**Craniofacial trauma: Keys for the radiology report**

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Learning objectives

- To carry out a **systematic approach to the imaging findings** that are relevant on the craniofacial trauma diagnostic.
- To perform a **full and rapid radiological report** since it’s a matter of emergency / urgency.
- **To identify the major fracture patterns**: upper third, middle third and lower third.
- To describe the **main anatomical structures** and their corresponding subtype (for example, in maxillo-malar fractures: LeFort 1, LeFort 2 and LeFort 3).
 INTRODUCTION

Facial skeletal fractures are common and frequently associated with other life-threatening conditions, such as traumatic brain injuries.

Although they represent serious injuries, the workup and treatment of facial fractures is often properly delayed until more pressing problems have been addressed, such as the establishment of an adequate airway, hemodynamic stabilization, and the evaluation and treatment of other more serious injuries of the head, chest and skeleton. Once these problems have been managed, it is time to work up facial fractures.

COMMON CAUSES OF FACIAL TRAUMA

The most common mechanism producing facial trauma is auto accidents. About 70% of motor vehicle accidents produce some type of facial injury, although most are limited to soft tissue.

The face seems to be favorite target in fights or assaults (interpersonal violence), which are the next most common mechanism.

The remainder of facial fractures are produced by falls, sports, industrial accidents (see Fig. 2 on page 9 and Fig. 3 on page 9 ) and gunshot wounds.

FACIAL SKELETAL ANATOMY

The normal skeletal anatomy of the face frequently is classified into upper, middle, and lower thirds (see Fig. 4 on page 10 ). This system is used by otolaryngologists to describe locations of fractures in the facial skeletal anatomy.

The upper third of the face consists of the frontal bone (including the frontal sinuses) and is delineated from the middle third by the superior orbital rims and walls.

The mandible or jawbone represents the lower third of the face.

Between the 2 is the middle third of the face which extends downward from the superior orbital rims and orbits and includes the nasal cavity and associated sinuses (maxillary, ethmoid and sphenoid). The midface skeleton is bounded posterolaterally by the zygomaticotemporal sutures, which connect the midface to the calvaria, and posteromedially by the pterygoid plates, which connect it to the skull base.
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 Fig. 5 on page 11).

There are 4 paired vertical facial skeletal buttresses and 4 transverse buttresses, creating a cagelike array of thickened facial bones.

Vertical Buttresses

• 1. Lateral maxillary (+ lateral orbital walls of orbit and maxillary sinus): yellow
• 2. Medial maxillary (+ medial orbital wall and lateral nasal walls): purple
• 3. Posterior maxillary (+ pterygoid plates): pink
• 4. Posterior vertical: orange

Transverse Buttresses

• 1. Upper transverse maxillary (+ orbital floor): blue
• 2. Lower transverse maxillary (+ hard palate): green
• 3. Upper transverse mandibular: magenta
• 4. Lower transverse mandibular: orange

All of the buttresses are linked, directly or indirectly, to the other buttresses, influencing the transmission of external forces throughout the facial skeleton.

THE ROLE OF CT IMAGING IN PATIENT ASSESSMENT

Multidetector computed tomography (CT) imaging has become the standard choice for quick and accurate assessment of head and face trauma.

Three-dimensional image are reconstructions usually are produced and are useful in diagnostic imaging and surgical planning for high-energy facial fractures because they precisely visualize the location and extent of fractures.

But, although CT 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, CT is not recommended because of its relatively high radiation doses.
The plain film facial series has taken a back seat to CT in the past few years, and is now used only in certain situations, such as when the facial trauma is very focal (nasal fracture), or when CT is unavailable.

A basic facial series consists of three or four films:

- 1. A Waters view (PA view with cephalad angulation). See Fig. 6 on page 11.
- 2. A Caldwell view (PA view). See Fig. 7 on page 12.
- 3. A lateral view. See Fig. 7 on page 12.
- 4. A submentovertex view (occasionally).

Of these views, the most consistently helpful view in facial trauma is the Waters view.

There are three anatomic contours best seen on the Waters view of the face, and they were first popularized by Dolan et al. (See Fig. 8 on page 13).

The 3 lines of Dolan lead the eye along some facially important structures. Lee Rogers pointed out that the 2nd and 3rd lines together form the profile of an elephant.

If a nasal fracture is suspected, then a lateral view of the nasal bone with special nasal technique may be done. (See Fig. 9 on page 13).

FRONTAL SINUS FRACTURES

Fractures of the upper third of the face typically affect the wall of the frontal sinus because the bone there is thinner than the rest of the frontal bone.

Result from high-velocity blunt trauma and they are frequently accompanied by other craniofacial fractures, and can be fatal.

Fractures may involve only the anterior sinus wall or extend into the posterior wall (creates a communication between the frontal sinus and the anterior cranial fossa # rhinorrhea, brain herniation and intracranial infection).

A fracture along the medial aspect of the frontal sinus may extend into the nasofrontal duct # mucocele.

See Fig. 10 on page 14.
MANDIBULAR FRACTURES

The mandible is another commonly fractured bone in the head, and most of these fractures are obvious on clinical exam.

Clinical findings:

• Facial distortion
• Malocclusion of the teeth
• Abnormal of portions of the mandible or teeth

The mandible is one of those bones covered by the "ring bone rule", which may be stated thusly: if you see a fracture or dislocation in a ring bone or ring bone equivalent, look for another fracture or dislocation.

The mandible is a U-shaped bone that is connected to the calvaria through the temporomandibular joints, creating a ringlike structure.

Because of this ringlike configuration, a traumatic blow to the mandible typically produces at least two discrete fractures.

Fractures of the mandible are characterized according to their location, the degree of comminution, and the presence of displaced fragments.

Fractures involving the mandibular canal, which traverses the mandibular ramus, angle, and body, may result in injury to the inferior alveolar nerve.

See Fig. 11 on page 14, Fig. 12 on page 15 and Fig. 13 on page 16.

NASOSEPTAL FRACTURES

Nasal bone fractures are the most common of all facial skeletal injuries because of the superficial location of the nose and the relative thinness of the bone.

Severe bony septal injury commonly occurs with naso-orbito-ethmoidal (NOE) fractures and they are the most difficult midfacial injuries to diagnose and manage. Isolated NOE fractures are uncommon; up to 60% of NOE fractures are associated with ZMC fractures, and 20% are associated with panfacial fractures.

See Fig. 14 on page 16 and Fig. 15 on page 17.

ORBITAL FRACTURES
Orbital fractures are not clinically obvious in unconscious patients with facial swelling; and diagnosis, prognostication, and treatment planning rely heavily on the findings at CT.

Fractures of the orbital walls can be localized and simple (those limited to the internal orbit or "pure"); or they can be complex fractures extending beyond the orbits, such as those extending into or through the orbital rims (those with orbital rim involvement or "impure").

Both simple and complex orbital fractures can affect the position and integrity of the eyes, eye muscles or optic nerves.

More than 80% of pure internal orbital fractures are blow-out fractures involving the medial wall or orbital floor, increase the risk of enophthalmos or the sinking of the eye from its normal anatomic position. See Fig. 16 on page 18

Lateral wall involvement is a hallmark of ZigomaticoMaxillary Complex (ZMC) fractures.

Roof fractures are impure, are displaced in up to 95% of cases.

The orbit should be evaluated in three orthogonal planes at CT.

Coronal CT images have the greatest overall utility for assessing defect size, the direction of fractures, and changes in orbital shape and volume.

Axial an sagittal CT images help delineate the posterior defect margin.

CT images with soft-tissue windowing depict the relationship of the extraocular muscles and fibrofatty tissue to fractured segments.

**ZMC FRACTURES**

The tetrapod-shaped ZMC fragment dissociates from the midface at four major points of failure:

- 1. The **zygomatico-maxillary buttress** from the inferior margin of the crest to the inferior orbital rim.
- 2. The **zygomaticosphenoid suture** along the lateral orbital wall
- 3. The **frontozygomatic suture** of the lateral orbital rim
- 4. The **zygomaticotemporal suture** of the zygomatic arch.

The zygomatic surface of the orbit contributes to the lateral orbital wall and floor, and rotation of the ZMC fragment in any axis can dramatically change orbital volume.

ZMC fractures produce **facial asymmetry and enophthalmos**.
Three-dimensional volume-rendered CT images simplify grading of fractures and are used to plan the magnitude and direction of forces needed for disimpaction and reduction of the ZMC. See Fig. 17 on page 18.

**LE FORT FRACTURES**

Le Fort fractures are classified by the site and extent of fractures, using coronal and axial 2D CT images and 3D surface renderings.

**Le Fort I**: Involve the lateral and medial walls of the maxillary sinus, propagating posteriorly from the piriform aperture.

**Le Fort II**: Involve the frontonasal suture, the inferior orbital rim and floor, and the maxillary sinuses, forming a pyramidal shape.

**Le Fort III**: Extends horizontally from the frontonasal suture to the frontozygomatic suture and zygomatic arches.

All three patterns converge through the pterygoid plates, resulting in dissociation of the involved midfacial segment, and that if the pterygoid plates are intact, a Le Fort fracture is excluded. See Fig. 18 on page 19, Fig. 19 on page 20 and Fig. 20 on page 20.
**Fig. 2:** CASE 1A. Multiple fractures in the same patient after industrial accident with grinder or electric radial in three-dimensional (A) and unenhanced coronal (B and C) CT images of an adult face. They depict a ZMC fracture, orbital roof fracture, mandibular fracture (with tooth fracture), pterygoid plate (Le Fort) and extensive involvement of soft tissues on the left side. But the most important thing of all is to appreciate occupation of the airway by calcium density material in the image C (red arrow).

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**Fig. 3:** CASE 1B. Same patient that previous case. Unenhanced axial (A and B) and three-dimensional CT images. They demonstrate occupation of the airway by calcium density material and mandibular fracture in image A and ZMC fracture (image B) with tetrapod-shaped ZMC fragment (image C).

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Fig. 4: System of facial partitions. A. Three-dimensional CT image of an adult skull with color overlays shows partition of the facial anatomy into upper (red), middle (blue) and lower (yellow) thirds. B. Three-dimensional CT images of an adult skull in frontal (B) and lateral (C) orientations with color overlays show the osseous facial structures that are typically affected by type I (red), type II (blue) and type III (yellow) Le Fort fractures.


Fig. 5: The facial skeletal buttresses. 4 Vertical buttresses: Lateral maxillary (yellow), medial maxillary (purple), posterior maxillary (pink) and posterior vertical (orange). 4 Horizontal buttreses: Upper transverse maxillary (blue), lower transverse maxillary (green), upper transverse mandibular (magenta) and lower transverse mandibular (orange).

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Fig. 6: Plain film facial series. Water view in two different patients. A. Agenesis of right frontal sinus and hypoplasia of left frontal sinus, as anatomical variants of normality.

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Fig. 7: Plain film facial series. A. A Caldwell view (PA view). B. A Lateral view.
Fig. 8: The three lines of Dolan represent the three anatomic contours (red lines) of the Waters view.
Fig. 9: Lateral view of the nasal bone with special nasal technique in two different patients. A. Normal anatomy. B. Nasal bone fracture.

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Fig. 10: FRONTAL SINUSES FRACTURES. Axial (A) and coronal (B) unenhanced CT images of the frontal bone demonstrate two lines of fracture of the anterior and posterior walls of the frontal sinuses without complication associated. Three-dimensional CT image (C) shows bilateral frontal sinuses fractures.

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**Fig. 11:** MANDIBULAR FRACTURES. Image (reprinted from University of Washington) demonstrates the common sites of mandibular fractures. Coronal unenhanced CT images demonstrate left mandibular fracture (A) without dislocation of the temporo-mandibular joint (B).

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**Fig. 12:** Case 2 of Mandibular fracture. Male, 33 years old. Precipitated from 4 meters. Multifragmentary left mandibular fracture (A) without dislocation of the temporo-mandibular joint (B) with three-dimensional CT image (C).

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**Fig. 13:** Case 3 of Mandibular fracture. Image demonstrates mandibular dislocation. The condyle (c) is anterior to the articular eminence (e). Reprinted from University of Washington. Child of 5 years. Fall of the bicycle. Impossibility for oral opening. Right mandibular condylar fracture (A and C) with dislocation of the right temporo-mandibular joint (B). Left temporo-mandibular joint preserved (B and C). Second fracture on the symphysis right mandibular bone because the "Ring bone rule".

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**Normal nasal bone anatomy**

*Fig. 14:* A. Image demonstrates groove for nasociliary nerve. B. Normal nasal bone anatomy. Solid black arrow: nasofrontal suture. Open White arrows: frontomaxillary suture. *: nasomaxillary suture.


**Middle Third Fractures:**

**NASOSEPTAL FRACTURES**
**Fig. 15:** NASOSEPTAL FRACTURES. Axial (A) and Coronal (B) unenhanced CT images show a nondisplaced fractures through the bilateral nasal bones and nasal septum.

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**Middle Third Fractures:**

**ORBITAL FRACTURES**

*Blow-out fracture*

**Fig. 16:** Blow-out fracture. Image reprinted from University of Washington. The arrows point to the fracture fragments and periorbital tissue which have herniated into the maxillary sinus. Axial (A and B) and coronal (C) unenhanced CT images show the medial wall and orbital floor fractures with pre-orbital hematoma (A and B).

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**Middle Third Fractures:**

**ZMC FRACTURES**

Fig. 17: ZMC FRACTURES. Axial (A and B) and coronal (C) unenhanced CT images of the ZigomaticoMaxillary Complex (ZMC) fracture. Three-dimensional CT image (D) shows tetrapod-shaped ZMC fragment.

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**Middle Third Fractures:**

**LE FORT FRACTURES**

Fig. 18: Frontal and lateral views of LeFort complex fractures I - III.
Fig. 19: LE FORT FRACTURES. Coronal unenhanced CT images. All three patterns converge through the pterygoid plates (A). Le Fort I # Floating palate (B) Le Fort II # Floating maxilla (C) Le Fort III # Craniofacial dissociation (D).

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Fig. 20: Le Fort Fractures. Same patient that Figure 19. Unenhanced coronal (A) and sagittal (B and C) CT images. Sphenoidal sinus fracture (A), fracture of the right orbital roof (B), frontal sinus fracture, floor orbital fracture and fracture of the anterior wall of the maxillary sinus of the left side (C).

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Findings and procedure details

KEYS FOR DIAGNOSE FACIAL TRAUMA

- Look at the orbits carefully, since 60 - 70 % of all facial fractures involve the orbit in some way.
- Know the normal anatomy (including buttresses). Ver Fig. 5 on page 31.
- Know the most common patterns of facial fractures and look for them.
- Bilateral symmetry can be very helpful.
- Carefully trace along the lines of Dolan when examining the Waters view in a facial series. Ver Fig. 8 on page 32.
- Use CT in working up facial fractures.

KEYS FOR FRONTAL SINUS FRACTURES

- Result from high-velocity blunt trauma to the upper face.
- Frequently accompanied by other craniofacial fractures.
- Pneumocephalus is an indication of severe injury and requires surgical intervention.
- See Fig. 10 on page 24.

KEYS FOR MANDIBULAR FRACTURES

- Remember the ring bone rule.
- Look carefully along the cortical margin of the whole mandible for discontinuities. This may be the only sign of a fracture that you will see.
- Also carefully examine the mandibular canal for discontinuities.
- A fracture line entering the root of a tooth is considered an open fracture by definition.
- See Fig. 11 on page 24, Fig. 12 on page 25 and Fig. 13 on page 26.

KEYS FOR NASOSEPTAL FRACTURES

- The most common of all facial skeletal injuries.
- These fractures are much better seen when the film is shot with special low KVP nasal bone technique (essentially soft tissue technique).
- The channel for the nasociliary nerve runs parallel to the bridge of the nose, while most nasal bone fractures will run perpendicular to the bridge. See Fig. 14 on page 26.
• Remember that the humble nasal bone fracture may be associated with more extensive injuries, such as the orbital rim or floor and the ethmoid or frontal sinuses.
• See Fig. 15 on page 27.

KEYS FOR ORBITAL FRACTURES

• Blow-out fractures: When fractures in the orbital wall extend outward into the sinuses \(\rightarrow\) enophthalmos. See Fig. 16 on page 28.
• Blow-in fractures: When fractured bone introduces into the orbital space inhabited by the eye.
• The orbit should be evaluated in three orthogonal planes at CT.

KEYS FOR ZMC FRACTURES

• Multiplanar assessment is required to evaluate the four common points of failure of a "tetrapod" ZMC fracture. See Fig. 17 on page 28.
• The zygomaticsphenoid suture is the most sensitive CT indicator of asymmetry and orbital volume changes from ZMC malalignment.
• Failure to anticipate floor defect expansion is a major cause of late enophthalmos after ZMC reduction.

KEYS FOR LE FORT FRACTURES

• Le Fort I \(\rightarrow\) Floating palate
• Le Fort II \(\rightarrow\) Floating maxilla
• Le Fort III \(\rightarrow\) Craniofacial dissociation.
• The maxillary occlusion-bearing fragment is typically managed at Le Fort I.
• Look for incomplete hairline fractures at the piriform aperture and pterygoid plates on coronal images and for retrusion and / or impaction on axial images.
• Palatal fractures are best assessed with combined evaluation of axial and coronal images.
• See Fig. 18 on page 29, Fig. 19 on page 30 and Fig. 20 on page 30.
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**Maxillofacial buttresses**
**Fig. 5:** The facial skeletal buttresses. 4 Vertical buttresses: Lateral maxillary (yellow), medial maxillary (purple), posterior maxillary (pink) and posterior vertical (orange). 4 Horizontal buttresses: Upper transverse maxillary (blue), lower transverse maxillary (green), upper transverse mandibular (magenta) and lower transverse mandibular (orange).

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**Fig. 8:** The three lines of Dolan represent the three anatomic contours (red lines) of the Waters view.

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Conclusion

- The knowledge of the **main anatomical structures** involved in craniofacial fractures is essential for the performance of a **proper radiological report**.

- To become familiar with the fracture patterns and anatomical structures more frequently involved. This will allow us to be more confident when faced with this clinical situation which causes many doubts and stresses in the younger radiologists.
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