional CT image of an adult face in oblique orientation depicts a right ZMC fracture with a nondisplaced zygomaticofrontal suture (green arrow), mildly displaced zygomaticomaxillary suture (blue arrow), and comminuted and displaced zygomatic arch extending through the zygomaticotemporal suture (red arrow); the zygomaticosphenoid suture was involved but is not depicted. A nondisplaced fracture of the base of the right coronoid process (arrowhead) also is depicted. B. Three-dimensional CT image in the same orientation demonstrates fixation of the zygomaticomaxillary and zygomaticotemporal sutures with plates and screws in place. Reprinted with permission from Winegar BA, Murillo H, Tantiwongkosi B. Spectrum of critical imaging findings in complex facial skeletal trauma. Radiographics. 2013;33(1):3-19.
NOE fracture patterns often are associated with protruding eyes, telecanthus (abnormal distance between the eyes caused by tendon injury), and cerebrospinal fluid discharge from the nose.

**Pediatric Complications**

Relatively little research has been published on complications associated with facial fractures in children, partly because of poor standardization of definitions and reporting criteria and standards for adverse events. But pediatric complications are important because children’s faces are still developing; fractures can subtly or profoundly alter craniofacial development and adult facial appearance and function and have lifelong implications for patients’ quality of life.

Researchers at the Children’s Hospital of Pittsburgh in Pennsylvania developed a simple qualitative classification system that identifies 3 broad, nonmutually exclusive types of complications that result from pediatric facial fractures:

- **Type 1**—complications “intrinsic to, or concomitant with the fracture itself,” such as the loss of permanent teeth.
- **Type 2**—complications associated with medical interventions, such as loss of nerve function after reduction and internal fixation of a fragmented mandible, or surgical scars.
- **Type 3**—complications stemming from growth and development after the fracture and medical treatment, such as asymmetric growth of the mandible resulting from a condylar (TMJ-region mandibular) fracture.

This classification scheme is based on experiences at the researchers’ hospital, and they acknowledged that no classification system, including theirs, has been tested and validated with longitudinal studies of large populations of patients over time.

Type 1 pediatric complications include eye trauma, with some studies suggesting that up to 24% of children sustaining orbital midfacial fractures suffer nerve and globe damage leading to blindness. As among adults, fractures at the orbital apex are a risk factor for optic nerve damage.

Facial lacerations are commonly and unsurprisingly associated with facial fractures and can scar children’s faces for life. Septal hematoma following pediatric nasal bone fractures is a potentially serious type 1 complication that can lead to necrosis and infection if not quickly evacuated. In addition, septal hematomas can lead to a long-term “saddle nose” disfigurement if not evacuated quickly. Tooth injuries also commonly accompany facial fractures, including root and crown fractures.

Type 1 and type 2 pediatric complications of the sensory nerves of the face include alterations of taste and smell, as well as nerve palsies associated with cranial nerves. TMJ ankylosis (impaired jaw movement) sometimes occurs as a type 1 or type 2 pediatric complication following mandibular fractures; it is rarely associated with prolonged maxillomandibular fixation.

Among children who have sustained facial fractures, surgical reduction and fixation lead to complications in fewer than 5% of cases. These complications can include infection, bilateral facial asymmetry, or scarring.

Patients who have suffered pediatric facial fractures should undergo surveillance throughout childhood to detect TMJ ankylosis, tooth loss, and type 3 developmental complications, including facial asymmetries stemming from aberrations in facial bone development and growth.

**Computed Tomography Imaging of Facial Fractures**

Diagnostic MDCT has higher sensitivity for detecting midface fractures than conventional radiography. MDCT examinations should be undertaken following a facility’s written standardized trauma assessment protocol.
CT scan acquisition direction typically is craniocaudal. With a 16- or 64-channel MDCT scanner, scan parameters are 120 kV tube voltage, 115 mA, a 0.9 pitch, narrow acquisition slice thickness (eg, 0.65 mm on a 64-channel MDCT scanner37) and a gantry rotation time of 1 second.37,39 Reconstruction of multiplanar coronal, sagittal, and axial images using bone and soft-tissue algorithms at 1.25-mm slice thickness is undertaken for image interpretation.37

Three-dimensional image reconstructions usually are produced.37 Both 3-D volume and surface-rendered MDCT images are useful in diagnostic imaging and surgical planning for high-energy (eg, complex) facial fractures because they precisely visualize the location and extent of fractures.38 Conversely, 3-D volume-rendered images frequently poorly visualize low-energy simple fractures involving no major bone displacement, such as simple type 1 nasal fractures.28,39

When clinical examination indicates that a nasal fracture involves minimal displacement and is not likely to be accompanied by other facial fractures (such as type 1 nasal fractures resulting from low-velocity external blunt forces), diagnostic imaging usually is not indicated, particularly for children and adolescents.24 However, when other facial fractures are suspected (eg, type 3 nasal trauma with significant displacement), imaging usually is undertaken to confirm the presence and extent of nasal bone and other fractures and to plan nasal reduction to avoid aesthetic and functional complications.39 Lateral radiographs of the nose sometimes are still undertaken for this purpose but have poor sensitivity (as low as 53%) for fracture detection.24 MDCT has far better sensitivity, but concerns have been raised about the relatively high radiation dose associated with this modality and whether it is medically justified for investigating nasal bone fractures, particularly when clinical examination suggests minimal fracture displacement.24,39 Because of the long-term hazards posed by radiation, unnecessary CT of the head and face should be avoided, particularly with children, in keeping with the as low as reasonably achievable (ALARA) principle. Ultrasonography can be used as a nonionizing alternative to CT for confirming and characterizing lateral nasal wall fractures in children.39

When a nasal fracture is to be assessed in the course of CT imaging for other possible facial fractures or because the nasal fracture has caused significant displacement, however, MDCT sagittal multiplanar reconstruction images appear to offer better diagnostic precision than axial CT images alone, particularly when used alongside axial images.39

CT is necessary for orbital fracture surgery planning to assess entrapped tissue positions, muscle anatomy, and fracture displacement.40 As is the case with other midface MDCT imaging applications, thin-section multiplanar images are used to evaluate orbital fractures. Orbital fractures are common in cases of midface trauma, including NOE and ZMC fractures. NOE fractures most frequently affect the medial orbital wall; ZMC fractures tend to occur in the orbital floor and lateral wall.40 Le Fort type III craniofacial dissociation fractures affect the medial and lateral orbital wall and the posterior portion of the orbital floor.40 Most orbital fracture planning images are 2-D reconstructions. Axial CT reconstructions are prepared for medial wall fractures to confirm increased orbital volume and enophthalmos and to visualize muscle entrapment by blow-in or blowout fractures.40 Two-dimensional CT images can be reconstructed to visualize fractures of the external orbital wall and orbital apex, the presence and exact locations of bone fragments, and the location of the optic nerve and any compression of the optic nerve displaced portions of the fracture or fragments.40 Evidence of optic nerve involvement is an indication for emergency surgery to prevent blindness.40 Orbital roof fractures are assessed with 2-D axial and coronal reformatted CT images that visualize comminuted fractures of the frontal sinus; indications for referral to neurosurgery include orbital roof fractures associated with pneumocephalus, cerebrospinal fluid leaks, or hematomas within the cranial vault.40
Soft-tissue wounds within the orbits, including laceration of the cornea, damage to the globe, and bleeding within the orbits, also can be assessed using MDCT imaging to confirm clinical and ophthalmologic examinations. Open-globe injury (ruptured eye) is indicated by changes in the external contour and volume of the affected eye (the “flat tire” sign) and the presence of bone fragments or hyperdense foreign materials within the body of the orbits. (CT is sensitive in the detection of metal and bone, but glass and wood fragments might not be well visualized.) Ocular lacerations cause fluid accumulations.

As noted above, cerebrospinal fluid leaks, telecanthus, and optic nerve injury are complications of medial maxillary buttress fractures; these can be detected with coronal and axial CT reconstructions. Orbital apex fractures frequently are an indication for immediate surgical intervention.

Suspected orbital trauma among children should be evaluated carefully for possible trap-door fractures in the orbital floor, which can ensnare soft tissues and reduce the range of eye movement and function. When the bone has snapped back into place and trapped soft tissue, the only sign of a trap-door fracture is likely to be the snared soft tissue, such as optical muscle. Even in the absence of trap-door fractures, orbital floor fracture and associated soft-tissue herniation are risk factors for diplopia. Larger fractures are more likely than medium or small fractures to cause diplopia. This non–trap-door orbital floor fracture and herniation is seen in adults and can be detected on CT as multiple contact points between the eye muscle and the edge of the fracture. When orbital floor fractures and soft-tissue herniation are not confirmed by CT, diplopia might be due to eye muscle or optic nerve injury.

### Injury Severity Scores

Several authors have proposed maxillofacial trauma severity scores to replace local and regional descriptions of facial fractures and fracture patterns, to standardize currently qualitative and somewhat subjective descriptions of trauma severity, and to facilitate more uniform standards of care. No single test has gained universal acceptance or widespread use for guiding facial trauma treatment, but proponents argue that such scores might prove to be valuable prognostic tools. The 4 validated scoring systems for complex craniofacial fractures are described in the Box.

Using multiplanar 2-D reformations and 3-D renderings of archived CT data for 119 patients with facial trauma, British researchers tested all 4 severity scoring systems to develop a new proposed maxillofacial trauma scoring system called the ZS Scoring System. Only the proposed ZS model successfully discriminated between varying levels of trauma, the authors reported. This is likely in part because the 4 existing trauma scales did not sufficiently weight more severe fractures (assigning them a large enough number compared with less severe fractures). For example, the ZS score heavily weights bone fracture comminution and scores dental trauma, making it a more sensitive measure of high-velocity trauma.

However, existing systems have other limitations. For example, the Maxillofacial Injury Severity Score scale does not include frontal or orbital fractures.

### Treatment of Facial Fractures

Simple nasal fractures frequently are reduced through nonsurgical manipulation. More serious facial trauma is triaged into 3 broad categories:

### Box

<table>
<thead>
<tr>
<th>Validated Scoring Systems for Complex Craniofacial Fractures</th>
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<tr>
<td><strong>Facial Injury Severity Score</strong> – assigns weighted numerical scores for different fractures, the sum of which represents the final score.</td>
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<tr>
<td><strong>Maxillofacial Injury Severity Score</strong> – assigns numerical scores to malocclusion, limited mouth opening, and magnitude of facial deformity, using components from the Abbreviated Injury Scale 1990, with predefined weighting of scores that assigns higher numbers, for example, to Le Fort III fractures than to isolated mandibular injuries.</td>
</tr>
<tr>
<td><strong>Cooter and David Score</strong> – grades fractures on a scale of 0 to 3 for each of 20 craniofacial skeletal zones.</td>
</tr>
<tr>
<td><strong>Facial Fracture Severity Score</strong> – similar to the Cooter and David Score system, the Facial Fracture Severity Score assigns numerical severity scores to 41 facial skeletal anatomies, the sum of which represents the final score.</td>
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</tbody>
</table>
Fractures or other injuries requiring immediate intervention to save the patient's life or eyesight. Identifying these fractures might require immediate CT scanning, particularly if injuries are suspected that could threaten the patient's eyesight. High-speed MDCT allows single-scan acquisition of facial, skull base, intracranial, neck, and other anatomies, avoiding repeat imaging examinations and delayed care.

Wounds requiring treatment within a few hours, such as contaminated wounds. These injuries are addressed once the patient has been stabilized.

Injuries that can wait 24 hours or more, if necessary, in the judgment of the clinician.

The third category includes definitive reduction and fixation of complex facial fractures, but the timing of these interventions is not widely agreed upon. No optimal time to repair has been identified, in part because no simple rule applies to complex patterns of facial trauma. Traditionally, such interventions were postponed until acute brain injuries and swelling had subsided, but in recent years, many hospitals have begun “early and total repair of facial injuries” within days of, or even on the day of, a patient’s admission to the emergency department.

To minimize surgical scarring, internal reduction and fixation of mandibular and midface trauma involves small skin incisions or surgical access through the mouth. Transoral miniplates and screws can be placed through the mouth or a very small transbuccal cheek incision. Orbital fixation often can be achieved transcutaneously through the lower eyelid or transconjunctivally.

Endoscopy commonly is used for TMJ arthroscopy and treatment of condylar fractures as well as some isolated frontal sinus, orbital floor, and zygomatic arch fractures.

With more extensive or complex patterns of facial fractures, a coronal scalp flap allows complete surgical access to and visualization of the upper face but carries a risk of nerve injury, diplopia, telecanthus, and scalp necrosis. Midface fractures might be accessed through a midfacial “degloving” procedure, an intraoral surgical exposure of the anterior mandible. Traditionally, load-bearing plates have been used for fracture fixation, when buttresses such as mandibles allow implantation with screws. Miniplates can replace the temporary larger plates, and unlike large traditional plates, miniplates do not require removal later. Even smaller microplates and tiny screws have been developed for use with the orbital rim, nasal bones, and frontal sinus.

Fixation with titanium pins and plates can restrict bone growth in pediatric patients, complicate imaging, and present long-term local biological hazards, such as possible carcinogenicity. Alternative biological absorbable fixation device materials are in use, but questions have been raised about their safety. Absorbable material devices appear overall to involve a 20% higher complication rate than titanium among patients treated for maxillofacial fractures, according to one recent study.

Conclusion

Facial fractures are a common form of trauma and frequently occur in complex patterns predictably associated with some types of soft-tissue damage and clinical complications. Accurate classification of facial fractures is key to successful medical management.

MDCT has revolutionized the diagnostic assessment of facial trauma and associated head and neck injuries, allowing rapid acquisition of precise diagnostic images in a single examination that spares traumatized patients repeated imaging examinations and allows more rapid and better informed treatment planning. MDCT provides clinicians the accurate spatial information they need for successful surgical intervention, as well as information to help avoid unjustifiable interventions.

As always, however, the benefits of imaging must be balanced against the inherent risks of ionizing radiation, particularly for children. The ALARA principle must be observed for all patients. Simple, minimally displaced nasal fractures without other facial trauma, for example, are rarely an indication for MDCT examinations.

New Mexico–based medical writer and health care journalist Bryant Furlow, BA, is a regular contributor to Radiologic Technology, The Lancet Oncology, and other medical journals and medical news outlets. In addition to medical research and diagnostic imaging, he covers health care in rural and tribal communities.
Computed Tomography of Facial Fractures

References


1. The average patient with a facial fracture is a(n):
   a. preschooler injured on the playground.
   b. high school athlete who plays a contact sport.
   c. elderly woman with impaired balance.
   d. man in his late 30s.

2. In patients with facial fractures, intracranial hemorrhage can be ruled out based solely on normal neurological findings.
   a. true
   b. false

3. Which of the following are possible complications in patients with facial fractures?
   1. significant blood loss
   2. displacement of the eyes
   3. compromised airway
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

4. According to a 2008 analysis of the National Trauma Data Bank, which of the following is the leading cause of facial fractures among children in the United States?
   a. automobile accidents
   b. child abuse
   c. falls from heights
   d. animal attacks

5. Among children who receive a diagnosis of facial fracture, one-third simultaneously receive a _______ diagnosis.
   a. collarbone fracture
   b. cranial fracture
   c. concussion
   d. hearing loss

6. The midface skeleton extends downward from the:
   a. frontal bone and frontal sinuses.
   b. mandible and nasal cavity.
   c. superior orbital rims and orbits and includes the nasal cavity and associated sinuses.
   d. frontal and nasal sinuses.

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Read the preceding Directed Reading and choose the answer that is **most correct** based on the article.
7. What is the term for the cagelike array of thickened facial bones that supports muscles, eyes, teeth, and the uppermost airways?
   a. facial skeletal buttresses
   b. zygomatic processes
   c. orbital cavities
   d. viscerocranium

8. Which of the following represents a much larger proportion of the facial skeleton in children than in adults?
   a. maxilla
   b. mandible
   c. bony orbits
   d. sinuses

9. In younger children, _______ facial fractures are more common, whereas among older children _______ fractures are more common.
   a. orbital floor; blow-in superior orbital
   b. blow-in superior orbital; orbital floor
   c. frontal sinus; blow-in superior orbital
   d. orbital floor; frontal sinus

10. Frontal sinus fractures are an indication for diagnostic imaging for which of the following conditions?
    a. enophthalmos
    b. diplopia
    c. ophthalmoplegia
    d. pneumocephalus

11. Among patients with frontal sinus fractures, up to 91% present with which of the following criteria for computed tomography (CT)–based diagnosis of nasofrontal outflow injuries?
    a. sinus floor fractures
    b. pneumocephalus
    c. anterior or posterior table fractures
    d. obstruction

12. Diagnostic imaging is indicated to evaluate suspected type _______ nasal fractures.
    a. 1
    b. 2
    c. 3
    d. 4

13. Blowout fractures affecting more than 50% of the orbital floor are a risk factor for which of the following conditions?
    a. enophthalmos
    b. diplopia
    c. ophthalmoplegia
    d. pneumocephalus

14. Simple (isolated) fractures of the _______ are more frequent among children than adults.
    a. maxilla
    b. mandible
    c. orbits
    d. sinuses

15. Jaw injuries are a common type of facial fracture in _______ accidents.
    a. workplace
    b. automobile
    c. home-based
    d. horseback riding

16. Presentation with reduced nose projection from the face and abnormal protrusion of one or both eyes is typical of _______ fractures.
    a. Le Fort
    b. nasoorbitoethmoid
    c. zygomaticomaxillary complex
    d. “trap-door”

17. Which of the following is a sign of Jacod syndrome?
    a. enophthalmos
    b. diplopia
    c. ophthalmoplegia
    d. pneumocephalus

continued on next page
18. When ______ persists beyond a few days after an injury, soft-tissue herniation is a more likely culprit than edema or hemorrhage.
   a. enophthalmos
   b. diplopia
   c. ophthalmoplegia
   d. pneumocephalus

19. A deformity of the globe’s overall shape, visible on CT scans, is called the ______ sign.
   a. “deflated balloon”
   b. “donut”
   c. “flat tire”
   d. “figure 8”

20. Which 16- or 64-channel multidetector CT scanning parameters are used for imaging the face, orbits, and brain?
   1. 120 kV
   2. 115 mA
   3. 1-second gantry rotation time
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

21. CT is sensitive for detecting:
   1. bone.
   2. metal.
   3. glass.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

22. Which of the following type of fracture is frequently an indication for immediate surgical intervention?
   a. orbital apex
   b. orbital ceiling
   c. lateral orbital wall
   d. inferior orbital wall

23. Which of the following facial trauma severity models successfully discriminated between various levels of trauma, according to a recent study of multiplanar 2-D reformations and 3-D CT images?
   a. Facial Injury Severity Score
   b. Facial Fracture Severity Score
   c. Cooter and David Score
   d. ZS Scoring System

24. What is the optimal timing for reduction and fixation of complex facial fractures?
   a. 24 to 48 hours after the injury
   b. 72 hours after swelling has subsided
   c. as soon as possible after the patient is stabilized
   d. no optimal time has been identified

25. Which of the following problems has been associated with titanium pins and plates used for facial fracture fixation?
   1. restricted bone growth in pediatric patients
   2. possible carcinogenicity
   3. imaging complications
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3