Orbital and Facial Fractures

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KEYWORDS

• Facial buttresses • Nasofrontal outflow tract • Orbital blow-out • Orbital blow-in
• Naso-orbito-ethmoid fracture • Zygomaticomaxillary complex fracture
• Intermaxillary (maxillomandibular) fixation

KEY POINTS

- Knowledge of typical patterns of facial fractures is important because each pattern may be associated with its respective functional complications.
- Three-dimensional images are commonly used by surgeons for operative planning in restoration of alignment and correction of cosmetic deformities, but can be occasionally useful to the radiologist as a summary view of complex midface fractures.

INTRODUCTION

Traumatic facial fractures are caused most often by motor vehicle accidents, falls, and assaults.[1] At our level I trauma center, the interpretation of facial fractures is routine in daily imaging. By far the most common injuries are the fractures of the midface, followed by fractures of the lower face (mandible) and the upper face (frontal bone and superior orbital rim).[1] The partition of the face into thirds (upper, middle, and lower) has particular relevance for surgical intervention. This article reviews, from cranial to caudal, the most common fracture patterns and the clinical relevance of the imaging findings as they impact patient management.

Multidetector computerized tomography (CT) is the imaging study of choice currently used to evaluate acute and nonacute facial trauma. Axial submillimeter bone algorithm images with sagittal, coronal, and three-dimensional reformations are routinely obtained. Occasionally, such as in the detailed evaluation of the orbit, oblique reformations are useful. The three-dimensional images are particularly helpful for the assessment of complex facial deformities, preoperative planning, and patient consultation.

It is well known that traumatic collapse of the face has a "cushion" or "bumper" effect that helps dissipate the impact force and thereby protect the neurocranium and cervical spine. However, the distribution of forces via the areas of thicker bone (facial buttresses) may still be transmitted to the cranial vault and cervical spine. Awareness of the facial buttresses (**Figs. 1** and **2**) helps with the understanding of the fracture patterns and the identification of osseous segments that require surgical reconstruction for restoration of the normal facial skeleton.

FRONTAL SINUS

Fractures of the fronto-orbital bar (frontal boss, tuber frontalis) usually involve the outer table of the frontal bone and sinus (**Fig. 3**), but they may also involve both tables (**Fig. 4**). Extension of a frontal sinus fracture into the posterior sinus wall

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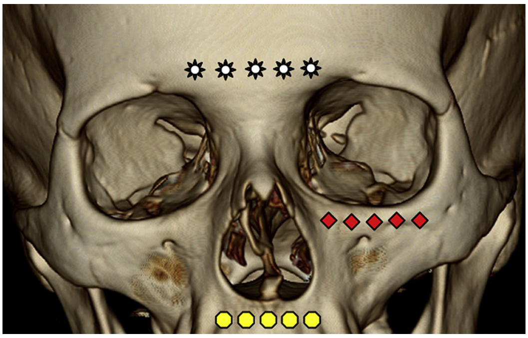

Fig. 1. Transverse midface buttresses: three-dimensional coronal reformatted CT demonstrates the three transverse buttresses of the midface: frontal (*white stars*), upper (*red diamonds*), and lower maxillary (*yellow circles*).

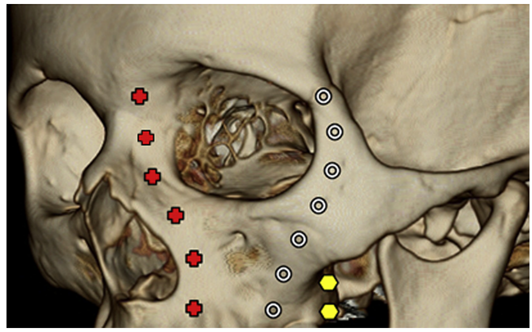

Fig. 2. Vertical midface buttresses: three-dimensional oblique reformatted CT demonstrates the three vertical buttresses of the midface: medial (*red crosses*), lateral (*white circles*), and posterior (pterygomaxillary, *yellow circles*).

results in communication with the anterior cranial fossa and may be associated with a dural tear and cerebrospinal fluid (CSF) leak. Potential intracranial spread of a pre-existing sinus infection may occur. In addition, these fractures are frequently associated with intracranial hemorrhage.

Isolated fractures of the inner table are uncommon and usually result from an occipital impact. Fractures through the medial aspect of the floor of frontal sinus typically involve the cribriform plate and fovea (roof) ethmoidalis and may result in a dural tear and/or chronic sinusitis. Fractures through the lateral aspect of the frontal sinus floor often involve the orbital roof (see Fig. 4A), depending on the lateral extent of frontal sinus pneumatization.

Frontal Sinus (Nasofrontal) Outflow Tract

Nasofrontal outflow tract injury is strongly suspected when the CT examination demonstrates involvement of the base of the frontal sinus, the anterior ethmoids, or both (Fig. 5). The posteromedial position of the nasofrontal outflow tract within the sinus makes it particularly susceptible to injury.[2]

Injury to the outflow tract can result in a frontal sinus mucocele and creation of an anaerobic environment with subsequent osteomyelitis and possible intracranial extension leading to a brain abscess. These complications may develop in delayed fashion, years after the inciting trauma.

Management of Frontal Sinus Fractures

A patent frontal sinus outflow tract deems the frontal sinus salvageable and the comminuted outer table is then repaired with plates and screws. If normal frontal sinus drainage pathway cannot be restored, the frontal sinus is surgically eradicated[3] by obliteration or cranialization (ie, the cranial cavity is expanded into the former sinus space). The nasofrontal outflow tract is eliminated with a graft. These procedures are best performed within 2 weeks posttrauma.

Frontal sinus obliteration is best achieved if, after the sinus mucosa is exenterated, the cavity is filled with vascularized pericranial flap (rather than devascularized abdominal fat, muscle, or bone graft).[4] The sinus mucosa is removed to

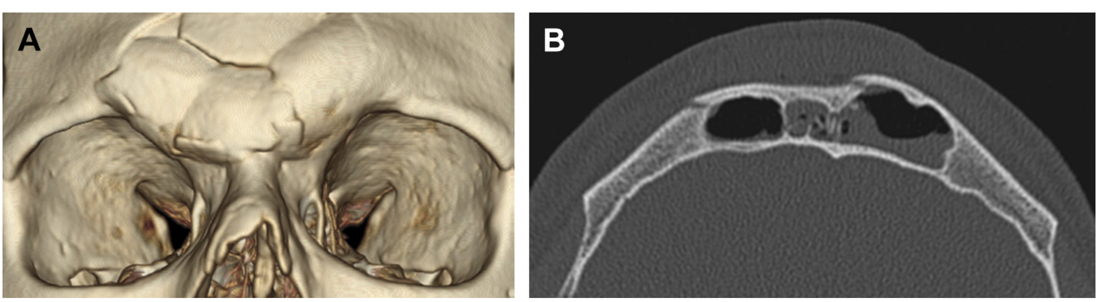

Fig. 3. Frontal orbital bar fracture with isolated involvement of the outer table of the frontal sinus. This 54-year-old male bicyclist went over the handle bars and landed on his forehead. (*A*) Coronal reformatted three-dimensional CT through the orbits demonstrates a comminuted, depressed fracture of the frontal bar. (*B*) Axial CT shows relative sparing of the inner table.

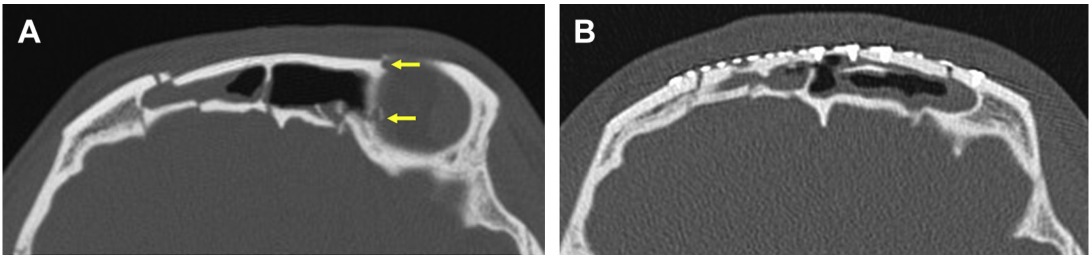

Fig. 4. Preoperative and postoperative views of a comminuted fracture involving both tables of the frontal sinus and orbital roof. (*A*) Preoperative axial CT shows the fracture extending into medial left orbital roof (*arrows*). (*B*) Postoperative CT demonstrates good cosmetic alignment following fixation of the outer table with mini-plates and screws.

prevent mucocele and subsequent mucopyocele formation.

Fractures that cause significant displacement of the posterior table and/or compromise of the dura are cranialized.[5] The posterior wall of the sinus is removed, the mucosa is meticulously stripped, and the dura and brain are brought to rest against the surgically repaired outer table of calvarium.

The management of frontal sinus fractures has become increasingly conservative because of the accumulated experience and the advent of endoscopic sinus surgery.[6] In the future, follow-up CT to ensure the absence of complications of conservatively managed fractures may likely be more frequently used.

Key points: frontal sinus fractures

1. Fracture through the frontal sinus base and/or anterior ethmoid implies possible involvement of nasofrontal outflow tract. If sinus patency cannot be restored, the sinus is sacrificed.
2. Involvement of frontal sinus posterior table increases the risk of CSF leak and intracranial infection.

ORBITAL TRAUMA

Blow-Out Orbital Fractures

An injury involving mainly the orbit is considered at higher risk of ocular trauma and optic nerve injury than orbital involvement by adjacent facial trauma. Isolated orbital fractures most commonly involve the weak medial orbital wall or floor, sparing the orbital rim, lead to enlargement of the orbit, and are known as blow-out fractures (**Fig. 6**). Enophthalmos can occur with large fragment blow-out fractures and its extent is best appreciated and repaired in delayed fashion, after the edema has resolved.

On CT evaluation, the presence of soft tissue herniation through the defect and the fracture size are important predictors of persistent diplopia. Somewhat surprisingly, small and medium size floor fractures with soft tissue herniation are more likely to cause entrapment than large floor fractures.[7] Any soft tissue incarceration at the fracture site may cause restriction as fibrous septa unite orbital tissue to the sheaths of the inferior rectus and oblique muscles making the diagnosis of entrapment a clinical one. Relatively large orbital floor fractures (**Fig. 7**) are at less risk for entrapment and, again, operative repair may be delayed.

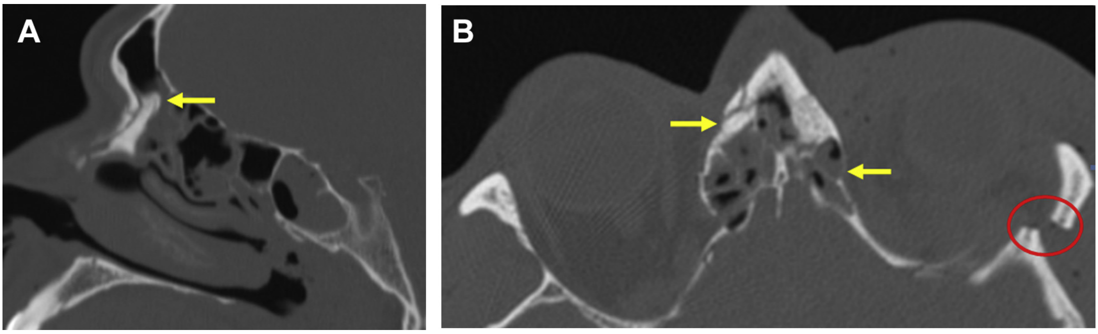

Fig. 5. Traumatic obstruction of the nasofrontal outflow tract. This 30-year-old man fell from a ladder onto his face. (*A*) Sagittal CT reformation shows a large nasoethmoidal fragment extending into the inferior frontal sinus (*arrow*) and obstructing the outflow tract. (*B*) Axial CT demonstrates bilateral comminution of the anterior ethmoids (*arrows*). A distracted fracture of the left superolateral orbital wall is also noted (*circle*).

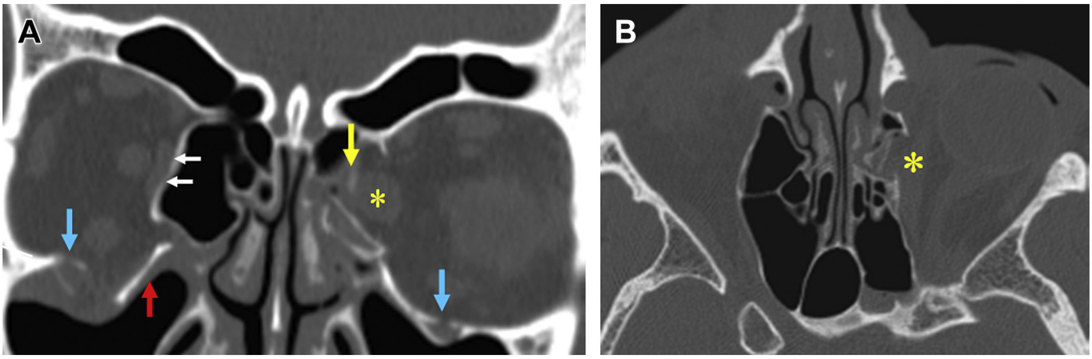

Fig. 6. Orbital blow-out fractures (inferior and medial). This 35-year-old man fell through a manhole. (*A*) Coronal and (*B*) axial CT images show bilateral orbital blow-out fractures: right orbital floor (*red arrow*) and left medial orbital wall (*yellow arrow*). The left medial rectus muscle (*yellow asterisk*) is enlarged, deformed, and medially displaced (*asterisk*). Compare with the normal right medial rectus extraocular muscle (*white arrows*). Note how the inferior blow-out fracture interrupts the inferior orbital foramen (*right blue arrow*), because all foramina are a point of weakness within the facial skeleton. Compare with the normal left inferior orbital foramen (*left blue arrow*).

Blow-In Orbital Fractures

The far less common blow-in fractures occur when the fractures fragments buckle within the orbit leading to a decrease in the orbital volume (**Fig. 8**). The decreased orbital volume, commonly aggravated by an intraorbital hematoma, leads to proptosis and poses risk of damage to the optic nerve.

Proptosis and Optic Nerve Injury

Orbital fractures are commonly accompanied by a subperiosteal intraorbital hematoma (**Fig. 9**) and less commonly associated with extensive orbital emphysema (**Fig. 10**), but both complications can result in proptosis. A large blow-out fracture results in actual decompression of the orbit and obviates the need for surgical hematoma evacuation. Severe proptosis with posterior globe tenting is an ophthalmologic emergency (**Fig. 11**).

Patients with fractures involving the optic canal (**Fig. 12**) require vigilant evaluation of the optic nerve because the edema and hematoma can rapidly result in vision loss. In most cases, traumatic optic neuropathy represents a nerve contusion caused by a blow to the superior orbital rim with the force transmitted to the optic canal.

The clinical challenge lies in the timely diagnosis of optic nerve injury to ensure rapid intervention. An afferent pupillary defect may be the only clinically reliable sign of traumatic optic neuropathy because many of these patients have suffered concomitant traumatic brain injury and routine ophthalmologic testing (ie, visual acuity, color vision, and visual field) cannot be easily performed.

Endoscopic surgical decompression is usually reserved for an obvious optic canal hematoma or bone fragment impinging on the nerve.[8] The International Optic Nerve Trauma Study concluded that

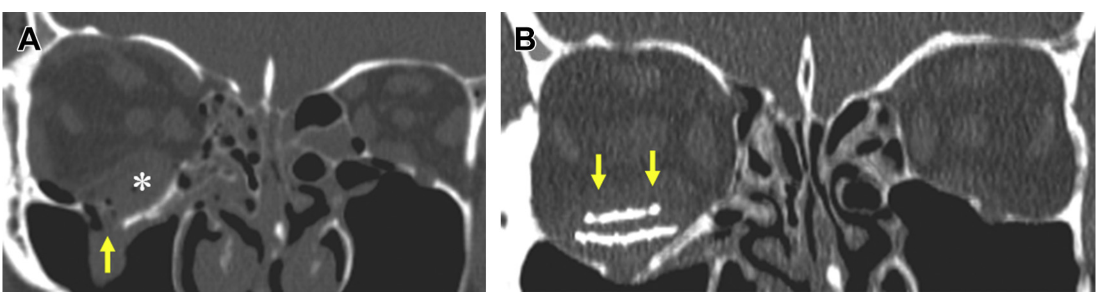

Fig. 7. Inferior orbital blow-out fracture. (*A*) Coronal reformation obtained immediately after the patient's fall from a ladder shows an inferior orbital extraconal hematoma (*asterisk*) inseparable from inferior rectus muscle. Note the subjacent depressed orbital floor fracture (*arrow*). (*B*) Coronal CT demonstrating reconstruction of the orbital floor that was performed 16 months postinjury because the patient developed enophthalmos and diplopia in all fields of gaze. An expected small postoperative hematoma (*arrows*) is seen surrounding the Medpor implant at 2 weeks.

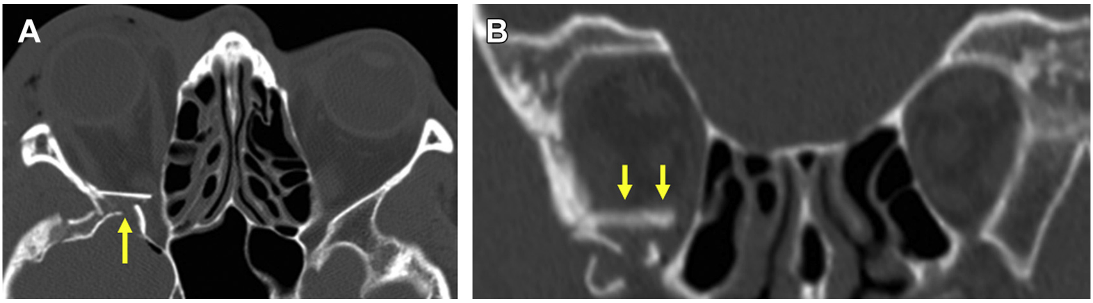

Fig. 8. Orbital blow-in fracture. (*A*) Axial CT image demonstrates a comminuted fracture of the right sphenotemporal buttress with a fracture fragment extending into the right orbital apex (*arrow*). (*B*) The coronal reformation shows the volume of the right orbit reduced by the fracture fragments that are protruding from below (*arrows*). Impingement of the inferior rectus muscle is also suspected.

decompression should be reserved for worsened or not improving visual acuity.[9] In addition, at our institution, the use of steroids for treatment of optic nerve trauma has been abandoned given the questionable benefit and the known morbidity associated with steroid administration.

Complications of Orbital Roof Fractures

Immediately posttrauma, intraorbital herniation of contused brain parenchyma may mimic a subperiosteal hematoma (Fig. 13). Follow-up imaging may reveal a traumatic meningoencephalocele that can be misinterpreted as an orbital neoplasm (Fig. 14).

Key points: orbital fractures

1. Proptosis resulting in posterior globe tenting is an ophthalmologic emergency.
2. Large fragment blow-out fractures can lead to enophthalmos after the edema subsides.
3. Smaller fragment orbital blow-out fractures are more likely to cause entrapment.
4. Clinical entrapment may occur even in the setting of normal extraocular muscle position and morphology on CT.
5. Fractures involving the optic canal imply a high risk for optic nerve injury. Fragments into the optic canal need to be emergently removed to salvage vision.

CEREBROSPINAL FLUID LEAK

CSF rhinorrhea or orbitorrhea occurs in a small percentage of facial fractures and is most commonly encountered with nasoethmoid complex fractures. CSF is confirmed by detection of β2 transferrin in the fluid collected. Fortunately, most CSF leak cases spontaneously resolve within the first week posttrauma. The remainder of patients usually responds to decrease of intracranial pressure by temporary use of a lumbar subarachnoid drain and only a small number require endoscopic placement of a graft at the site of CSF leak.[10]

If precise localization of a persistent CSF leak is desired, a CT cisternogram is performed. A baseline noncontrast sinus CT is obtained for purposes of comparison with images obtained following intrathecal contrast administration. Under intermittent lumbar imaging guidance, never more than 10 mL (given the risk of provoking a seizure) of Omnipaque-300 nonionic iodinated contrast is introduced into the thecal sac by lumbar puncture. The patient is then placed in a prone Trendelenburg position to facilitate intracranial flow of contrast. Even though a 25-minute wait is recommended, some patients may be scanned earlier, because arrival of the contrast within the intracranial subarachnoid space may be signaled by the development of a headache. Obtaining a delayed single image through the brain at the level of the sinuses objectively confirms the contrast opacification of subarachnoid space and a repeat CT of the sinuses in prone position is then performed.

Identification of the exact location of CSF leakage is important (Fig. 15). However, either an intermittent leak or rapid filling of nasal cavity or sinuses because of a large CSF fistula may hinder the diagnosis. In addition, blood products also have high density and their presence may obscure contrast extravasation.

Cisternogram pitfalls

1. Intermittent CSF leakage.
2. Rapid leakage of contrast into nasal cavity or paranasal sinus.
3. Residual traumatic blood products in the sinuses or nasal cavity.

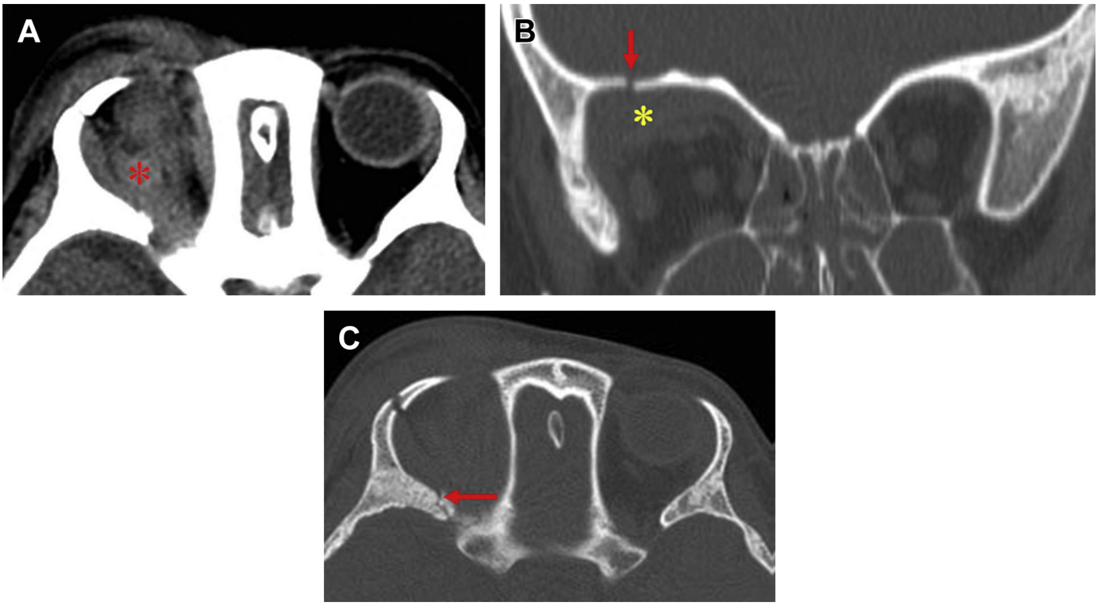

Fig. 9. Orbital hematocyst. Child status post fall. (*A*) Axial CT soft tissue window image and (*B*) coronal bone window CT image show an extraconal hematoma (*asterisk*) underlying an orbital roof fracture (*arrow*). (*C*) Note how the fracture line extends into the right lesser wing of the sphenoid (*arrow*). Because the lateral orbital roof is relatively rigid, fractures tend to propagate into the neurocranium.

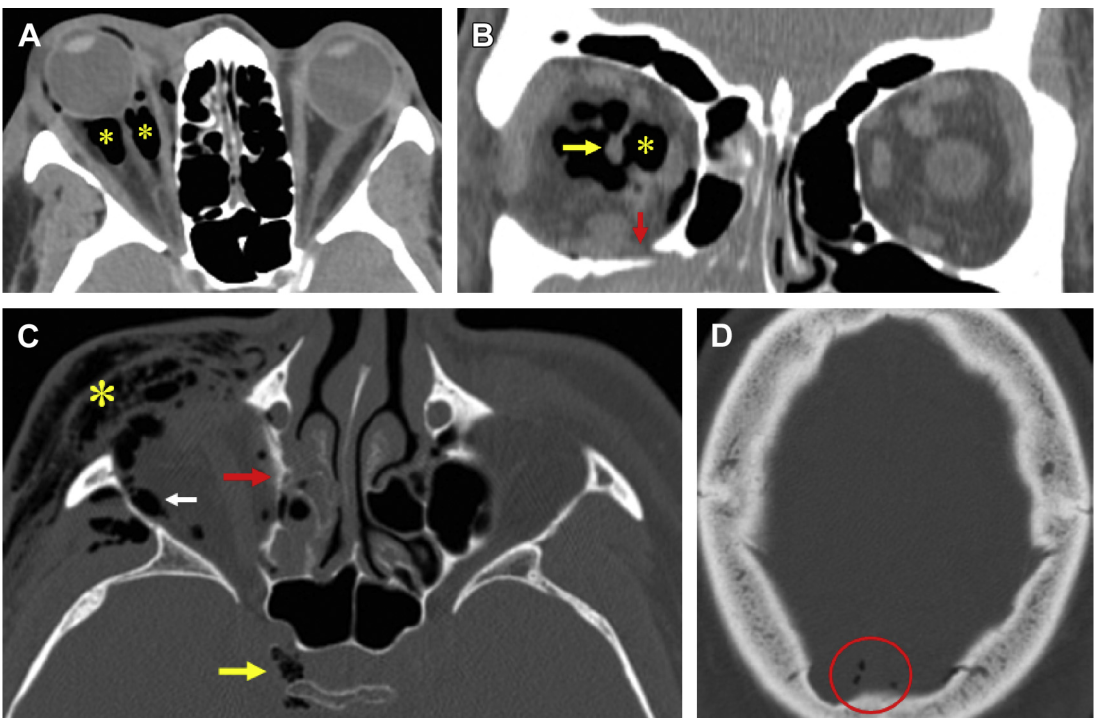

Fig. 10. Orbital emphysema with intracranial extension. (*A*) Axial and (*B*) coronal CT images viewed at soft tissue window demonstrate extensive orbital emphysema (*asterisks*) outlining the optic nerve (*yellow arrow*). Note that this is caused by a small orbital floor fracture (*red arrow*). There is proptosis and abnormal straightening of the optic nerve. The patient underwent a decompression/canthotomy in the emergency room with rapid restoration of vision. (*C*, *D*) Axial CT images in a different patient demonstrate a medial orbital wall fracture (*red arrow*) and both preseptal (*asterisk*) and postseptal orbital emphysema (*white arrow*). The air extends intravenously into the right cavernous sinus (*yellow arrow*) and into the superficial cortical veins draining to sagittal sinus (*circle*).

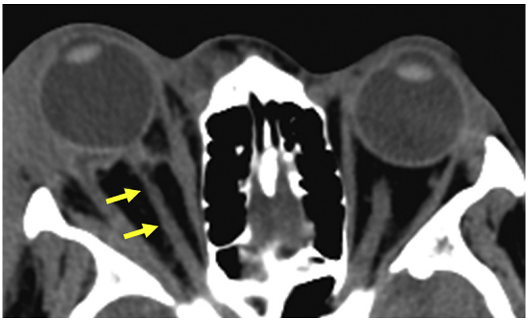

Fig. 11. Globe tethering and increased intraorbital pressure. Axial CT image shows that the posterior aspect of the right globe has lost its normal spherical shape because of proptosis with nerve tethering (*arrows*). In rare cases, the tethering can actually result in separation of the optic nerve from the globe. This elderly female underwent emergent orbital decompression/canthotomy in the emergency room for vision preservation.

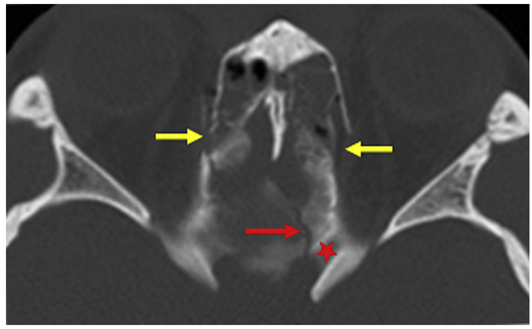

Fig. 12. Comminuted fracture of ethmoids and floor of anterior cranial fossa. Axial CT image shows multiple medial orbital wall fractures (*yellow arrows*). The fracture line (*red arrow*) extends to the left optic canal (*asterisk*) raising concern for optic nerve injury.

MIDFACE FRACTURES

The face is supported by stronger/thickened areas of the facial skeleton termed buttresses. These buttresses confer the facial structures a rigid protective frame. The vertically oriented buttresses are considered stronger than the buttresses oriented horizontally (see **Figs. 1** and **2**).

Zygomaticomaxillary Complex Fractures

Zygomaticomaxillary complex fractures (ZMC) are second only to fractures of the nasal bone in overall frequency.[1] Previously misnamed the "tripod" fracture, the ZMC fracture is the result of a direct blow to the malar eminence and involves disruption at four sites: (1) the lateral orbital rim, (2) the inferior orbital rim, (3) the zygomaticomaxillary buttress, and (4) the zygomatic arch. The ZMC fracture disrupts all four zygomatic sutures (**Fig. 16**). Fixation plates may be placed across the orbital rim, the sutures, and buttresses (**Fig. 17**). The ZMC fracture may be associated

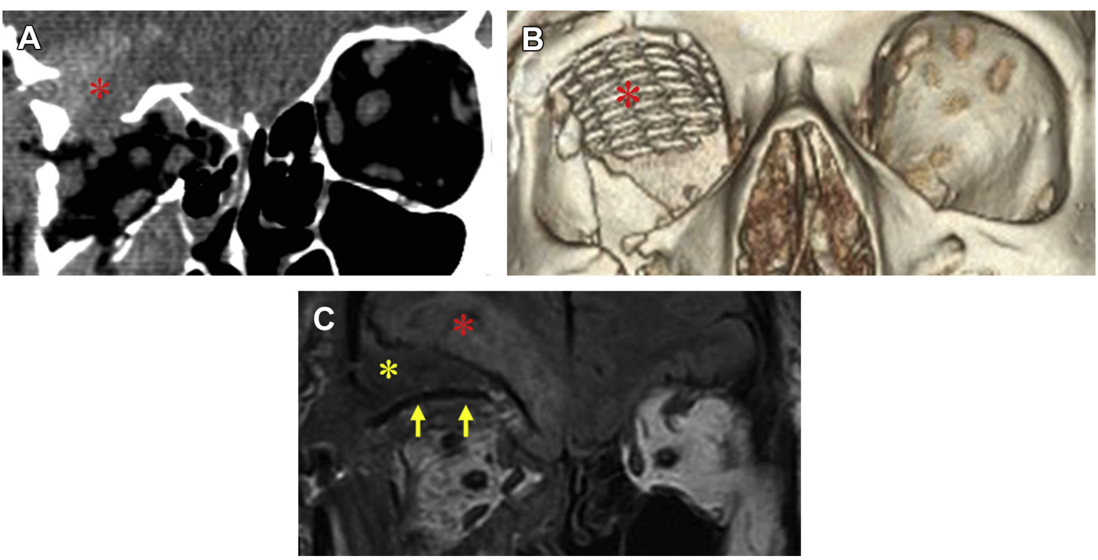

Fig. 13. Orbital roof fracture. This 49-year-old man had a motorcycle accident. He developed CSF orbitorrhea 1 week later. (*A*) Coronal reformation CT viewed at soft tissue window shows intraorbital herniation of a hemorrhagic contusion of right frontal lobe (*asterisk*). (*B*) Three-dimensional reformation illustrates orbital roof reconstruction with a Medpor plate (*asterisk*). (*C*) Coronal magnetic resonance imaging FLAIR sequence demonstrates the vascularized pericranial flap (*yellow asterisk*) placed cephalad to the Medpor plate (*arrows*) to prevent recurrence of CSF leak. The right inferior frontal lobe contusion is identified (*red asterisk*).

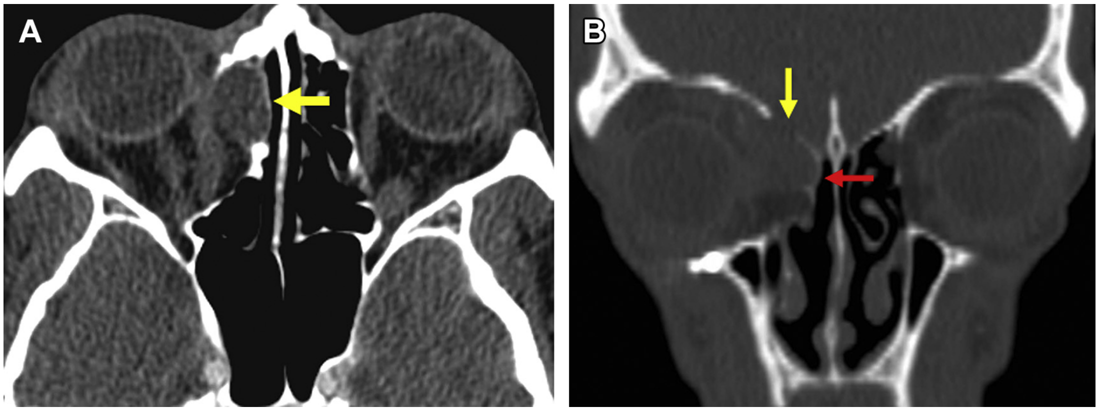

Fig. 14. Posttraumatic meningocele. This 58-year-old man has a history of sinonasal polyposis and a clinical concern for an inverted papilloma. (*A*) Axial CT image viewed at soft tissue window demonstrates an extraconal water attenuation lesion (*arrow*). (*B*) Coronal reformation bone window CT image shows right orbital roof dehiscence (*yellow arrow*) and a remote medial orbital blow-out fracture (*red arrow*). The orbital lesion is consistent with posttraumatic meningocele.

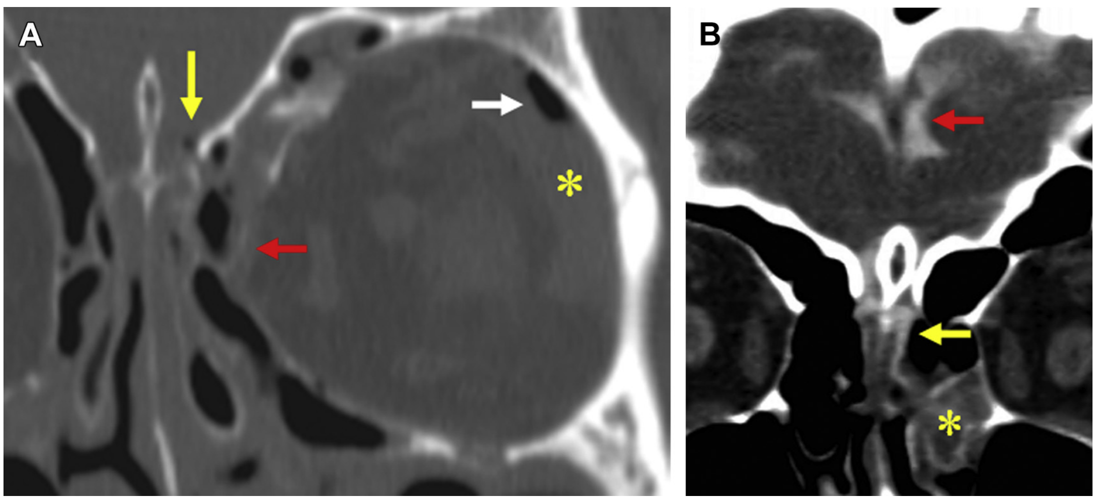

Fig. 15. Pneumocephalus and CSF leak secondary to a fracture through the lateral lamella of the cribriform plate. (*A*) Coned-down coronal nonenhanced view of the left orbit demonstrates a tiny focus of air within the anterior cranial fossa (*yellow arrow*). Also evident is an extraconal hematoma (*asterisk*) and emphysema (*white arrow*) within the lateral left orbit and a medial wall blow-out fracture (*red arrow*). (*B*) Coronal CT cisternogram shows contrast extravasation into the left nasal olfactory recess (*yellow arrow*) and pooling into the left anterior ethmoid air cells (*asterisk*). Intracranial subarachnoid contrast accumulation is also noted (*red arrow*).

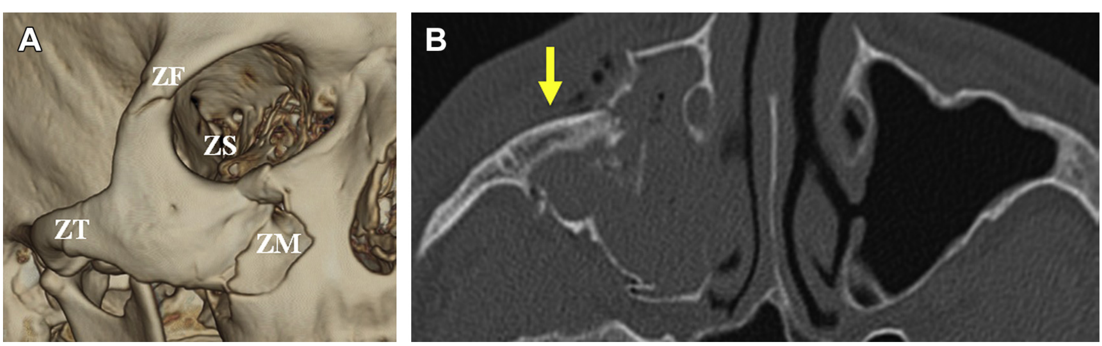

Fig. 16. ZMC fracture. (*A*) Three-dimensional oblique CT reformation of the malar eminence reveals the four zygomatic sutures: zygomaticofrontal (ZF), zygomaticomaxillary (ZM), zygomaticotemporal (ZT), and zygomaticosphenoid (ZS). (*B*) Axial CT image demonstrates the markedly flattened right malar eminence (*arrow*). Acutely, the cosmetic deformity is often clinically unappreciated because of the overlying soft tissue swelling.

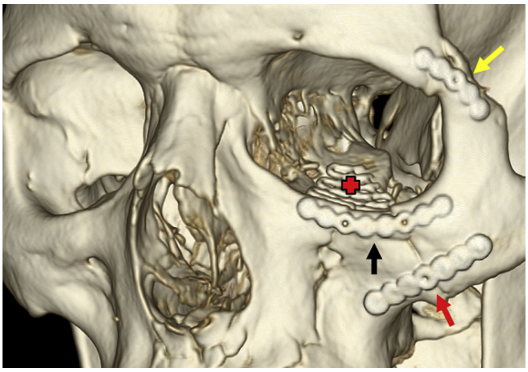

Fig. 17. Postoperative CT in a complex ZMC fracture. Three-dimensional oblique reformatted CT in a patient who underwent open reduction internal fixation (ORIF) for a left ZMC fracture. Note the zygomaticomaxillary (*red arrow*), zygomaticofrontal (*yellow arrow*), and inferior orbital rim (*black arrow*) fractures that have been surgically repaired with monocortical plates and nonlocking screws. The orbital floor fracture was repaired with a reconstruction plate (*red cross*) by a vestibular and transconjunctival approach.

with either increased or decreased volume of the orbit, depending on the direction and rotation of fracture fragments.

Although mildly displaced ZMC fractures can be managed conservatively (if the patient is asymptomatic), displaced fractures should be corrected surgically[11] for prevention of visual impairment and trismus. Trismus typically occurs when a depressed zygomatic arch (Fig. 18) compresses the masticator muscles.

Midface fractures often involve the nasolacrimal duct and may result in epiphora. Most commonly, a bypass tube is placed within the native nasolacrimal duct to restore patency.[12] Occasionally, the nasolacrimal duct cannot be salvaged (Fig. 19).

Le Fort Fractures

Le Fort fractures are defined by craniofacial dissociation (disjunction), because all Le Fort fractures (I–III) involve the posterior maxillary buttress (see Fig. 2) formed by the pterygoid plates, which connect the sphenoid bone (skull base) to the midface.

Many midface fractures do not follow the true Le Fort pattern and are more complex with coexistence of different additional fractures superimposed on Le Fort fractures. However, describing a midface fracture using the Le Fort classification helps summarize and succinctly communicate the midface injury.

Le Fort Fracture Classification	Imaging Clue
Le Fort I: "The floating palate" (Fig. 20)	Involvement of nasal aperture
Le Fort II: "The floating maxilla" (Fig. 21)	Fracture through inferior orbital rim
Le Fort III: "The floating face" (Fig. 22)	Involvement of zygomatic arch

Recognition of the Le Fort pattern by a single specific area involved can be helpful: Le Fort I, the anterolateral margin of the nasal fossa; Le Fort II, the inferior orbital rim; and Le Fort III, the zygomatic arch.[13] However, more complex fractures may occur and Le Fort II and III can coexist on the same side of the face.

Given the severity of injury, a screening CT angiogram of the neck is recommended and should be performed in Le Fort II and III fractures to exclude blunt traumatic neck arterial dissections.[14]

Nasal Bones and Septum

Nasal bone fractures are the most common facial fractures encountered in the daily emergency room imaging for trauma[1] because of the protrusion of this relatively thin bone (Fig. 23).

Immediately after trauma, before edema ensues, a closed reduction of nasal fractures may be performed. Open reduction is reserved for comminuted fractures with loss of nasal support, severe septal injuries, and marked soft tissue

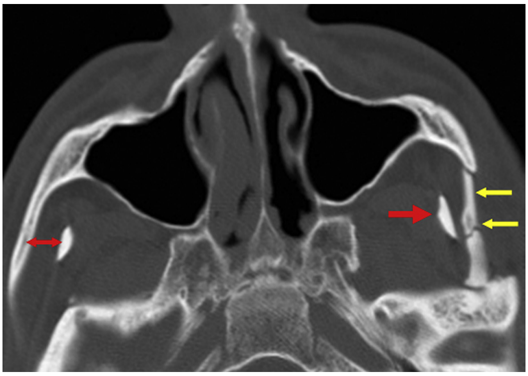

Fig. 18. Comminuted and depressed fracture of left zygomatic arch. Axial CT demonstrates flattening of the left zygomatic arch (*yellow arrows*). The fragments are displaced against the coronoid process (*red arrow*) of the mandible. Compare with the distance between the normal right coronoid process and the zygomatic arch (*double-headed arrow*). Compression of masticator muscles by the zygomatic arch fracture fragments results in trismus.

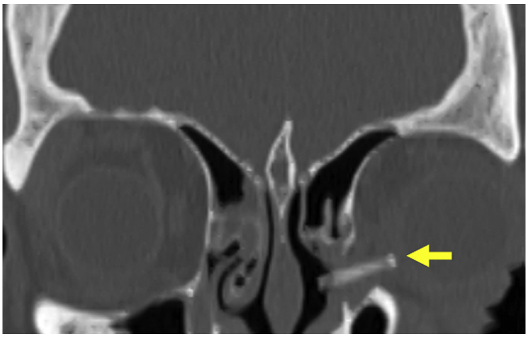

Fig. 19. Dacryocystorhinostomy. Coronal CT examination demonstrates bypass of the normal lacrimal drainage pathway by a Jones tube (*arrow*) surgically placed to drain into the middle nasal meatus in a case of traumatic nasolacrimal duct injury.

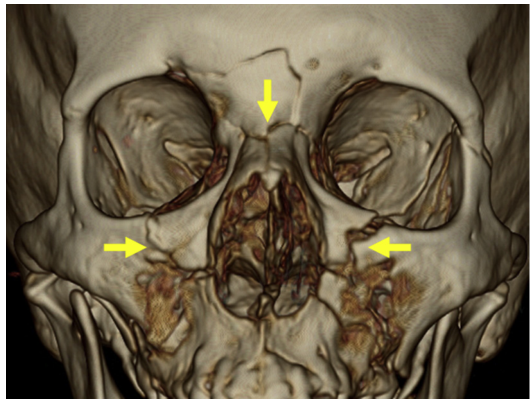

Fig. 21. The Le Fort II fracture. Coronal three-dimensional reformatted CT image demonstrates a triangular-shaped fracture (*arrows*) traversing across the maxilla leaving a larger portion of the maxilla and nasal aperture in the inferior fragment. The fracture characteristically involves the inferior orbital rims, separates the nose and inferior maxilla from the lateral midface, and involves the nasofrontal suture. Note that the medial maxillary sinus wall is spared in the Le Fort II fracture.

damage. Delayed surgical intervention after the initial swelling subsides is considered adequate if circumstances prevent acute correction. The deformity correction is necessary for restoration of function of the nasal passages,[15] because a turbulent nasal cavity air flow may lead to sinusitis. Sinusitis may also occur if a bone fragment is displaced into the maxillary sinus.

Nasal septal hematomas must be addressed acutely to prevent cartilaginous pressure necrosis and a subsequent "saddle-nose" deformity. In addition, untreated hematomas can result in abscess formation. A large nasal septal hematoma may be evident on CT (Fig. 24), but the diagnosis is usually made clinically.

Naso-Orbito-Ethmoid Fractures

Imaging of nasal bone fractures is considered optional, unless significant trauma has occurred with involvement of the proximal nasal bones. These fractures can extend to the frontal bone and the cribriform plate, involve the midface and orbit, and are named naso-orbito-ethmoid (NOE) fractures. The NOE fractures are complex because they can be associated with intracranial and orbital injuries and a head and face CT scan is warranted. NOE fracture frequency has markedly decreased since the universal use of airbags, and reportedly currently account for approximately 5% of adult and 15% of pediatric facial fractures.[16]

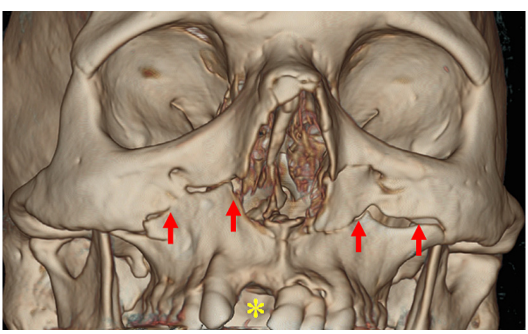

Fig. 20. The Le Fort I fracture. Coronal three-dimensional reformatted CT image demonstrates a transverse maxillary fracture traversing through the maxillary antrum and the nasal cavity above the nasal floor (*arrows*). This horizontal fracture characteristically extends into the lateral wall of the nasal aperture. Avulsion of the right incisors is also noted (*asterisk*).

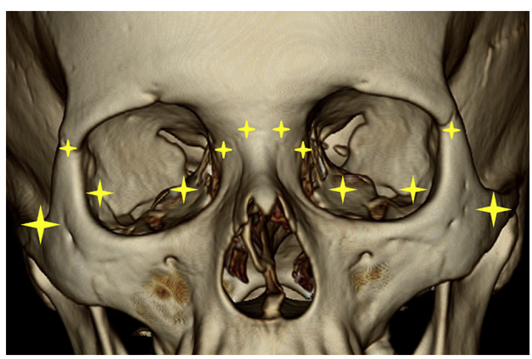

Fig. 22. The Le Fort III fracture. Coronal three-dimensional CT shows a horizontal fracture traversing the lateral and medial orbits (*small stars*) to separate the cranium from the face. The zygomatic arches (*large stars*) are characteristically involved.

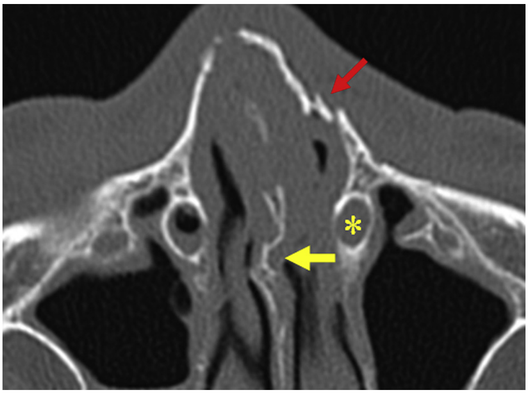

Fig. 23. Comminuted nasal-septal fracture. Axial CT demonstrates rightward nasal deviation and a comminuted left nasal bone fracture (*red arrow*) and buckled osseous nasal septum (*yellow arrow*). The nasolacrimal duct is intact (*asterisk*).

NOE injuries are divided in three groups according to the degree of injury to the medial canthal attachment using the Manson classification:

Manson classification of NOE fractures

Type I: Single fragment (most common) (Fig. 25A).

Type II: Comminuted with intact insertion of medial canthal tendon.

Type III: Comminuted with lateral displacement or avulsion of medial canthal ligament (uncommon).

Fig. 24. Upper nasal septal hematoma in a patient with nasal bone fractures. Noncontrast axial CT demonstrates extensive anterior nasal soft tissue swelling (*yellow asterisk*) and hyperdense soft tissue (*red asterisks*) on both sides of nasal septum. The septal hematoma in this elderly man was managed conservatively.

The most important factor in determining the need for surgical correction of NOE injury is stability of the bone to which the medial canthal tendon attaches. The medial canthal tendon inserts at the most anterior aspect of medial orbital wall. Although comminution of medial orbital rim and wall can be assessed radiographically, avulsion of the medial canthal tendon is best diagnosed clinically under anesthesia. A mobile fracture at the insertion of medial canthal tendon or avulsion of the tendon results in telecanthus.

Additionally, NOE fracture is commonly associated with nasolacrimal canal fracture (see Fig. 25B). The CT report should mention this injury

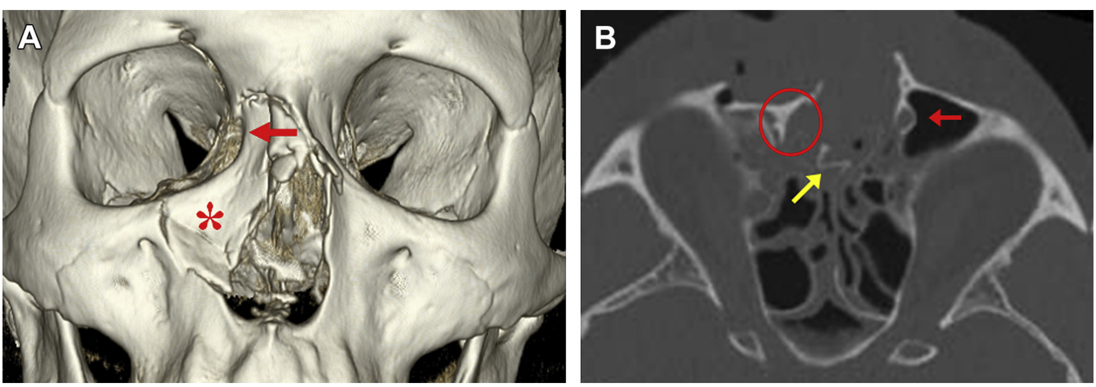

Fig. 25. NOE fracture. (*A*) Large medial orbit rim fragment (*asterisk*) usually implies preserved insertion of right medial canthal tendon. Note involvement with depression at the right nasofrontal suture (*red arrow*). (*B*) The area of the right nasolacrimal duct (*circled*) is severely distorted (compare with the normal left nasolacrimal canal [*red arrow*]). The osseous nasal septum is buckled posteriorly (*yellow arrow*). This substance abuse patient deferred treatment and, to date, has not undergone surgical repair.

because it may not be clinically apparent early on and patients may develop epiphora and/or recurrent dacryocystorhinitis.

Inadequate treatment may result in difficult-to-treat secondary deformities. Severely comminuted fractures require repositioning of the medial canthal tendon.[17] The nasal septum plays an important role as a central sagittal buttress and must be restored for successful surgical repair of NOE fracture and nasal depression.[18]

Key points: midface fractures

1. Most frequent midface fractures involve the nasal bone, followed by fractures affecting the ZMC.
2. With Le Fort II and III injury, strong consideration should be given to CT angiogram of the neck to exclude vascular injury.
3. The radiology report should include the status of the medial orbital rim, because its comminution implies involvement of the medial canthal tendon.
4. Fracture fragments within the maxillary sinus should be noted because they may function as a nidus for infection.
5. Nasolacrimal duct involvement may lead to epiphora, dacryocystocele, and dacryocystitis.

DENTAL

Tooth injuries are frequently identified on CT scans of the face. At times it may be difficult to clearly distinguish periodontal disease from dental injury, but evaluation of adjacent teeth would provide a clue to the overall dental health.

Andreasen and colleagues[19] described dental trauma as divided into nine fracture and six luxation entities, but with as many as 54 combination injuries in which both luxation and fracture occur. These complex injuries have distinct healing scenarios for which treatment consensus is still a work in progress. The main traumatic entities identified on imaging are as follows:

Dental trauma classification

1. Intrusion
2. Extrusion (Fig. 26)
3. Lateral luxation
4. Crown fracture
5. Root fracture
6. Crown/root fracture (Fig. 27)
7. Avulsion (see Fig. 26; Fig. 28)

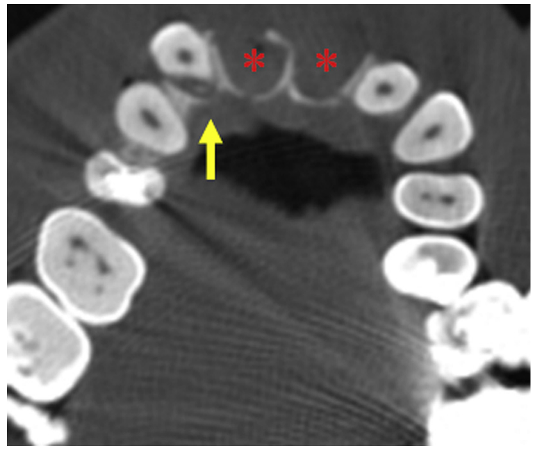

Fig. 26. Tooth extrusion and avulsion. Axial CT image shows the right lateral maxillary incisor is extruded (*arrow* points to periapical lucency) and the central incisors are avulsed (*asterisks*).

Alveolar ridge fractures (see Fig. 28) are considered open fractures and require, besides splinting, an antibiotic regimen.

Once a tooth avulsion is identified, scrutiny of neck and chest films for the aspirated tooth should be performed. An avulsed tooth in the airway/upper aerodigestive tract (Fig. 29) must be retrieved because aspirated foreign bodies within the small airways can lead to obstructive pneumonia, and even abscess formation. Tooth aspiration is reportedly more common in children. If the patient is intubated, a flexible bronchoscope is introduced through the orotracheal tube for safe foreign body retrieval.

Once in the esophagus, the avulsed tooth need not be retrieved because a high proportion of accidentally ingested teeth are passed in the stool within 1 month. Only a minority of ingested teeth lead to gastrointestinal obstruction, perforation, or bleeding.

Initiation of treatment of injured teeth, either primary or permanent, has the best outcome if performed within 1 hour to prevent pulp necrosis and loss of bone.

Key points: dental trauma

1. Alveolar ridge fractures should be noted because they are treated as open fractures and patients are placed on an antibiotic regimen.
2. Scrutiny of chest and neck images for aspiration of an avulsed tooth should be performed because aspirated teeth may cause pneumonia and lung abscess.

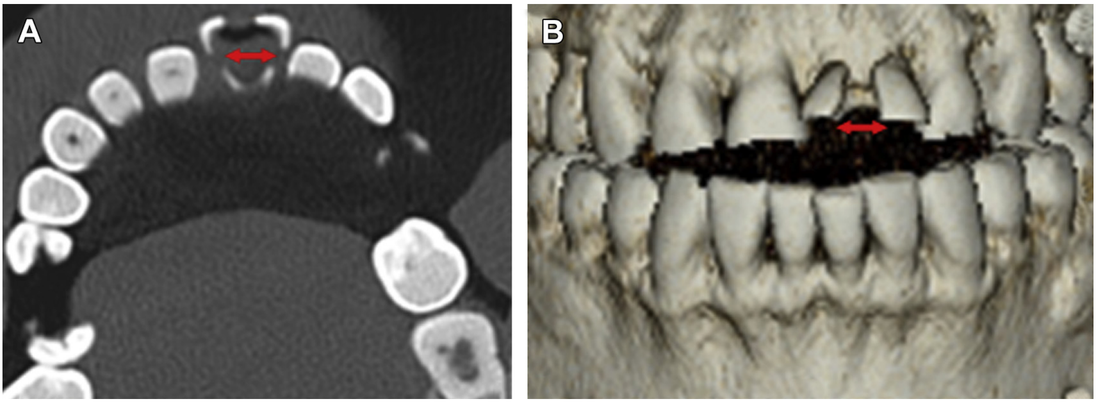

Fig. 27. Crown fracture. (*A*) Axial and (*B*) three-dimensional coronal reformatted CT images show a fracture of the left maxillary central incisor crown and root (not shown) with splaying of fracture fragments (*arrow*). The patient underwent dental extraction.

MANDIBLE

As described previously with the midface, the mandible also has its own buttresses (ie, areas of strong, thickened facial bone areas) (**Fig. 30**). These are similarly important for surgical repair planning.

Mandibular fractures are most commonly bilateral. A symphyseal or body fracture is typically associated with a contralateral angle or subcondylar neck fracture (**Fig. 31**). The angle fracture frequently traverses the root of the third molar.

The surgical approach is first directed toward repair of the anterior (teeth-bearing, symphysis, and body) mandible before reducing the posterior segment (angle, ramus, coronoid, and condyle). “Intermaxillary” (maxillomandibular) fixation is often the first step in repair of mandibular fractures (**Fig. 32**C, D).

Subcondylar Fractures and Condylar Dislocations

Closed treatment of subcondylar fractures through maxillomandibular fixation, even when associated with condylar dislocation (**Fig. 33**), has been advocated as prudent given the occurrence of complications with open surgery (salivary fistula, facial nerve paresis, and so

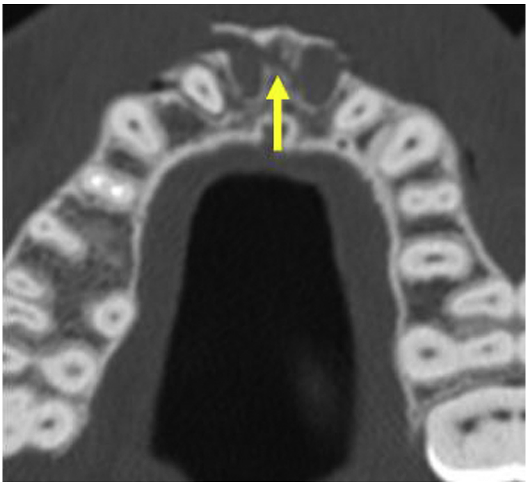

Fig. 28. Avulsed central incisors with alveolar ridge fracture. Axial CT shows absence of the maxillary central incisors and a fracture through the alveolar ridge (*arrow*).

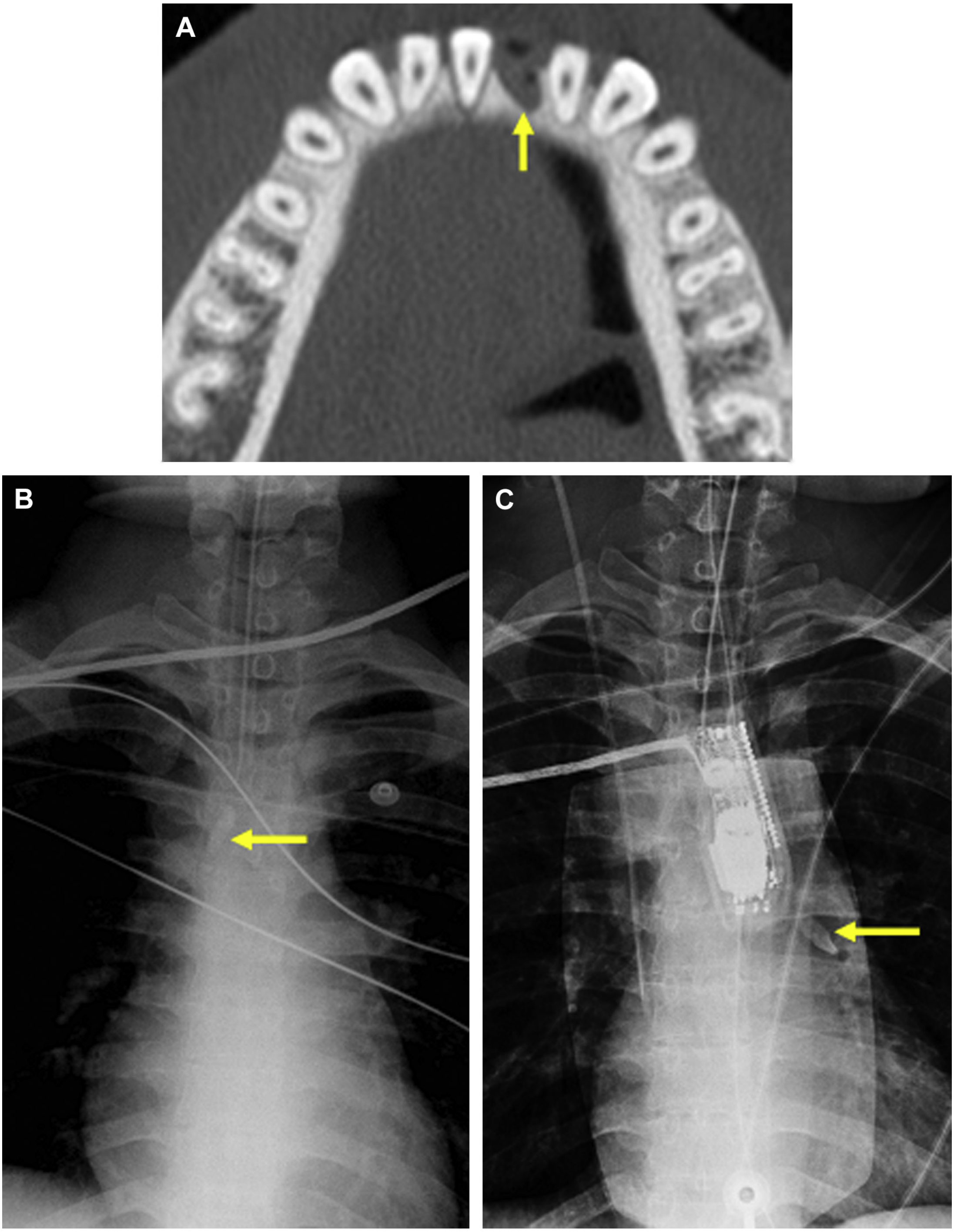

Fig. 29. Avulsed left central incisor. (*A*) Axial CT demonstrates absence of the left central incisor (*arrow*). Note the lucency around the apex of right central incisor suggesting an extrusion. (*B*) Anteroposterior chest radiographs reveal the missing tooth identified first in the trachea (*arrow*), and then (*C*) the left mainstem bronchus (*arrow*). The patient underwent bronchoscopy with successful tooth retrieval.

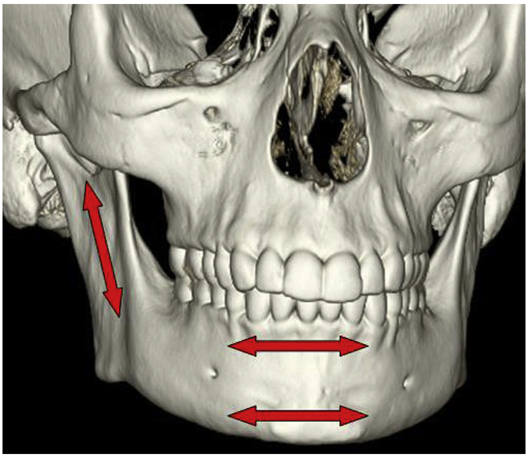

Fig. 30. Mandibular buttresses: upper, lower, and vertical (*arrows*).

forth).[20] Either open or closed reduction is chosen based on severity of comminution of condylar head and, most importantly, function impairment.[21,22] Open reduction internal fixation (ORIF) is becoming increasingly favored because endoscope-assisted ORIF is gaining ground.[23] The closed treatment approach for condylar fractures and dislocations is commonly chosen in children, unless function is severely impaired.

Quite frequently, the condyle is driven posteriorly into the external auditory canal by a blow or a fall onto the chin (**Fig. 34**).

As in Le Fort II and II fractures, screening CT angiography of the neck is recommended in the setting of condylar fractures with dislocaton. The CT angiogram is recommended to exclude internal carotid dissection or pseudoaneurysm.[14]

Coronoid Process Fractures

Conservative management is also used for fractures of the coronoid process when there is minimal displacement and no restriction of mouth opening. For patients with significant fracture displacement and limited mouth opening, or patients with concomitant fractures of the zygoma, zygomatic arch, or mandibular ramus, ORIF is often used.[24]

Key points: mandible trauma

1. The anterior (teeth-bearing) mandibular fractures are corrected first, typically by ORIF.
2. The alignment of the posterior segment (angle, ramus, and condyle) is subsequently corrected, most commonly by closed intermaxillary (maxillomandibular) fixation.
3. Condylar fracture dislocations are an indication for CT angiogram of neck to evaluate for vascular injury (dissection).

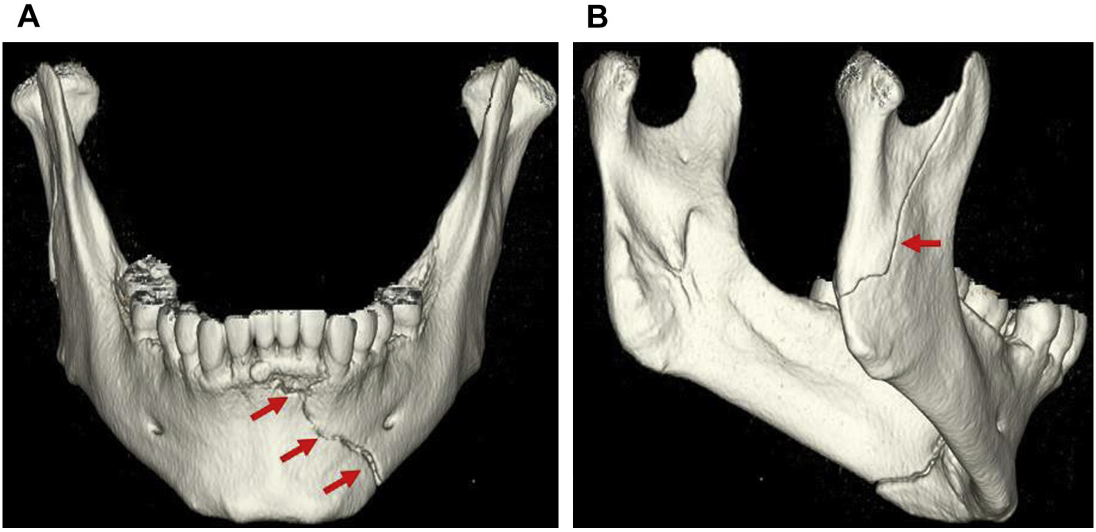

Fig. 31. Parasymphyseal fracture with extension into the alveolar ridge with en block mobility of mandibular incisors and contralateral posterior segment (subcondylar) fracture. (*A*) Isolated three-dimensional coronal CT reformatted image of the mandible demonstrates an oblique fracture line extending to the alveolar ridge fracture (*arrows*). (*B*) Three-dimensional posterior oblique reformatted CT image demonstrates the contralateral ramus fracture extending to the mandibular angle (*arrow*).

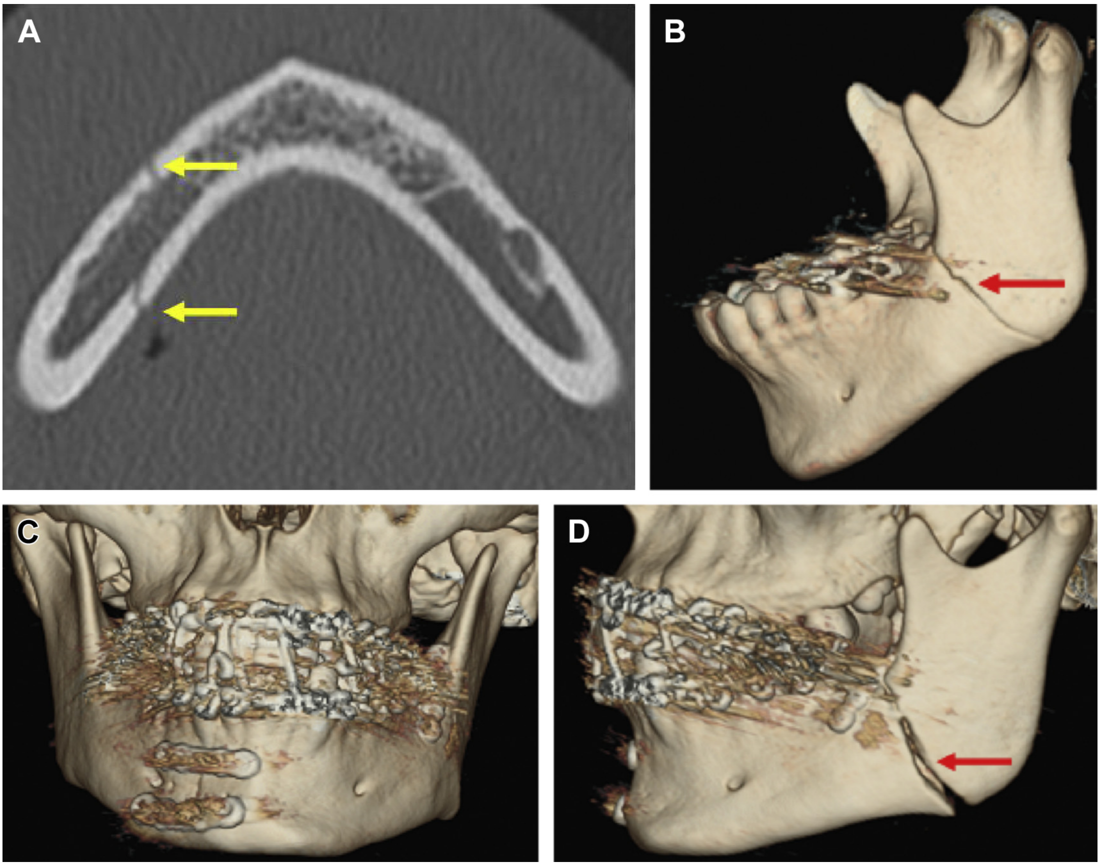

Fig. 32. Bilateral mandibular fractures and surgical repair. (*A, B*) Common bilateral fracture pattern of mandibular fractures. In this case linear fractures are seen in the right parasymphyseal region (*yellow arrows*) and the left mandibular angle (*red arrow*). (*C, D*) Mandibulomaxillary wire and arch bar fixation with right parasymphyseal plate and screw placement. Note the extensive postoperative beam-hardening artifact obscuring optimal visualization of the alveolar region. There is mild diastasis of the left mandibular angle fracture (*arrow*), which was subsequently corrected.

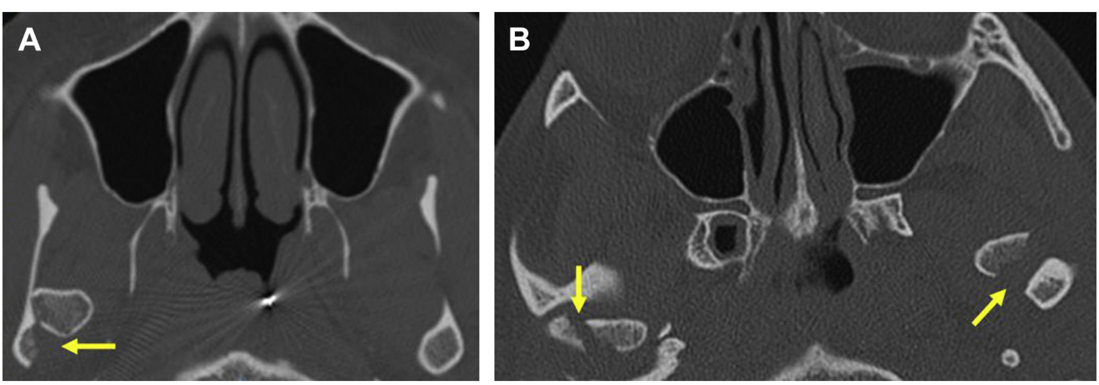

Fig. 33. Condylar fracture dislocation. (*A*). Axial CT demonstrates medially and anteriorly displaced right condylar fracture (*arrow*). (*B*) Axial CT in a different patient reveals bilateral distracted condylar fractures and left condylar dislocation (*arrows*). This patient underwent closed intermaxillary fixation.

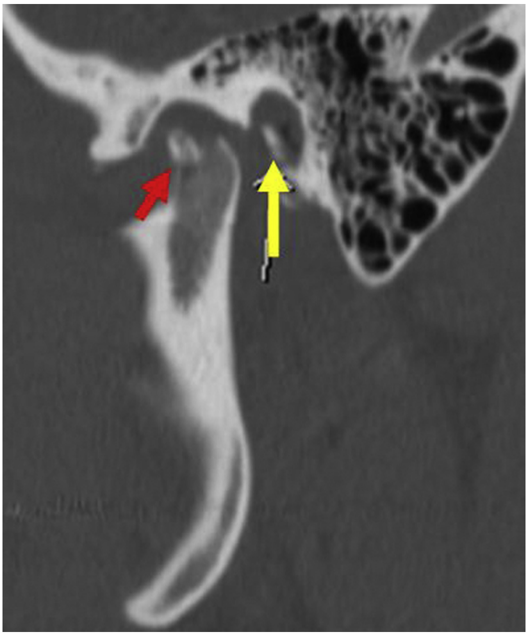

Fig. 34. Fractured condyle with anterior wall of external auditory canal fracture and posterior displacement. Parasagittal CT through the temporomandibular joint shows a fracture of the anterior wall of the external auditory canal (*yellow arrow*) caused by traumatic impact from the mandibular condyle. Note the mandibular condyle is also fractured (*red arrow*).

SUMMARY

Knowledge of typical patterns of facial fractures is important because each pattern may be associated with its respective functional complications. The three-dimensional images are commonly used by surgeons for operative planning in restoration of alignment and correction of cosmetic deformities, but can be occasionally useful to the radiologist as a summary view of complex midface fractures.

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