Maxillofacial Trauma

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Basic Trauma Principles

Hypovolemia (Table 7.1)

- Can be caused by bleeding or massive urinary or gastrointestinal fluid losses.
- One or two large bore (≥16 gauge) peripheral IVs should be inserted.
- Focused abdominal sonography for trauma (FAST) in a hypotensive patient to rule out intra-abdominal hemorrhage or cardiac tamponade.

Glasgow Coma Scale (Table 7.2)

- Objective measure of patient's neurological status and used serially to track clinical progress.
- Can be applied to patients 5 years of age and above.
- Use best response (left vs. right differential).
- Score 8 or less, early airway protection encouraged due to concern of respiratory arrest or hypoxia leading to secondary brain injury.
- Score minimum is 3.
- Requires serial exams and a CT scan of the head.

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Table 7.1 Classes of Hemorrhagic Shock. Based on a 70 kg Person

Classes of Hemorrhagic Shock				
	1	2	3	4
Blood loss (ml)	<750	750–1500	1500–2000	>2000
Pulse rate (BPM)	<100	100–120	120–140	>140
Blood pressure	Normal	Normal	Decreased	Decreased
Respiratory rate (per minute)	12–20	20–30	30–40	>40
Urine output ml/hr	>30	20–30	5–15	Scarce
Mental status	Slightly anxious	Mildly anxious	Confused	Lethargic

Table 7.2 Glasgow Coma Scale. Mnemonic to remember points allotted for each GCS component "4 Eyes, Jackson 5 (voice) and V6 (motor)"

Eye opening response	Verbal response	Motor response	Points
No response	No response	No response	1
To pain only	Incomprehensible	Extension in response (decerebrate posturing)	2
To verbal stimuli, command, speech	Inappropriate words	Flexion in response to pain (decorticate posturing)	3
Spontaneous–opening with blinking	Confused conversation, but able to answer	Withdraws in response to pain	4
	Oriented	Purposeful movement to pain	5
		Obeys commands for movement	6

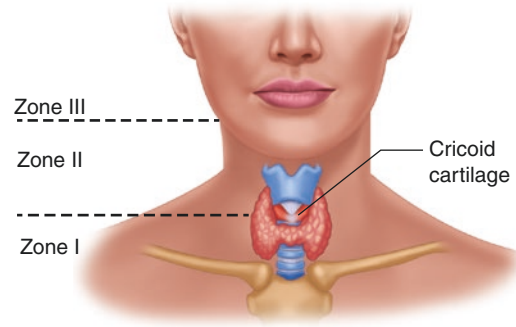

Fig. 7.1 Zones of the neck. (Reprinted with Permission from Georgopoulos C. Chap. 86 – Neck Trauma. Sixth Edition. Emergency Medicine Secrets. Elsevier Inc.; 2016)

Head Injury Classification

- Severe Head Injury/Coma – GCS score of 8 or less.
- Moderate Head Injury – GCS score of 9–12.
- Mild Head Injury – GCS score of 13–15.
- Denotation of T after the score is applied to an intubated patient.

Zones of the Neck for Penetrating Trauma (Fig. 7.1)

- Zone 1 – thoracic inlet to cricoid cartilage.
- Zone 2 – cricoid cartilage to angle of the mandible.
- Zone 3 – angle of the mandible to the base of the skull.
- Zones 1 and 3 are usually worked up using conventional or, more commonly now, CT angiography due to difficulty in access.
- Due to the multiple organ systems represented in the neck, multiple systems can be impacted by a single penetrating insult. Insults may result in cervical spine, carotid, esophageal, and/or laryngeal injuries.
- Patients who are unstable or present with hard signs such as bruits, thrills, large/pulsatile hematomas require immediate exploration.

Principles of Fixation

Rigid Fixation:
- Fixation that prevents interfragmentary movement when a load is applied.

Semi-Rigid Fixation:
- A form of fixation that is not of sufficient strength to prevent interfragmentary movement during loading but is adequate to allow union of bone.

Load Bearing:
- Hardware of sufficient strength that is able to bear the entire load.
- Plates and screws to immobilize the fractured segments.
- Use of thicker, rigid plates with bicortical screws to immobilize the fracture segments or lag screws.
- Requires at least three screws on each segment when plates are used.

Load Sharing:
- Form of hardware that is unable to bear all functional load across fracture.
- Open reduction, internal fixation without relying solely on the plates and screws to immobilize the fracture segments.
- Uses miniplates and monocortical screws along the lines of osteosynthesis as described by Champy.

Ideal Line of Osteosynthesis of the Mandible:
- Described by Maxime Champy in 1976 [1].
- A line around the mandible where plating the tension and compression forces are balanced, thus offering the best biomechanical advantage for positioning of plates and screws.

Plates and Screws for Internal Fixation

- Non-locking plates/screws:
  - Plates must be adapted intimately to the bone.
  - Compression of the plate onto the bone may cause bone resorption under the plate.
- Locking plates/screws:
  - Screws lock into the plate while it is being tightened.
  - Does not require a perfect adaptation of the plate to the bone.
  - The plate bears the load of mechanical forces.
- Plate and screw dimensions:
  - Most plates are composed of titanium.
  - Plating systems are named by the outer diameter of the screws.
- Thread shape:
  - Self-drilling – insertion without pre-drilling or tapping.
  - Self-tapping – requires pre-drilling of a pilot hole, the insertion of the screw will create its own thread in the bone.

Bone Healing

- Bone healing is altered by types of fixation and mobility of the fracture site in relation to function.
- Primary bone healing:
  - No fracture callus forms.
  - Heals by a process of:
    (a) Haversian remodeling directly across the fracture site if no gap exists (contact healing)
    (b) Deposition of lamellar bone if small gaps exist (gap healing).
  - Requires absolute rigid fixation with minimal gaps.
- Secondary bone healing:
  - Bony callus forms across fracture site to aid in stability and immobilization.
  - Occurs when there is mobility around the fracture site.
  - Secondary bone healing involves the formation of a subperiosteal hematoma, granulation tissue, and then a thin layer of bone forms by membranous ossification. Hyaline cartilage is deposited, replaced by woven bone and remodels into mature lamellar bone.

Approach to the Facial Trauma Patient

History of Present Illness

- Mechanism of injury and loss of consciousness are important points to note. It is difficult to assess a history from an unstable trauma patient and, therefore, witnesses should be questioned.
- Confirm ATLS/PALS has been performed. Threshold for intubation should be low. Ensure appropriate consultations have been made, e.g., neurosurgery, ophthalmology, orthopedic surgery, and pediatric surgery, etc., if necessary.
- Ensure C-spine has been evaluated and appropriate precautions taken. It's desirable to have the head and spine cleared prior to surgical intervention if possible.

Physical Exam

- After confirming the patient is stable and the airway secure, begin the head and neck trauma exam. This should be systematic and concise.
- Evaluate general demeanor and responsiveness. Patient cooperation may be extremely difficult with pediatric or inebriated patients.
- Evaluate neurological status to determine the level of consciousness (Glasgow scale).
- Evaluate for facial asymmetry, lacerations (rule out Stenson duct or facial nerve injury), edema and ecchymosis.
- Examine the cranial nerves II–XII and note any paresthesia (V1, V2, V3), or facial nerve deficits.
- If the orbit is involved, evaluate extra ocular movements, pupillary reaction, direct and consensual visual reflexes, monocular (indicative of retinal detachment) or binocular diplopia (can be secondary to edema or entrapment and restriction of gaze). Tonometry should be used for evaluating intraocular pressure. A fundoscopic exam is indicated for for evaluating the retina and optic nerve, and hyphema. A slit lamp exam is useful in evaluating the eyelids, lacrimal system, cornea and to rule out the presence of foreign bodies. Exam should assess for the presence of proptosis, dystopia (disturbance in globe position in the vertical and horizontal planes) or enophthalmos. Look for periorbital ecchymosis (Racoon eyes). Evaluate for telecanthus. Consider ophthalmology exam/clearance.
- Evaluate the ears for the presence of ecchymosis behind the ears (Battle's sign) or otorrhea, which may be indicative of a base of skull fracture (if positive neurosurgical consultation is required). Rinne and Weber exam to screen for hearing. Otoscopic exam to evaluate tympanic membrane and EAC (if injury apparent ENT should be consulted).
- Evaluate for exit wounds if a projectile was involved.
- Evaluate the midface for loss of projection, edema, ecchymosis, and step deformities.
- Evaluate the nose for asymmetries, blood, rhinorrhea, and septal hematoma.
- Evaluate jaws for range deviations on opening (this may indicate a condylar or subcondylar fracture), arch step deformities, lingual ecchymosis (highly indicative of a mandible fracture), hematomas, and intraoral lacerations.
- Evaluate the state of the dentition (dental fractures, missing teeth, changes in occlusion). For a pediatric patient correlate dental development with chronological age.
- Evaluate for a chin laceration, preauricular edema, or ecchymosis as these can be suggestive of a condylar fracture.
- The floor of mouth swelling or the possibility of airway compromise should be noted.

Imaging

- High-resolution maxillofacial computed tomography (CT) is the gold standard for evaluating facial trauma. Consider obtaining 3D reconstruction for surgical treatment planning and using it as an aid to discuss treatment with the family of the patient.
- If trauma is isolated to the mandible or dentition an orthopantomogram can be used.

- Plain film X-rays have limited value in the maxillofacial trauma patient.
- If teeth are missing or unaccounted for secondary to the trauma then an abdominal X-ray (KUB) and chest X-ray must be performed.

Mandibular Trauma

Nomenclature

- Fracture types:
  - Simple/closed – not opened to the external environment.
  - Compound/opened – fracture extends into an external environment.
  - Comminuted – splintered or crushed.
  - Greenstick – only one cortex fractured.
  - Pathologic – pre-existing disease of bone leads to fracture.
- Muscle Action Classification:
  - Vertically favorable vs. non-favorable, based on resistance to medial pull.
  - Horizontally favorable vs. non-favorable, based on resistance to upward movement.

Physical Exam

- Tenderness over the region of suspected fractures.
- Malocclusion:
  - Anterior open bite – bilateral condylar or angle fractures.
  - Unilateral open bite – ipsilateral angle, condylar and parasymphyseal fractures.
  - Posterior crossbite – symphyseal and condylar fractures with splaying of the posterior segments.
  - Prognathic bite – TMJ effusions.
  - Retrognathic bite – condylar or angle fractures.
- Loss of form – bony contour change, soft tissue depressions, deformities.
- Loss of function – can be from guarding, pain, or trismus.
  - Deviation on opening toward the side of the condylar fracture.
  - Inability to open due to impingement of coronoid or ramus on the zygomatic arch.
  - Premature contacts from alveolar, angle, ramus, or symphysis fractures.
- Edema.
- Abrasions/lacerations – the potential for compound fractures.
- Ecchymosis – especially floor of the mouth, symphyseal, or body fracture.
- Crepitus with manipulation.
- Altered sensation/paresthesia.
- Loss of teeth – require chest X-ray to rule out aspiration if not accounted.

Radiographic Evaluation

Panoramic Radiograph:
- Most informative radiographic tool.
- Shows entire mandible and direction of fracture (horizontal favorable, unfavorable).
- Disadvantages:
  - Patient must sit up-right/cooperative/non-sedated or intubated.
  - Difficult to determine buccal/lingual bone and medial condylar displacement.
  - Some details are lost/blurred in the symphysis, TMJ and dentoalveolar regions.

Mandible Series:
- Towne's view, anteroposterior and both oblique views.

Computed Tomography (CT):
- Excellent for showing intracapsular condyle fractures.
- Can get axial, sagittal, and coronal views; 3-D reconstructions.
- Disadvantage:
  - Expensive.
  - A larger dose of radiation exposure compared to plain film.
  - Difficult to evaluate the direction of fracture from individual slices (reformatting to 3-D overcomes this).

Treatment of Mandible Fractures

Closed Reduction (Table 7.3):
- Contraindications:
  - Medical conditions that should avoid intermaxillary fixation.
  - Alcoholics.
  - Seizure disorders.
  - Mental retardation.
  - Nutritional concerns.
  - Respiratory diseases (COPD).
  - Unfavorable fractures.

Techniques for Closed Reduction:
- Erich arch bars.
- Ivy loops.
- Essig Wire.
- Intermaxillary fixation screws.
- Splints.
- Bridal wires.

Length of Intermaxillary Fixation:
- Based on multiple factors:
  - Type and pattern of fracture.
  - Age of patient.
  - Involvement of intracapsular fractures.
- Average adult – 3-4 weeks.

Table 7.3 Advantages and disadvantages of closed reduction

Advantages	Disadvantages
Low cost	No absolute stability (secondary bone healing)
Short procedure time	Oral hygiene difficulty
Can be done in a clinical setting with local anesthesia or sedation	Possible TMJ sequelae
Easy procedure	Muscular atrophy/ stiffness
No foreign body in patients	Myofibrosis
	Possible effect on TMJ cartilage
	Decreased range of motion
	High degree of compliance required
	Weakness of muscles due to disuse
	Osteoporotic changes due to disuse

- Children 15 years or younger – 2-3 weeks.
- Elderly patients – 6-8 weeks.
- Condylar fractures – 2-4 weeks.

Open Reduction

- Implies accessing the fracture through skin or mucosa to aid in visualization and reduction of the fracture.
- Indications:
  - Unfavorable/unstable mandibular fractures.
  - Patients with multiple facial fractures that require a stable mandible for basing reconstruction.
  - Fractures of an edentulous mandible fracture with severe displacement.
  - Edentulous maxillary arch with opposing mandible fracture.
  - Delayed treatment with interposition of soft tissue that prevents closed reduction techniques to re-approximate the fragments.
  - Medically compromised patients.
  - Gastrointestinal diseases.
  - Seizure disorders.
  - Compromised pulmonary health.
  - Mental retardation.
  - Nutritional disturbances.
  - Substance abuse patients.

Contraindications for Open Reduction
- If a simpler method of repair is available, maybe better to proceed with those options.
- Severely comminuted fractures.
- Patients with healing problems (radiation, chronic steroid use, transplant patients).
- Mandible fractures that are grossly infected.

Edentulous Mandible Fractures

- Biomechanics differ for edentulous fractures compared dentate mandible fractures:
  - Decreased bone height leads to a decreased buttressing effect (alters plate selection).

  - Significant bony resorption in the body region.
  - Significant effect of muscular pull, especially the digastric muscles.
  - Incidence of fractures highest in the body.
  - Atrophy creates saddle defects in the body.
- Biological differences:
  - Decreased inferior alveolar artery (centrifugal) blood flow.
  - Dependent on periosteal (centripetal) blood flow.
  - Medical conditions that delay healing.
  - Decreased ability to heal with age.
- Closed Reduction.
  - Use of circummandibular wires fixated to the piriform rims and circumzygomatic wires with patient's denture or Gunning style splints.
  - Requires IMF – usually longer periods due to age.
- Open Reduction Techniques:
  - Treat mandible >20 mm as dentate mandible.
  - Requires load bearing type plates.
  - Due to poor healing quality of bone and reduced osteoprogenitor cells, bone grafts are commonly incorporated to transplant osteocompetent cells and augment mandible.
  - Reduction may be aided by the adaptation of miniplates at the inferior border.

Condylar Process Fractures

- Usually unilateral, and from indirect trauma from the opposite side of insult.
- Will have ipsilateral premature closure and midline pull on side of the fracture.

Classifications:

- Wassmund Scheme [2]:
  - I – minimal displacement of the head (10–45°).
  - II – fracture with tearing of medial joint capsule (45–90°), bone still contacting.
  - III – bone fragments not contacting, condylar head outside of capsule medially and anteriorly displaced.
  - IV – head is anterior to the articular eminence.
  - V – vertical or oblique fractures through the condylar head.
- Condylar fractures (AO classification – see Fig. 7.2):
- Goals of condylar fracture repair:
  - Pain-free mouth opening with an opening of 40 mm or greater.
  - Good mandibular motion of jaw on all excursions.
  - Restoration of pre-injury occlusion.
  - Stable TMJs.
  - Good facial and jaw symmetry.

Treatment Options for Condylar Fractures

- Non-surgical – diet, observation, and physical therapy.
- Closed Reduction:
  - Treated with a short course of IMF with post-operative physical therapy.
- Open Reduction [3]:
  - Zide's Absolute Indications:
    (1) Middle cranial fossa involvement with disability.
    (2) Inability to achieve occlusion with closed reduction.
    (3) Invasion of joint space by a foreign body.
    (4) Lateral capsule violation and displacement.
  - Zide's Relative Indications:
    (1) Bilateral condylar fractures where the vertical facial height needs to be restored.
    (2) Associated injuries that dictate early or immediate function.
    (3) Medical conditions that indicate open procedures.
    (4) Delayed treatment with misalignment of segments.

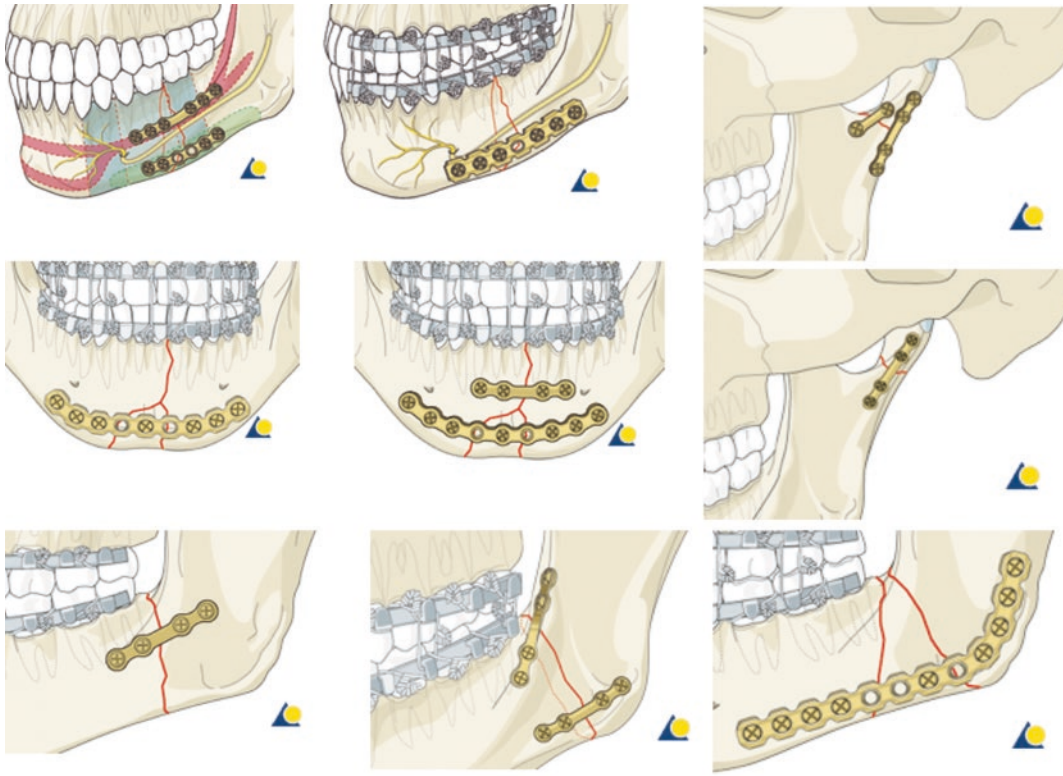

Fig. 7.2 AO Classification of Condyle Fractures. The condylar neck region can be divided into high and low halves by equally dividing the distance between the sigmoid notch line and the lateral pole line. (Copyrighted by AO Foundation, Switzerland)

- Closed reduction techniques rarely produce pain, limit function, or produce growth disturbances.
- Open reductions techniques show an early return to normal function, but are technique sensitive, time extensive, and can lead to facial nerve dysfunction depending upon surgical approach.

Teeth in the Line of Fracture

Generally accepted tooth to be removed if:

- Gross mobility.
- Periapical pathology.
- Preventing reduction.
- Roots with a fracture.
- Exposed root.
- Delay in repair from time of fracture.
- Recurrent infection at the fracture site despite antibiotic therapy.

Complications

Malunion – Fracture that has healed in non-anatomic alignment. More common when complex fractured with multiple segments. May also be due to occlusion that is forced into position, loose IMF, inadequate reduction, or poor adaptation of a fixation plate. If there are minor dental discrepancies, orthodontic or occlusal adjustments can be used as treatment. Early recognition may allow for breaking down hardware and proper alignment. Late identification can mean osteotomies at the fracture sites or orthognathic

concepts with surgical stents to reestablish occlusal and facial qualities.

Non-union – Arrested healing after the appropriate time has passed (mobility after 4 weeks without treatment and 8 weeks with surgical management). Can be multifactorial but includes mobility at the fracture site, poor reduction, infection, substance abuse, delay in treatment, or tooth in line of fracture. Diagnosis is characterized by persistent pain, mottled bone at the fracture site, mobility of mandible, and sign of hardware loosening/failure. Treatment occurs after infections are controlled and oral/cutaneous communications have closed. Establish occlusion and a rigid fixation plate is placed. Screw placement is recommended to be 1 cm from borders of segments as some bone is thought to be non-vital. The bone edges are smoothed, and commonly a cancellous bone graft is used to reconstruct the continuity defect if needed.

Osteomyelitis – Complaint of continued pain, paresthesia, feeling of the mobility of plate. Diagnosis can be made with labeled white blood cell scans (indium-111), bone scans (technetium 99), MRI, or biopsy of bone. Treatment can involve removal of hardware with closed reduction, resection/debridement/cortication of bone, placement of rigid fixation, IV antibiotics, and consideration of hyperbaric oxygen therapy.

LeFort Fractures

- Transfacial fracture of the midface, involving the maxillary bone and surrounding structures in either a horizontal, pyramidal, or transverse direction. It involves the pterygomaxillary suture and the nasal septum.
- Classified according to the experiments by anatomist Rene LeFort.

Classifications (Fig. 7.3)

LeFort I (Horizontal Fracture) – extends above the apices of the maxillary dentition across the nasal septum and maxillary sinuses. Posteriorly it extends through the pyramidal process of the palatine bone and the pterygoid processes of the sphenoid bone. It also may involve the fracture of the palate.

LeFort II (Pyramidal Fracture) – extends from the nasofrontal region down through the medial orbital wall, crossing the inferior orbital rim and zygomatic buttresses. Posteriorly similar to a LeFort I fracture.

LeFort III (Complete Craniofacial Disjunction) – fracture lines extend through the nasofrontal junctions, zygomaticofrontal articulations, zygomaticomaxillary suture, temporozygomatic suture, pterygomaxillary junction, medial and lateral orbital walls, and superior articulation of the nasal septum.

Rarely is there a pure category of fracture; usually there's a mixed combination.

Physical Exam

- Generally, look for increased facial height (equine facies), loss of anterior projection (dishpan facies). Look for edema, lacerations, contusions, hematoma formation, and ecchymosis.
- Ocular – pupils, extraocular muscle function, visual acuity, ocular pressure, subconjunctival hemorrhage, infraorbital nerve sensation, and intercanthal distance.
- Battle Sign – ecchymosis in the mastoid region, suggestive of a base of skull fracture. Can be seen in midfacial fractures due to high-energy injuries.
- Palpate – look for tenderness, crepitus, bony step deformities, mobility of segments at zygomaticofrontal and nasofrontal sutures, or maxillary mobility.
- Nasal – rhinorrhea, septal hematoma, epistaxis, mobility of nasofrontal suture.
- Intraoral exam – evaluate dentition, relative class III malocclusion, vestibular ecchymosis, tooth loss/fracture, and occlusion and anterior open bite.

Radiographic Evaluation

Maxillofacial CT with axial, coronal, and sagittal cuts. There are four key areas to evaluate.

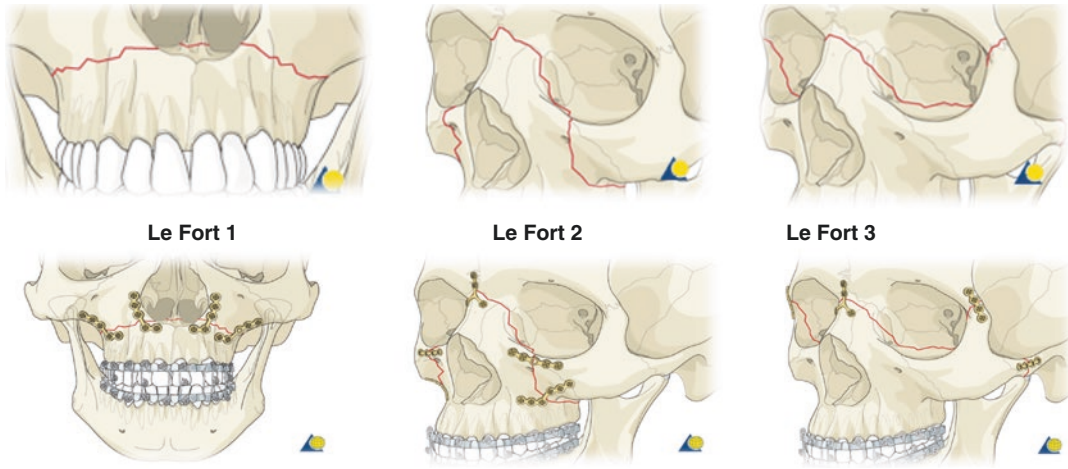

Fig. 7.3 LeFort fracture patterns and recommended plating schemes. (Copyrighted by AO Foundation, Switzerland)

- Pterygoid plates, strong indication of LeFort fracture.
- Lateral margin of nasal fossa, suggestive of LeFort I fracture.
- Inferior orbital rim, suggestive of LeFort II.
- Zygomatic arch, suggestive of LeFort III.

Principles of LeFort Fracture Management

- Nondisplaced fractures without clinical compromise can be managed by a soft diet with observation or 4–6 weeks of IMF.
- Edentulous patients may be treated with open treatment or observation.
- Treat as soon as possible. The longer open or compound fractures are untreated, the greater incidence of infection and malunion.
- Fixate fractures to allow immobilization and optimal healing.
- Use buttresses for fixation.
- Restore preoperative occlusion.
- Ensure to treat nasal complex and orbital fractures as indicated.

Approaches to LeFort I

- Access is via the transoral approach.
- Place into IMF (consider using disimpaction techniques if necessary to aid in the alignment of fractures and restoration of occlusion).
- Reduce fractures and plate stabilization at piriform rims and zygomaticomaxillary buttresses.
- Check occlusion.

Approaches to LeFort II

- Access is via transoral and/or periorbital/coronal approach.
- Place into IMF.
- Reduce fractures and plate stabilization at the piriform rim, zygomaticomaxillary buttresses, orbital rim, and management of NOE component if necessary.
- The orbital floor should be treated last after ensuring that the zygoma and the maxilla are in the proper position to prevent increased orbital volume.
- Check occlusion.
- Nasal repairs as needed.

Approaches to LeFort III

- Access is usually via a combination of the transoral, lower lid, coronal approaches.
- Good mobilization.
- Place into IMF.
- Reduce fractures ensuring restoration of adequate facial height and width.
- Fixate starting at the frontozygomatic suture, nasal region, zygomaticomaxillary but-

tresses, piriform rims, and zygomatic arch as needed.
- Check occlusion.
- Reduce/reconstruct orbit.
- Nasal reduction as needed.

Description of the Maxillary Vestibular Approach

- Length of the incision depends on the area of interest or extent of injury. Can be unilateral or bilateral.
- Incision is placed ~3–5 mm superior to the mucogingival junction making sure to leave adequate unattached gingiva for closure. (Usually extends posteriorly to first molar.)
- Incise through mucosa, submucosa, and periosteum down to the bone using electrocautery Bovie or #15 blade.
- Subperiosteal dissection superiorly and anteriorly to piriform buttress and posterior to zygomaticomaxillary buttress.
- May encounter infraorbital canal and neurovascular bundle if dissection extends enough superiorly.
- If necessary, may need to dissect nasal mucosa from the lateral wall, floor, or septum using a Freer elevator.

Complications

- *Malocclusion Noted After IMF Is Released* – Occlusion may spring open after the IMF is released. Remove fixation and then place patient back in IMF and make sure occlusion is stable and condyles are in the fossa before fixating fractures again; remove from IMF and recheck occlusion.
- *Malocclusion Noted 1 Week Postoperatively* – Most likely loss of fixation. Obtain new imaging to confirm and if fixation failed then return to OR to correct. If malocclusion is minor and fixation appears intact on imaging, then allow full healing of fractures and refer for orthodontic correction of the minor malocclusion.
- *Bleeding During Mobilization of the Maxilla* – If from the pterygoid muscles at posterior maxilla, then treat with surgicel or fibrin sealants. If from the pterygoid plexus, then treat with local anesthesia and packing. If from the terminal branches of the maxillary artery (descending palatine, PSA, or sphenopalatine arteries) treat with vessel clips and/or anterior and posterior nasal packs. If local hemostatic measures are used and bleeding is still not controlled, then consider embolization with interventional radiology. Late bleeding may occur due to pseudoaneurysm formation.
- *Malunion* – May require osteotomies or onlay grafting to address the resulting anatomical anomaly.
- *Nonunion* – Continual mobility noted after 8 weeks after the fixation has been placed. May require removal of faulty fixation, bone grafting, and placement of rigid internal fixation.

Zygomaticomaxillary Complex (ZMC) Fractures

- The zygoma has four articulations (frontozygomatic, zygomaticomaxillary, zygomaticosphenoid, and zygomaticotemporal). These sutures represent common areas of fracture points.
- It should be noted that the weakest portion of the zygomatic arch is not the zygomaticotemporal suture, but a point approximately 1.5 cm posterior to this suture.

Classification of ZMC Fractures

- The most commonly quoted is Knight and North, based on the direction of displacement on a Water's view radiograph.
  - Group 1 – nondisplaced.
  - Group 2 – arch fractures.
  - Group 3 – unrotated.

  - Group 4 – medially rotated.
  - Group 5 – lateral rotation outward.
  - Group 6 – complex fractures.
- Zingg Classification based on review of CT scans.
  - Type A fractures are incomplete zygomaticomaxillary complex and broken into three subcategories:
    - A1 – Isolated arch fracture.
    - A2 – Isolated lateral wall.
    - A3 – Isolated inferior orbital rim.
  - Type B – monofragment with all four buttresses.
  - Type C – comminution of zygomatic bone.

Physical Exam

- ZMC fractures are also orbital fractures. An ocular exam is imperative including visual acuity, assessment of extraocular muscles in the six cardinal fields of gaze, integrity of rim, ecchymosis, hyphema, shape of pupil (traumatic mydriasis or iridodialysis), reactivity of pupil, size of pupil, subconjunctival ecchymosis, periorbital edema/ecchymosis, and chemosis and position of the globe. Deepening of the supratarsal crease is one of the earliest signs of enophthalmos.
- Flattening of the malar eminence. Decreased projection is best assessed from a bird's eye view.
- Depression in the preauricular region denoting flattening of the zygomatic arch.
- Antimongoloid slanting (due to disruption of the frontozygomatic suture and inferior displacement of Whitnall's tubercle).
- Neurological disturbances over the distribution of the infraorbital nerve.
- Step deformities denoting discontinuity of the orbital rim, zygomaticomaxillary buttress, and frontozygomatic region.
- Ecchymosis in the maxillary vestibule (Guerin's sign).
- Trismus if coronoid is impinged and possibly spasm of masseter.
- Pupillary level – fracture of orbital floor allows for displacement of suspensory ligaments and Tenon's capsule causing hypoglobus of the affected side.

Radiographic Evaluation

- CT is the gold standard for evaluation of ZMC fractures. It allows for the visualization of all buttresses and to assess the degree of displacement and/or comminution. It also allows for assessing the orbital floor, muscle entrapment, and the integrity of the globe.
- CT scans obviate the need for plain radiographs.
- Plain radiographs that were used in the past for assessing ZMC fractures were the Caldwell and Submentovertex views (submentovertex views are still used intraoperatively to assess adequate reduction of the zygomatic arch).

Management of Zygomatic Fractures

Zygomatic Arch Fractures

- Isolated zygomatic arch fractures can be approached via a Keen or Gillies approach.
- Some surgeons wire/suture a finger splint or Fox shield over the arch to maintain reduction while healing.
- Closed reduction has also been described using a towel clip to aid reduction.
- ORIF of zygomatic arch fractures. Not performed for isolated arch fractures. Usually stabilized with miniplates as part of a high-impact ZMC fracture or a panfacial fracture.

ZMC Fractures

- It is important to employ a systematic sequence when treating ZMC fractures. Multiple approaches are necessary to expose

the frontozygomatic, zygomaticomaxillary, orbital rim, and orbital floor regions. Minimum two points of fixation are required.
- Recommended sequencing of fixation:
  - Fixate the frontozygomatic region first to restore facial height of the complex.
  - Fixate the zygomaticomaxillary buttress region to restore facial projection and to ensure that the medially rotated body is back in its normal anatomical position.
  - Fixate the orbital rim to define orbital volume and facial volume.
  - The orbital floor should be managed last as it is critical that the aforementioned sites are placed back into alignment to prevent enophthalmos and facial widening.
- Alignment of the sphenozygomatic suture is a good indicator of the three-dimensional position of the zygoma.

Complications

Malunion/Asymmetry – May result in facial widening and/or malar flattening. Can be managed by osteotomies (difficult due to lack of bony landmarks), onlay grafts, alloplastic implants, or a combination of the aforementioned. Consider navigational instrumentation when using custom implants.

Enophthalmos – Due to increase in orbital volume or atrophy of fat. Posttraumatic enophthalmos is difficult to manage. Requires placement of space-occupying material such as bone or prosthetic material behind the globe to displace it anterior. Consider custom implant.

Blindness – Rare but devastating either by direct trauma to globe or retrobulbar hematoma. In retrobulbar hematoma, the patient will have pain, proptosis, elevated intraocular pressure, and decrease in visual perception (first decrease in red-green color perception followed by decreased visual acuity).

Retrobulbar Hemorrhage – Managed by a lateral canthotomy or by reopening the surgical wound used for periorbital access to allow for decompression.

Vertical Dystopia – Reconstitution of orbital floor height with autogenous bone, alloplastic implant, or custom plate.

Orbital Fractures

Anatomy

- Quadrilateral/pyramidal bony cavity with base facing anteriorly. The widest dimension is 1 cm posterior to the orbital rim.
- Volume: 30 ml, 4 cm horizontal dimension, 3.5 cm vertical on average [4].
- Medial walls parallel to each other; lateral walls at 90 degrees to each other. Lateral wall to medial wall 45 degrees. (Fig. 7.4).

Bones of the Orbits

- Orbital roof (two bones): Frontal and lesser wings of sphenoid.
- Lateral wall (two bones): Greater wing of sphenoid and zygomatic bone.
- Orbital floor (three bones): Maxillary bone, zygomatic bone, and palatine bone.
- Medial wall (four bones): Frontal process of maxillary, ethmoid (lamina papyracea), lacrimal and sphenoid bones.

Anatomic Landmarks

- Inferior orbital fissure gives rise to the infraorbital groove at about 2.5–3.0 cm posterior to the orbital rim; exits the infraorbital foramen about 5 mm below the infraorbital rim.
- Superior orbital fissure: CN III, IV, VI, sensory nerve V1, sympathetic fibers, superior ophthalmic vein, recurrent and middle meningeal artery.
  - Separates the greater and lesser wings of the sphenoid.
  - Delineates between orbital roof and lateral orbital wall.

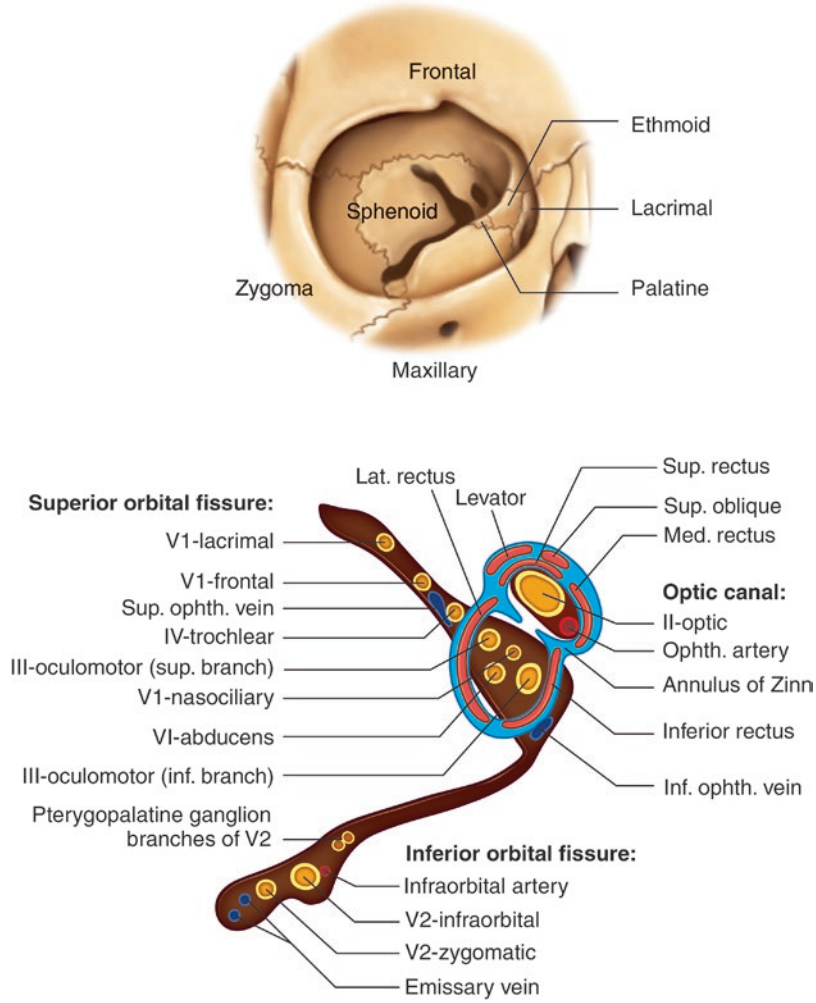

Fig. 7.4 Anatomy of the orbit and its contents. (Reprinted with permission from Bevans and Moe [4])

- Inferior orbital fissure: sensory nerve V2, parasympathetic branch of pterygopalatine ganglion and inferior ophthalmic vein.
- Optic canal: optic nerve, ophthalmic artery, and sympathetic fibers.
- Whitnall's tubercle: located 10 mm below the FZ suture and 3–4 mm inside the lateral orbital rim. Attachments (1) lateral horn of levator aponeurosis, (2) lateral canthal tendon of the eyelids, (3) Lockwood's ligament, (4) check ligaments. All four of these comprise the lateral retinaculum.
- Annulus of Zinn: a tendinous ring of fibrous tissue at the apex of the orbit surrounding the optic nerve that is the origin of the rectus muscles of the eye.
- Safe Dissection: All measurements are from an intact anterior lacrimal crest. Anterior ethmoidal foramen 24 mm, posterior ethmoidal foramen 36 mm, optic foramen 42 mm [4].

Eye Lid Anatomy

- Layers of the eye (skin, subcutaneous tissue, orbicularis oculi, septum, tarsal plate, conjunctiva) (See Fig. 7.5).
- Orbital septum: dense connective tissue arising from the orbital periosteum; forms the anterior boundary of the orbit. 1–2 mm below the infraorbital rim, it fuses with an area of thickened periosteum known as the *arcus marginalis.*

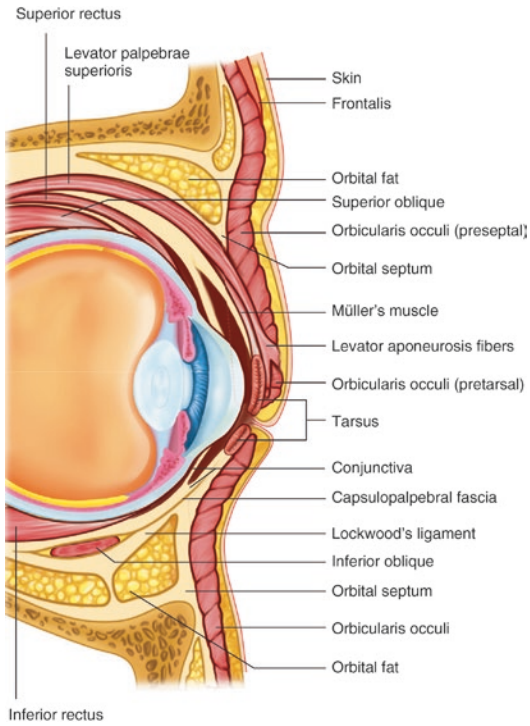

Fig. 7.5 Sagittal view of the orbital soft tissues. (Reprinted with permission from Bevans and Moe [4])

- Tarsus: dense fibroconnective tissue; approximately 1–1.5 mm thick, approximately 25 mm in horizontal length.
  - Upper eyelid: 10–12 mm in height.
  - Lower eyelid: 3–5 mm in height.
  - Contains meibomian glands which form lipid layer of tears.
- Orbicularis oculi (CN VII).
  - Palpebral (pretarsal, preseptal): reflex eyelid closure.
  - Orbital (covers orbital rims): forceful voluntary eyelid closure.
- Levator palpebrae superioris (CN III): main retractor of upper eyelid.
- Muller's (superior tarsal) muscle (sympathetic): responsible for the tone of the upper eyelid, ~2 mm of lift; minor retractor of the upper eyelid.
- Whitnall's ligament.
  - Supports the superior anterior eyelid; provides vertical support for the orbit.
  - Inserts superomedially on the frontal bone behind the trochlea; inserts superolaterally near the frontozygomatic suture.
  - Key landmark that marks the transition from levator muscle to aponeurosis (at the junction of the levator muscle and aponeurosis).
- Capsulopalpebral fascia: main retractor of the lower eyelid; terminal extension of the inferior rectus muscle.
- Inferior tarsal muscle (sympathetic): minor retractor of the lower eyelid.
- Lockwood's ligament.
  - Lower lid counterpart to Whitnall's ligament (formed by conjoined fascia of inferior rectus and inferior oblique muscles).
  - Inserts on the medial and lateral canthal ligaments as well as the bony orbital rim.
- Medial canthal ligament (tripartite attachment).
  - Anteriorly inserts onto maxillary bone, posteriorly onto posterior lacrimal crest, superiorly onto orbital process of frontal bone.
- Lateral canthal ligament.
  - Inserts onto Whitnall's tubercle (zygomatic bone) 2–3 mm inside the lateral orbital rim, 1 cm inferior to the frontozygomatic suture.
- Nasolacrimal duct opens into the inferior meatus of the nasal cavity 10 mm behind the nasal aperture; reflux of tears is prevented by Hasner's valve.

Terminology

- Anisocoria – different sizes of the pupils.
- Diplopia – double vision. May be monocular (concern for retinal attachment or lens dislocation) or binocular (unequal movement of eyes usually due to edema or possible entrapment).
- Enophthalmos – inward positioning of the globe, usually due to increased volume of orbit.
- Exophthalmos – outward positioning of the globe, usually due to edema but concern for hematoma or in-fracture versus out-fracture of orbit walls.
- Hyperglobus – superior positioning of the globe.
- Hypoglobus – inferior positioning of the globe.

- Hypertropia – misalignment of eyes, a form of vertical strabismus.
- Proptosis – synonymous with exophthalmos.
- Ptosis – drooping of the eyelid.

Evaluation

- History, mechanism of injury: High velocity/low velocity; in high-velocity injuries increased concern for penetrating globe injuries, concomitant injuries such as head, spine, or NOE, etc.

Physical Evaluation

- Inspection – look for edema, ecchymosis, subconjunctival hemorrhage, and proptosis.
- Evaluate for exophthalmos; Hertel (based off zygomaticofrontal suture) or Naugle exophthalmometers (based off of the frontal bone, more useful when lateral orbital rim involved).
- Palpation – used to assess the presence of bony discontinuity/steps indicative of fracture.
- Visual acuity (Snellen chart), visual fields (Goldman chart, confrontation), pupils (afferent pupillary defect), EOM (entrapment, forced duction test to r/o incarceration of orbital contents, diplopia in forward gaze is of most concern), slit lamp (Wood's lamp (cobalt blue) for corneal injury), fundoscopic (vitreous or retinal hemorrhage), tonometry pen (pressures normal 10–20 mmHg).
- Confrontation exam: Testing the visual fields consists of confrontation field testing in which each eye is tested separately to assess the extent of the peripheral field. To perform the test, the individual occludes one eye while fixated on the examiner's eye with the non-occluded eye. The patient is then asked to count the number of fingers that are briefly flashed in each of the four quadrants.
- Sensory changes in infraorbital distribution, document sensory testing level.
- Intraocular injuries – shape of lens, traumatic iritis, hyphema, angle recession, commotio retinae/Berlin's edema, vitreous hemorrhage, retinal tears/holes/detachments.
- Muscle entrapment. Ductions can illicit nausea, vomiting, and bradycardia due to oculocardiac reflex. In children, be cautious of a "white eyed" blowout fracture.

Radiological Examination

- A helical CT w/o contrast scanning with 1–3 mm cuts in axial and coronal planes with soft tissue and bone windows.
- Useful to identify craniofacial deformities, globe and optic nerve integrity, orbital foreign bodies (metallic), and diagnosing a retrobulbar hemorrhage.
- MRI – Poor bony details but can aid in globe trauma or foreign body detection.

Classification

- Linear: fractures maintain periosteal attachment and do not result in a defect with orbital content herniation.
- Blow-out: most common; limited to one wall and typically 2 cm or less in diameter. Infraorbital rim remains intact.
- Complex: extensive fracture involving 2 or more walls.

Management

- Consider ophthalmology evaluation to document globe or vision concerns.
- Most fractures may be observed for 2 weeks for resolution of motility disturbance resulting from edema, hemorrhage, or rectus muscle contusion.
- Indications for fracture repair:
  - Large orbital fractures >50% orbital floor; enophthalmos >2 mm, diplopia in primary gaze.
  - Asymptomatic patients without the aforementioned signs and symptoms – observation.
  - Muscle incarceration is a true emergency as entrapped tissue will become ischemic.

Signs of oculocardiac reflex require emergent surgical intervention.
- Consider antibiotics (with sinus coverage), sinus precautions, nasal decongestants, ice packs, and head of bed elevation.
- If status of one eye is blinded, be more guarded to operate.

Surgical Approaches

1. Transconjunctival:
   - Lower rate of eyelid malposition.
   - Direct access to the orbital floor can be extended with a lateral canthotomy and transcaruncular incision to get wide access to lateral and medial walls.

Technique:
- A corneal shield with ophthalmic-grade bacitracin/ocular lubricant is placed on the globe.
- Local with vasoconstrictor is injected under the conjunctiva to aid in hemostasis as well as around the lateral canthus if lateral canthotomy is planned.
- Using a 15 blade, a sharp incision is made through the lateral canthus. The tip of an iris scissor is placed inside the palpebral fissure, extending laterally to the depth of the underlying lateral orbital rim (lateral extension should not exceed 7 mm, ensuring a safe distance from the temporal branch of the facial nerve). The scissors are used to cut horizontally through the lateral palpebral fissure (incising through skin, orbicularis muscle, orbital septum, lateral canthal tendon, and conjunctiva).
- Using the lateral orbital rim as a stop, inferior cantholysis is performed by turning the orientation of the scissors vertically to incise the inferior canthal ligament.
- The conjunctiva is approached using blunt-tipped pointed scissors to dissect through the small incision through the conjunctiva, made during the lateral canthotomy. The conjunctiva is bluntly undermined over the orbital septum and extended as far medially (3 mm away from the caruncle).
- Scissors are then used to incise the conjunctiva below the curvature of the tarsal plate. (2 5–0 nylon traction sutures may be used through the cut edge of the bulbar conjunctiva to assist in retraction and to hold the corneal shield in place.)
- The inferior bony orbit is palpated. With retraction of the orbital contents and the lower lid, the dissection continues to the orbital rim, taking care to stay lateral to the lacrimal sac.
- Periosteal elevators are used to strip the periosteum over the orbital rim, anterior surface of the maxilla, zygoma, and orbital floor.
- A broad malleable retractor is placed to protect the orbit and to confine any herniating periorbital fat.
- After exploring the orbit, releasing entrapped tissue, and identifying the bony landings, the orbital floor is reconstructed to support the globe contents.
- Forced duction test is used to ensure uninhibited mobility of globe.
- A 4–0 Vicryl® is used to reattach the lower limb of the lateral canthal tendon.
- Subcutaneous sutures and 6–0 skin suture are placed along the horizontal lateral canthotomy.
- Some surgeons reapproximate the bulbar conjunctiva with 6–0 fast gut suture in a single or running fashion suture.

2. Subciliary:
   - Good access to floor.
   - Higher incidence of scarring, ectropion/entropion.
   - The skin incision is made 2 mm below the gray line. There are three approaches for dissection down to the orbital rim with the subciliary approach.
     - 1. Skin.
     - 2. Deep to the orbicularis oculi muscle (skin-muscle flap).
     - 3. Step dissection.
   - It is more common to utilize a skin-muscle flap, as it is less likely to lead to a lid malposition after healing. Violating the orbital septum integrity leads to a higher risk of vertical lid shortening.

Technique:

- A corneal shield with ophthalmic-grade bacitracin/ocular lubricant is placed on the globe.
- The skin incision is made 2 mm below the gray line.
- The path of dissection deep to the orbicularis oculi muscle includes the pretarsal orbicularis muscle in the elevated skin muscle flap if the skin incision is placed across the tarsus.
- With the skin muscle flap and the step technique, maintaining the integrity of the orbital septum is paramount. The incision through the periosteum for entry into the floor of the orbit is made beneath the infraorbital rim (3 mm below).
- A subperiosteal dissection is accomplished posteriorly exposing the orbital walls.
- Periosteal elevators are used to expose the orbital floor, release entrapped tissue, and identify stable margins.
- A broad malleable retractor is placed to protect the orbit and to confine any herniating periorbital fat.
- After exploring the orbit, releasing entrapped tissue, and identifying the bony landings, the orbital floor is reconstructed to support the globe and its contents.
- Closure is usually performed in two layers. The periosteum is reapproximated with a resorbable suture. The skin is then closed with a 6–0 non-resorbable or fast-resorbing suture.

Complications

Orbital Implant Infection – implant removal, culture and start antibiotics.

Implant Migration or Extrusion Early – repositioning with additional fixation.

Implant Migration or Extrusion Late – requires implant removal.

Ectropion – due to shortening of the anterior lamellae. May require tarsal strip.

Entropion – due to shortening of the posterior lamellae. May require Quickert-Rathbun suturing technique (passing a gut suture through the inferior fornix anteriorly toward the lashes). Severe cases may require grafting with oral mucosa.

Persistent Enophthalmos – due to improper position of implant, fat atrophy, and tissue loss.

Sympathetic Ophthalmia – injury-induced autoantibodies to uveal tissue; ~80% occur within 3 months.

- Treatment options include:
  - Enucleation: entire removal of globe without rupture.
  - Evisceration: leave the sclera +/− cornea.
  - Exenteration: entire contents of the orbit.

Retrobulbar Hemorrhage – 1% incidence, signs/symptoms: pain, proptosis, decreased visual acuity, increased intraocular pressure, and ophthalmoplegia.

- Manage medically with IV infusion 20% mannitol 2 g/kg to shrink the vitreous humor, acetazolamide (Diamox ®) 500 mg bid, or steroids.
- Manage surgically with lateral canthotomy with cantholysis.

Nasolacrimal Duct Injury

- Jones I test: few drops of fluorescence dye or propofol in the lower conjunctival sac, observe for fluorescein/propofol in the nose. If not identified, perform Jones II test.
- Jones II test: irrigate the punctum and inject fluorescein into the (SAC) puncta/canaliculi.
  - If fluorescein is seen, then the blockage is after the lacrimal sac; if not, then the blockage is near the punctum or canaliculus.
- If a laceration is present and visible, early repair is advocated, but reasonable to wait 3–6 months if no laceration is present.
- Primary repair: dilate with bowman probe, place stent (Crawford tube, Jackson tube) through the puncta and nasolacrimal duct opening in the nose, suture both ends with 8–0 PDS sutures, and leave the stent for 3 months.
- Secondary repair: dacryocystorhinostomy; the goal is to create a bony window between the lacrimal sac and nose.

Corneal Abrasions – Symptoms: pain, tearing, photophobia, foreign body sensation, treatment with topical antibiotics.

Hyphema – Bleeding from torn vessels at the root of the iris in the anterior chamber; signs/symptoms: positional blurred vision, photophobia.

- Grade 1: ¼ of anterior chamber; Grade 2: ½; Grade 3: ¾; Grade 4: complete coverage of the anterior chamber, aka blackball or 8-ball hyphema.
- Manage with atropine 1% ophthalmic drops bid/qid (dilates pupil and immobilizes the iris to prevent further bleeding), timolol ophthalmic drops bid (beta-blocker to decrease intraocular pressure, acetazolamide 500 mg PO bid (carbonic anhydrase inhibitor, IOP > 35 mm Hg), steroids, bed rest with HOB elevated.
- Complications: 2.5% to 38% re-bleeding most common 2–5 days post-injury; glaucoma after one year; corneal blood staining in 5% [5].

Afferent Pupillary Defect (Marcus Gunn pupil) – Swinging-flashlight test: light in the affected eye produces mild to no consensual light pupillary reflex; then swinging light to normal eye produces equal constriction; then swinging light to affected eye produces dilation during direct light stimulation.

Traumatic Optic Neuropathy – Decreased vision in the affected eye; ipsilateral afferent pupillary defect.

- Thought to be due to vascular insufficiency; goal is to reduce microvascular spasm and soft tissue edema.
- Treatment with large dose steroids (methylprednisolone 30 mg/kg IV loading dose, then 5.4 mg/kg/hr. IV infusion for 23 hours) within 8 hrs.

Traumatic Mydriasis – Pupillary dilation due to interruption of the parasympathetic innervation.

- Results in anisocoria; treatment with 2% prilocaine; may resolve over several days or weeks.

Traumatic Iritis – Inflammation of the anterior chamber of the eye, onset within 3 days of trauma.

- Symptoms: dull pain, tearing, and photophobia.
- Treatment with cycloplegic agents: scopolamine 0.25 or cyclopentolate 2%.

Horner's Syndrome – injury to sympathetic nerves supplying the globe.

- Triad of signs: (1) miosis (unopposed parasympathetic), (2) eyelid ptosis (decreased Muller's muscle tone), (3) anhidrosis (sweat glands).
- Diagnosis: 4% cocaine drops to the affected eye fails to dilate compared to the unaffected pupil.

Superior Orbital Fissure Syndrome – Ophthalmoplegia (CN III, IV, VI), lid ptosis (CN III), mydriasis and loss of direct pupillary light reflex (CN III parasympathetic fibers). Treatment is dependent on etiology. Retrobulbar hematoma (see above). If superior orbital fissure narrowed in the setting of fractures, then surgical intervention for the displaced fracture segments is required. IR may be indicated in the setting of a carotid-cavernous fistula. Ophthalmology and neurosurgery should be consulted as an intracranial/transethmoidal approach may be indicated should decompression in the posterior orbit be necessary.

Orbital Apex Syndrome – Superior orbital fissure syndrome + injury to CN II (loss of vision and direct and consensual pupillary light reflex). Treatment is dependent on etiology. Retrobulbar hematoma (see above). IR may be indicated in the setting of a carotid-cavernous fistula. If superior orbital fissure narrowed in the setting of fractures, then surgical intervention for the displaced fracture segments is required. Ophthalmology and neurosurgery should be consulted as an intracranial/transethmoidal approach may be indicated should decompression in the posterior orbit be necessary.

Naso-Orbito-Ethmoid (NOE) Fractures

NOE anatomy – the NOE complex consists of the nasal bones, frontal processes of the maxilla, nasal process of the frontal bone, and the medial orbital wall (comprised of the lacrimal bone and ethmoid bones).

Manson and Markowitz Classification

Based on the condition of the central fragment (frontal process of the maxilla) and the medial canthal tendon.

- Type I – no comminution of the central fragment and the tendon is intact.
- Type II – comminution of the central fragment and the tendon is intact.
- Type III – severe comminution of the central fragment and the tendon is avulsed.

Imaging

- CT scan is the most valuable tool for assessment with axial and coronal view 1.5 mm slices. Axial cuts can aid in the diagnosis of the status of the frontal sinus and the medial canthal tendon.

Physical Evaluation

- Depressed nasal dorsum (saddle nose deformity).
- Crepitus.
- Telecanthus – intercanthal distance should be coincident with the width of the alar bases. Clinician would perform the bow-string test to confirm disruption of the medial canthal tendon. Intercanthal distance varies between ages, races, and gender. Normal range for a white adult is 28–35 mm. Intercanthal distances greater than 35 mm are suggestive of medial canthus involvement and 40 mm or more are diagnostic for traumatic telecanthus.
- Almond-shaped eyes – due to the detachment of medial canthus.
- Periorbital edema and ecchymosis.
- Anosmia – damage to cribriform plate leading to damage of olfactory nerves.
- Paresthesia/anesthesia along distribution of the infraorbital nerve.
- Epiphora – occurs due to obstruction within the nasolacrimal apparatus. Jones I and Jones II tests. Early onset may be due to swelling.
- Enophthalmos (remember the medial wall being involved can also lead to increased orbital volume).
- Epistaxis.
- Rhinorrhea – CSF leak noted as thin blood-tinged discharge from nose. Test for beta-2 transferrin. May also send sample for glucose and chloride level. Chloride is usually greater and glucose is less than serum. Halo test involves placing a drop of the bloody rhinorrhea on filter paper and seeing a center of blood and a straw-colored halo.

Treatment:

- As the name implies, nasal and orbital treatment is required in these fractures.
- Type I and type II fractures are treated by securing the main fragment(s) in an anatomically reduced position.
- Type III fractures require a canthopexy with a posterior superior vector.
- Approaches usually include overlying laceration, orbital approaches, and coronal approaches.

Nasal Dorsal Augmentation/ Reconstruction

- Often the dorsal nasal bones need reconstruction due to weak support. This is seen as a saddle nose deformity with or without flattening of the nasal dorsum.
- Treatment is commonly done with the outer cortex of the calvarium as it is relatively flat

and easily recontoured. It is stabilized by a small bone plate.
- Extension of bone graft should reach region of lower lateral cartilages for nasal tip support.

Management of the Avulsed Medial Canthal Tendon via Canthopexy

- Transnasal wiring technique. The vector of fixation is posterior and superior to the lacrimal fossa.
- Suturing the tendon to a miniplate in the NOE region. A non-resorbable suture is used and the vector of fixation is posterior and superior to the lacrimal fossa.
- Mitek anchoring procedure – use of suture anchoring device for management of medial canthal tendon. The vector of fixation is posterior and superior.

Complications

Dacryocystitis – infection of lacrimal sac due to obstruction. Treatment with antibiotics such as penicillin-based drugs.

Epiphora – first attempt lower lid massage; if no improvement, dacryocystorhinostomy should be considered. In this procedure, an incision is placed 6 mm from the medial canthal angle and dissection is carried to the lacrimal sac. An H incision is made in the nasal soft tissue and lacrimal sac. The posterior flaps are sutured together. The puncta are intubated with a Crawford tube and passed through the openings of the nose. The ends of the Crawford tube are tied and the anterior flaps of the nasal mucosa and lacrimal sac are sutured together. The orbicularis muscle and skin are closed. The stent is left in place for 3–6 months.

Nasal Fractures

- Nasal bones are the most commonly fractured facial bones in adults.
- Paired nasal bones are attached superiorly to frontal bone and laterally to the frontal processes of the maxilla.
- The inferior attachment of the nasal bones is to the upper lateral cartilage.
- Nasal septum rests on the nasal crest of maxilla.
- Nasal septum is thick posteriorly along the bony junction with vomer and ethmoid bones.
- Kiesslebach's plexus, located along the anterior aspect of the septum, is the confluence of anterior ethmoidal artery, posterior ethmoidal artery, nasopalatine artery, and septal branch of the superior labial artery; the plexus is the most common site of epistaxis.

Physical Evaluation

- Swelling.
- Bruising around mid-face.
- Epistaxis (anterior and posterior nasal bleeding).
- Deviation of nasal complex.
- Mobility of nasal complex upon digital manipulation.
- Difficulty in breathing (congestion).
- Numbness of midface.
- Peri-nasal lacerations.
- Loss of nasal projection (especially true with naso-orbital-ethmoid fractures).
- Anosmia.
- Trauma to the nose can also create trauma to the nasal septum; septal hematoma can occur with nasal trauma and must be evaluated and treated immediately; the nasal septum is the major source of support for the nasal complex.
- It is always advisable to inquire about previous nasal fractures or the appearance of the nasal complex prior to injury (i.e., looking at the driver's license photograph of the patient).

Radiographic Evaluation

- Computed tomography without contrast is the imaging modality of choice for initial evaluation; plain X-rays are acceptable but only in isolated cases and clearly do not offer as much information as a CT scan.

Treatment

- Fractures of the nasal bone can be treated with closed or open reduction under general anesthesia.
- If treated within the first 10–14 days following injury, most nasal fractures can be appropriately and predictably treated with closed reduction.
- Closed reduction involves administration of a vasoconstrictor into the nasal cavity and then digitally, or through the aid of appropriate instrumentation (e.g., Boise elevator), reducing the nasal bones in their appropriate premorbid state.
- If a septal hematoma is present, it must be drained immediately at the time of the initial evaluation; otherwise, collection of blood between the septal cartilage and the mucoperichondrium will eliminate the only source of blood supply to the cartilage, resulting in cartilage necrosis and future saddle nose deformity.
- Oftentimes, the nasal septum is also displaced and requires appropriate reduction back on the crest of the maxilla.
- Open reduction of nasal fractures may be required when the injury is older than 10–14 days and the nasal bones can no longer be manipulated easily.
- Open reduction requires incision within the nose in order to perform osteotomies (endonasal lateral osteotomy) or accessing the fracture sites through existing lacerations in order to reduce fractures.
- Internal fixation of nasal bones with titanium plates and screws is seldom performed in isolated cases of nasal fracture.
- Placement of nasal packing or intranasal splints is advisable to maintain the reduction and to aid in hemostasis.
- External splints along the dorsum are also useful in order to maintain the external architecture of the nose during the healing period.
- If internal packing is used, systemic antibiotics should be administered for a few days.

Post-operative Management

- External and internal packings are typically removed within the first 7 days following repair.
- Systemic decongestant and nasal saline rinses can be used in the post-operative phase.
- Topical nasal decongestants should not be used for longer than 48 hours; chronic use of nasal decongestants interfere with normal nasal mucosal thickness and increase the need for frequent usage (rhinitis medicamentosa, aka rebound nasal congestion).
- Persistent nasal edema and swelling should be expected; typically, majority of the swelling is resolved in the first few weeks after surgery.
- Normal nasal function and airflow will be impaired for the first few weeks; patients need to be reassured of this possibility.
- Persistent nasal airflow obstruction and/or nasal complex deviation beyond 2–3 months will require a post-traumatic rhinoplasty.
- Full thickness laceration, especially along the nasal tip, can compromise the vascularity of the nasal tip; therefore, open structure rhinoplasty should be delayed for 12 months to avoid tip necrosis.

Complications

Bleeding – treat with anterior and posterior nasal packs. If local hemostatic measures are used and bleeding is still not controlled, then consider embolization with interventional radiology.

Post-Traumatic Nasal Deformity – wait until 1 year after the initial surgery. Consider septorhinoplasty after 1 year.

Frontal Sinus Fracture

- Requires between 800 and 1600 lbs. of force for fracture. (Much higher than mandible, NOE, or zygoma.) Should look for other injuries.

- The mucosal fluid exits the frontal sinus through the ostium located on the posteromedial portion of the sinus floor.
- 15% of the population has a true nasofrontal duct facilitating frontal sinus drainage into the middle meatus of the nose. The remaining population drains via the hiatus semilunaris to the nasal frontal tract.
- No universally accepted classification system of frontal sinus fractures exists. However, Gonty's classification is often used, and describes the location, extent of bony injury, and associated fractures.

Gonty's Classification

- Type 1 – isolated anterior table.
- Type 2 – anterior and posterior table fractures.
- Type 3 – posterior table fracture.
- Type 4 – comminuted fracture.

Radiography

- CT scan modality of choice: axial (anterior and posterior table evaluation) and coronal (frontal recess evaluation) slices are important.
- Thin cut (1 mm), high-resolution facial CT scan with reconstructions in the axial, coronal, and sagittal planes are standard for evaluation of frontal sinus fractures.
- Head CT scan is important for the evaluation of pneumocephalus, extradural hematoma, and subarachnoid hemorrhage, which are commonly associated with frontal sinus fracture and necessitate neurosurgical consult.
- Cervical spine evaluation and potential CT or MRI imaging is important as a cervical spinal fracture or ligamentous injury should be ruled out prior to definitive management of the fracture to prevent spinal cord injury during patient positioning and/or intubation.

Physical Evaluation

- Evaluate for laceration over frontal bone (possible direct access for repair).
- Glabellar swelling.
- Depression of frontal bone (not always visible due to swelling/hematoma).
- Supraorbital numbness.
- Eyelid ecchymosis.
- Air emphysema/crepitus.
- Rhinorrhea – present as a clear or strawberry-colored fluid; however visual inspection is often limited due to the presence of blood and nasal secretions.
  - A halo test, where the fluid is dropped onto a tissue paper can reveal the presence of CSF by formation of a clear ring around the blood.
  - Samples of CSF will show high chloride, low potassium, and low glucose concentration (>30 mg/dl) compared to normal serum.
  - Intrathecal fluorescein dye injection with imaging.
  - The definitive test for CSF rhinorrhea is the beta-2 transferrin assay. Collect nasal secretions in sterile tube and send to the lab. Can be held at room temperature for 1 week without compromise of sample. The assay is based on a western blot, which takes 4 days to process. Requires 5 cc of fluid collection for accurate diagnosis.
  - β-trace protein (βTP) may also be used as a diagnostic marker, but not reliable in patients with renal deficiency or bacterial meningitis.

CSF Leak

- Management of CSF leak should be done in collaboration with a neurosurgical consult. A CSF leak typically results from a posterior table fracture with an associated dural tear. The presence of a CSF leak can be managed conservatively with observation (the use of prophylactic antibiotics is controversial).
- If the CSF leak does not resolve with observation within 7 days, neurosurgical management may include placement of a lumbar drain to decrease the intracranial pressure or direct repair of the dural tear (if the drain is not successful).

Anterior Table Fractures

- Treatment of anterior table fractures is dictated by the aesthetic deformity secondary to the fracture. In the case of nondisplaced and minimally displaced fractures, the patient can be treated with observation alone. Decongestants may be indicated to aid in sinus system pressure relief. Consider 6 week reimaging to ensure fluid levels are dissipated and frontal duct system is intact.
- Typically, displacement of the anterior table is defined as 1–2 mm, or greater than the width of the anterior table; however, there is no accepted standard.
- After addressing the timing of surgical intervention, the approach must be planned.
  - In the case of an open frontal sinus fracture, the existing soft tissue laceration(s) can typically be used to expose the fracture and extended as needed to provide adequate visualization.
  - Options for exposure of closed frontal sinus fractures include the coronal and supraorbital approaches.
  - Additional options for exposure that are used by some authors include the frontalis rhytid approach.
  - Endoscopically assisted procedures have also been described with anterior wall fractures without duct involvement.
- Resorbable plates/screws may be a good alternative, as these bones are not load bearing.

Nasofrontal Duct Involvement/ Management/Obliteration (Ablation)

- Commonly patency is tested intraoperatively by injection of dye (fluorescein, methylene blue, propofol) into the duct/tract with a large bore catheter and observation for passage into the nasal sill.
- If outflow is compromised or uncertain, a sinus obliteration procedure is recommended. The key steps include complete exposure of the sinus, obliteration of the entire mucosal surface, and addressing the frontal sinus drainage tract.
- Complete removal of the mucosa is important in order to prevent mucocele formation. Depending on the size of the sinus and fracture, osteotomies should be considered to increase access and visualization. The borders of the cavity can be visualized with illumination with a fiberoptic cord or discovered using long pickups to identify borders. Care should be taken to remove mucosa invaginated into the foramina of Breschet. Goal is to ensure a "safe sinus."
- The lining of the sinus floor, containing the mucosa of the nasofrontal ducts, is then elevated, inverted, and placed back into the infundibulum to obstruct the outflow tract. The sinus floor is then typically packed with local tissue to ensure separation of the inverted mucosa from the sinus. Typically, a small piece of temporalis fascia or muscle is used, but a thin piece of calvarium can also be harvested and trimmed for this purpose. Synthetic fibrin sealants are an alternate option for occluding the nasofrontal duct.
- The optimal method for obliteration of the remaining free space is controversial. The most common materials used are abdominal fat or iliac crest bone. Additional autologous tissues that are commonly used include fascia, muscle, and pericranium.
- The use of synthetic materials such as hydroxyapatite, methyl methacrylate, bioglass, gelfoam, etc. is less common but has also been described [6, 7]. These synthetics are not recommended due to the risk of infection from poor vascularity.
- Another commonly used and accepted technique for sinus obliteration is spontaneous osteogenesis, which occurs when the sinus cavity is left empty.

Posterior Table Fractures

- These fractures rarely occur in isolation and are typically associated with an anterior table fracture. Additionally, the sinus floor and frontal sinus drainage tract may be involved.

- Indications for non-operative management of a posterior wall fracture include non-displaced fractures without a cerebrospinal fluid (CSF) leak.
  - A non-displaced fracture with a small CSF leak may be observed for up to 7 days for resolution of the CSF leak.
  - Conservative treatment includes bed rest, stool softeners, elevation of the head of bed between 35–45 degrees, and sinus precautions. CSF leaks greater than 72 hours may require a lumbar subarachnoid drain. Those leaks lasting greater than 7 days require surgical intervention.
- A posterior table fracture is generally considered displaced if the bone has moved a distance equal to or greater than one table width.
- Options for operative treatment of a posterior table fracture include:
  - Frontal sinus obliteration with or without cranialization.
  - Frontal sinus obliteration alone can be considered in cases with a displaced posterior table fracture that involves less than 25% of the posterior table, has minimal to no comminution, and does not have an associated CSF leak [7].

Cranialization

- In the case of large or highly comminuted displaced posterior fracture fragments, a cranialization procedure should be performed.
- It involves frontal craniotomy, repair of dura, debridement of the damaged brain segment, repair of dural lacerations, removal of the posterior wall, removal of the mucosal lining of the sinus, and plugging the nasofrontal ducts; a pericranial flap is used to separate the sinus from the splanchnocranium [8].
- The brain is allowed to fill into the extradural space and the anterior table is reconstructed.

Approaches to Frontal Sinus Fractures

- If there is a division of the sinus by a septum, no treatment of the unharmed portion is necessary.
- In the case of open fractures, the most common approach is an extension of the laceration to obtain adequate exposure.
- The most common approach used for closed frontal sinus fracture is the coronal (bitemporal) approach.
- Additional options include the supraorbital, frontalis rhytid approach, the endoscopic approach, and combined open and endoscopic techniques.
- The coronal approach provides the best visualization and is ideal for bilateral frontal sinus fractures that necessitate a wide exposure.
  - This approach has an acceptable cosmetic result and the bulk of the incision is well hidden within the patient's hair.
  - Another advantage of this approach is that it facilitates harvesting of cranial bone graft if needed.

Coronal Approach Technique

- To aid in hemostasis and dissection, local anesthetic or tumescent may be used to insufflate the planned dissection.
- Consideration for hairline and lack thereof: The incision normally curves anterior at the vertex 5 cm behind the hairline. In the bald patient, consider a more posterior incision. Access is created the more inferior the incision extends, if the arches require exposure (incision may extend to the inferior portion of the ear lobule).
- The traditional initial incision is extended sharply through skin, subcutaneous tissue, and galea between the temporal lines exposing the loose areolar plane. Blunt dissection is used to elevate in all directions, but primarily anterior.
- Extension below the temporal line can be carefully completed using the subgaleal plane as a guide to bluntly dissect alongside the anterior helix. A sharp incision is made down to the instrument.
- Following the incision, additional hemostasis can be obtained with Raney clips.
- Continued exposure should be performed in the areolar tissues of the subgaleal plane. This can be developed easily with blunt dissection.

Lateral tension of the flap is due to the remaining attachments to the temporalis fascia and should be relieved to allow for anterior displacement of the flap.

- Approximately 2–3 cm superior to the supraorbital rims, the pericranium can be incised and the dissection can proceed in a subpericranial plane to obtain exposure.
- A periosteal elevator can be used at this point to continue the dissection and care should be taken to preserve the integrity of the pericranium for use as a vascularized flap if desired.
- If additional exposure is needed, the superficial temporalis fascia can be excised at the root of the zygomatic arch meeting the horizontal incision above the orbital rims at a 45-degree angle. The temporal branch of the facial nerve should be safely located on the undersurface of the temporoparietal fascia.
- The orbital foramen/notch may be osteotomized to allow release of the neurovascular bundles and further retraction.
- Access to subcondylar region can be reached through a coronal flap by detachment of the masseter muscle or osteotomizing the arch with attachment of the masseter.
- Closure should be performed in a layered fashion to minimize drooping. The temporalis fascia is often over suspended to minimize drooping and protect the facial nerve. Use of a flat suction drain is based on surgeon preference. If a running suture was placed for hemostasis at the beginning of the procedure, this should be removed.

Follow Up

Weekly follow up for 1 month. Every 3 months for the first year and every year up to year 5. CT scans are recommended at years 1, 2, and 5 or if symptomatic.

Complications

- *Meningitis* – Inflammation of the arachnoid membrane and the pia mater extending throughout the subarachnoid space, brain, spinal cord, and ventricles. Acute fever, headache, stiff neck, and confusion are common to meningitis. Kernig sign (inability to flex the leg with thigh at a right angle to the trunk) or Brudzinski sign (flexion of hips and knees when neck is flexed) may be present 30% of the time. Diagnosis made with CT scan of the head to rule out a mass or lesion; blood cultures and CSF examination for protein, glucose, cell count; and gram stain. Antibiotics are empirically used until cultures available with neurosurgical consultation.
- *Mucocele and Mucopyocele* – Mucoceles form from retained sinus mucosa with compromised sinus ventilation leading to mucous-filled lesions. A mucopyocele forms when the mucoceles are infected. Treatment involves obliteration of the sinus.
- *Intracranial Abscess* – Patients will normally have a subacute onset of illness and not appear toxic. Common signs are mental status changes, focal neurologic deficits, fever, nausea/vomiting, and seizures. Treatment involves neurosurgical consultation, parenteral antibiotics (e.g. third generation cephalosporins) with possible craniotomy for aspiration/drain placement.
- *Cavernous Sinus Thrombosis* – Clinical signs include headaches, ptosis, ophthalmoplegia, paresthesia of ophthalmic and maxillary branch of CNV, papilledema, and periorbital edema. Imaging best visualized with MRI with gadolinium but contrast enhanced head CT is also valuable. Treatment includes, broad spectrum antibiotics, anticoagulation with heparin, and sinus drainage. High dose steroids are controversial but may reduce cranial nerve dysfunction.
- *Contour Deformity* – Allow for swelling to resolve completely. May correct with bone grafting, bone cement, or custom alloplastic implants.

Panfacial Fractures

- Fractures involving the lower, middle, and upper portions of the face.

- About 20% associated with spine fractures (spine films should be taken).
- The facial buttresses act as pillars of strength and are useful in reconstruction for outcome and because they typically have thicker bone compared to the interposed areas.
- The vertical buttresses run in a cranial to caudal direction and are important for maintaining facial height. From anterior to posterior, they include the nasomaxillary, zygomaticomaxillary, pterygomaxillary, and posterior mandibular buttresses. The pterygomaxillary buttress is the only one that is not typically surgically reconstructed because it is inaccessible.
- The horizontal buttresses run in an anterior to posterior direction and are important to maintain facial projection. From inferior to superior, these include the mandibular, maxillary, zygomatic, and frontal buttresses.

Imaging

- Maxillofacial CT with axial, coronal, sagittal, and 3D reconstruction.
- Ensure cervical spine films are taken and read prior to treating the patient.
- Head CT without contrast to rule out intracranial involvement. Pneumocephalus, extradural hematoma, and subarachnoid hemorrhage commonly seen with panfacial trauma.
- Chest films to r/o aspiration of teeth or other materials. The right mainstem bronchus is more often obstructed because it is wider and more vertical than the left.

Patient Evaluation/Early Management

- ATLS protocol starting with a primary survey and evaluation of life-threatening problems.
- Airway protection, perfusion, and hemodynamic stability are confirmed or established.
- Medical history should be obtained when possible, either from the patient or family and friends.
- As previously described for the subunit, a full head and neck exam should be completed.
- Patient should be inspected for rhinorrhea and otorrhea. Cerebrospinal fluid (CSF) rhinorrhea and/or otorrhea will present as a clear or strawberry-colored fluid.
- Oral examination to identify integrity of occlusion, which can be useful as a stable base for reconstruction.

Treatment

- Extensive access to the entire facial skeleton is typically required in these fractures; therefore, a combination of surgical approaches may be needed. Patients may need tracheostomy for long-term airway control. Submental intubation may be considered if long-term airway control is not of concern.
- The timing of repair is dependent on associated injuries and can proceed once other life-threatening injuries have been addressed and stabilized. Waiting for swelling to subside is helpful to aid in appreciation of bony reduction; however, waiting too long may lead to callus formation and malunion. Consider steroid administration to expedite edema resolution.
- There is no "one size fits all" approach to developing a plan for surgical reconstruction of panfacial fractures. The choice of approach is dependent on the fracture characteristics. It is generally advisable to work from known to unknown (meaning that reconstruction should begin with the less comminuted fractures where anatomic reduction can be more easily assessed and then proceed to the more comminuted regions where bridging constructs and bone grafting may be required).
- There are two general sequences described that allow for a systematic approach to these injuries, and they include the bottom up and inside out approach, and the top down and outside in approach. Once you choose a method, you should not deviate.
- Best to visualize all fractures before you begin fixation.

Bottom Up and Inside Out

Use mandible as the foundation for reconstruction.

Typical Surgical Sequence:

- Maxillomandibular fixation – consider prefabricated splint, made from stone models, for comminuted dentate segment fractures.
- Mandibular bony/ramus/angle/symphysis fractures. Make sure to keep pressure at the angle of mandible to prevent splaying and increasing of lower facial width. Treatment of symphysis fractures may require over bending the plate to prevent splaying of the lingual cortex (always treat the dentate segment first).
- Condylar fractures if indicated to restore vertical height. If one condyle is intact, it may only require elastic training after period of maxillomandibular fixation.
- Treat the zygomaticomaxillary complex next. Fixate the frontozygomatic region first to restore facial height of the complex. Fixate the zygomaticomaxillary buttress region to restore facial projection and to ensure that the medially rotated body is back in its normal anatomical position. Fixate the orbital rim to define orbital volume and facial volume. The orbital floor should be managed last as it is critical that the aforementioned sites are placed back into alignment to prevent enophthalmos and facial widening.
- Naso-orbitoethmoid complex.
- Frontal sinus.
- Implants/augmentation – such as dorsal struts.
- Soft tissue support/repair.

Top-Down Approach

In the top down and outside approach, some authors feel there is no need to address a fractured condyle. Some authors choose this approach after restoring the occlusion.

- Frontal sinus/supraorbital rims sinus fracture.
- Zygomaticomaxillary complex.
- Naso-orbitoethmoid complex.
- Maxillary/palatal/LeFort.
- Maxillomandibular fixation.
- Subcondylar fractures.
- Mandibular bony/ramus/angle/symphysis fractures. Make sure to keep pressure at angle of mandible to prevent splaying and increasing of lower facial width. Treatment of symphysis fractures may require over bending the plate to prevent splaying of the lingual cortex.
- Implants/augmentation – such as dorsal struts.
- Soft tissue support/repair.
- In either approach, it is important to use the dental arches, mandible, sphenozygomatic suture, and intercanthal region as key landmarks to obtain an anatomic reduction.
- In the case of highly comminuted fractures or regions with extensive bone loss, primary bone grafting is recommended. The most common areas that necessitate bone graft include the frontal sinus, medial wall and floor of the orbit, the nasal dorsum, and zygomaticomaxillary buttress.
- Calvarial bone graft is typically used as it is exposed through the coronal approach and may have a lower incidence of resorption.
- The ribs and pelvis are also sites that can be used to obtain structural bone graft. All structural bone graft should be included in the fixation construct to minimize motion and increase the chance of graft incorporation.

Soft Tissue Injuries

Foreign Body

- The common foreign body is glass and easily detected in plain films if superficial.
- Negative CT scan does not rule out foreign body.
- The radiodensity of wood, plastic, and vegetative materials is very low and often missed.
- Wood will show on MRI.
- Ultrasound aids in detection of most foreign bodies in soft tissue.

Tetanus

- Tetanus is a neuromuscular disease caused by *Clostridium tetani,* a spore forming, gram-

positive, strictly anaerobic bacillus found in soil, intestines, and feces.
- Spores germinate to produce exotoxin tetanospasmin, a potent neurotoxin that is carried to the nerve terminals blocking spinal cord inhibitory neurons, which causes trismus, spasm of facial expression muscle (Risus sardonicus), and spasms of voluntary skeletal muscles [9].
- The CDC recommends tetanus part of immunization programs for children and is included in the DTaP (diphtheria, tetanus, and pertussis) vaccination.
- Tetanus prophylaxis should be evaluated for contaminated wounds.
- Tetanus toxoid should be administered if the patient has not been administered vaccination over 10 years, failed to complete a primary tetanus vaccination of at least three doses, or has an unclean wound and has not received tetanus vaccination in over 5 years (booster dose of 0.5 ml intramuscular).
- If no history of immunization or uncertain/incomplete, passive immunity with human tetanus immune globulin should be administered (250 U intramuscular single dose).

Soft Tissue Management

- Due to the rich vascularity of the face, facial wounds that are clean can be closed within 48 hrs. This differs from non-head wounds that should be closed no more than 19 hours after insult.
- Inoculation of infectious organisms must exceed 10 organisms/gram tissue for gram-positive and gram-negative bacteria. The number of bacteria present is of more concern than the species.
- Staphylococcus and Streptococcus are the species most involved in the contamination of facial skin.
- Tissue crushing injuries are 100 x more susceptible to infection.
- Wounds must be debrided of all foreign materials.
- Pulsatile (high pressure) irrigation requires pressure of 7 lb. Psi to remove adherent bacteria with a balanced salt solution or a scrub brush.
- Povidone-iodine and hydrogen peroxide are toxic to fibroblasts and must be diluted to a point where bactericidal effectiveness is compromised.
- Limit debridement of tissues (much will survive due to vascularity).
- Wounds should be closed in a tension-free manner, taking into account the phases of wound healing and Langer's lines of skin tension.
- Wounds maximally ever gain 80% of the strength of intact skin.
- Sutures recommended to be removed in the face in 7–10 days, and in thin tissue areas such as eyelids in 3–5 days (tensile strength regained is only 5–10% at this time point).
- Causes of marks include (1) epithelialization due to extended stay of sutures, (2) tissue necrosis secondary to tension across suture line, and (3) reactive suture type.
- Subcuticular sutures can remain up to 4 weeks.

Bites/Rabies

- Dog and feline bites – *Pasteurella multocida, Streptococci,* and *Staphylococcus aureus.* Domestic dogs on average have a biting force of 320 lbs. of pressure [10].
- Human Bites – *Eikenella corrodens, Staphylococcus Aureus, Haemophilus influenzae,* and *Corynebacterium*. Additionally, consideration should be given to Hepatitis B and C, herpes simplex virus, syphilis, tuberculosis, and HIV, which can be transmissible through human bites [10]. Human biting force on average is 120 lbs. of pressure.
- Unlike bites to regions other than head and neck, non-infected wounds should be closed primarily due to the abundance of vascularity. Early closure leads to the best aesthetic outcome.

- Wounds with exposed cartilage are most likely to become infected.
- Treat with high-pressure irrigation with normal saline.
- Antibiotic coverage of choice is amoxicillin and clavulanic acid (Augmentin®). If penicillin allergic, then consider doxycycline and metronidazole.
- Rabies is an important consideration following an animal bite. It is a viral infection of single stranded RNA virus (rhabdovirus family).
- Bats, raccoons, skunks, and foxes are the major reservoirs in the United States due to vaccination programs of domesticated animals.
- Bites from wild animals or domesticated animals (allowed to roam in rural or semi-rural areas) should be presumed to inoculate with the rabies virus.
- Domesticated animals should be observed for 10 days for changes in behavior. In the event of erratic behavior, the animal should be euthanized and brain examined for evidence of rabies.
- Human rabies virus infections are divided into two forms: (1) encephalitic ("furious") and (2) paralytic ("dumb") [11, 12]. The encephalitic form occurs with the hydrophobia, delirium, and agitation. The paralytic form shows symptoms ascending paralysis, hypophonia, polyneuropathy, and symmetrical quadriparesis (paralysis is usually more severe in the bitten limb).
- Spread of the virus is via peripheral nerves to the central nervous system.
- Post exposure prophylaxis includes involved passive immunity by giving 20 IU/kg human rabies immunoglobulin directly around the wound and any remaining volume intramuscularly [11]. 1 ml of human diploid cell vaccine or purified chick embryo cell vaccine should be given intramuscularly on days 0, 3, 7, 14, and 28.

Parotid Injury

- Buccal branch of the facial nerve often runs together with the parotid duct. Can estimate the course of the duct by drawing a line between the tragus and midportion of the upper lip.

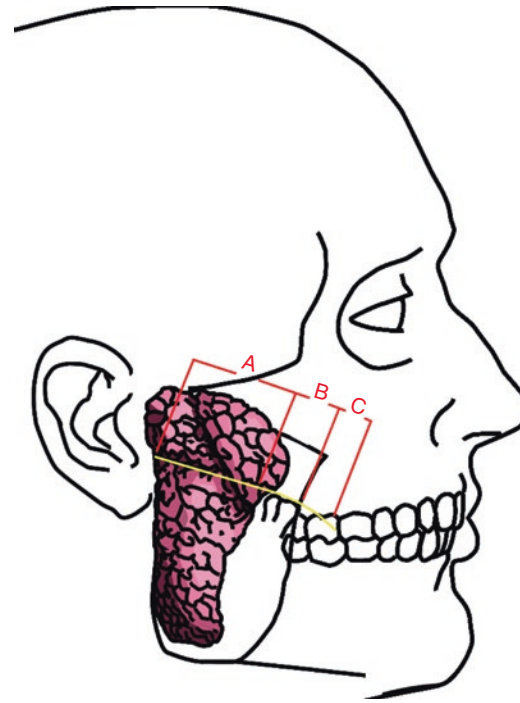

Fig. 7.6 Anatomic classification of parotid duct injuries. (Image courtesy of Erik Steenberg)

- Often transection of the buccal branch of the facial nerve is accompanied by duct injury.
- Van Sickels divided Stensen duct in three distinct sites (Fig. 7.6) [13]. Site A corresponds to the most proximal part of the duct, intraglandular. Site B corresponds to the part of the duct that is located superficial to the masseter muscle. Site C corresponds to the part of the duct located anterior to the masseter muscle and subsequently enters the buccinators. The duct terminates intraorally, adjacent to second maxillary molar. If injury is at sites B or C, attempt to identify stumps for repair. For site A injuries, treatment is only closure of parotid capsule; these injuries have lower complication rates.
- Lacerations require routine repair of the soft tissue injury. Consider drain placement. Intermittent aspiration may be required and compression dressing must be done.
- Sialocele.
  - Formed by leak of saliva into glandular or periglandular tissue.

- Check to ensure saliva via amylase levels >10,000 u/l is confirmatory.
- Treatments include: pressure dressing and multiple aspirations with or without antisialogogues (propantheline 15 mg PO QID half hour prior to meals), octreotide, parasympathetic denervation (tympanic neurectomy), secondary duct repair, intraoral fistula creation (dochoplasty), low radiation (1800 rad/treatment for more than 6 weeks total of 30 Gy) and for nonresponders Botox (10–20 units of botox-A), superficial or total parotidectomy.
- Anticholinergic pharmacotherapy in the form of propantheline, scopolamine, or glycopyrrolate may be used to reduce saliva production and the risk of recurrence.

Table 7.4 House-Brackmann scale for facial nerve injury

House-Brackmann Grading scale		
Grade	Description	Characteristics
I	Normal	Normal facial function in all areas
II	Mild dysfunction	Synkinesis – Hypokinetic/ uncoordinated facial movement with symmetry at rest
III	Moderate dysfunction	Noticeable weakness or synkinesis; symmetry at rest; complete eye closure with maximal effort
IV	Moderately severe dysfunction	Obvious weakness/ disfigurement; symmetry at rest; incomplete eye closure with maximum effort
V	Severe dysfunction	Only perceptible movement, asymmetry at rest
VI	Total paralysis	No movement

Stensen Duct Repair

Repair should be done preferably in the first 24 hrs.

- Anesthesiologist to avoid sympatholytics or only short acting agents.
- Use ketamine to encourage salivary flow.
- Identify distal end with 20–22-gauge silastic tube via the opening of the duct, which can be identified with a lacrimal probe.
- Identify proximal end of duct, may be eased by parotid massage to encourage salivary flow.
- Repair duct with 6–0 nylon.
- Stent to be kept in place 5 days up to 3 weeks and given sialogogues (lemon drops) to prevent scarring.

Facial Nerve Transection

- The House-Brackmann scale is used to test facial nerve function (Table 7.4).
- Facial nerve repair should be attempted posterior to a line drawn perpendicular to the lateral canthus (Fig. 7.7).
- Repair within 72 hours, prior to Wallerian degeneration and loss of ability to identify nerve with stimulator.
- Use nerve stimulator to identify distal end; proximal end identification may be aided by retrograde dissection; repair the epineurium with 9–0 nylon on a GS-8 needle. Use three sutures to obtain anastomosis. Fibrin glue and collagen tubes have been used to aid anastomosis.

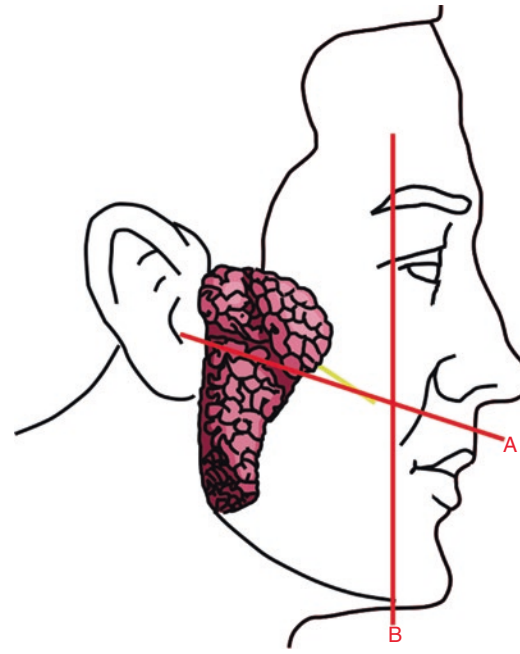

Fig. 7.7 A line joining the midline of the upper lip with the tragus of the ear approximates the course of the parotid duct. Injury along this line behind a line from the lateral canthus to the mental foramen has great chance of injuring the parotid duct or gland and the facial nerve. (Figure courtesy of Erik Steenberg)

Laceration of Submandibular Gland

- Repair of duct normally unnecessary as will form a fistula in the floor of mouth. If submandibular fistula forms, serial aspirations with pressure bandage will normally resolve this. If not, the submandibular gland should be removed.
- Sialodochoplasty done for pathological resections that include the floor of the mouth.

Lacrimal Apparatus

- Laceration through medial canthal region and NOE injuries should raise suspicion for nasolacrimal injury.
- Consider ophthalmology consult to rule out globe injury.
- Epiphora may be present.
- Anesthetize the medial canthus, dilate punctum with dilator, and pass silicone intubation stent (Crawford tube); pigtail probe is passed through the intact punctum and canaliculus to identify the transected portion.
- Cannulate upper and lower punctum and thread stent into nose (below inferior turbinate), cut the steel rods, and tie a knot. Allow 3 months to heal, remove tube through the segment visible in the corner of the eye.
- Alternatively, may use a stainless steel rod threaded with black silk or monocanalicular monoka® stent.
- Chronic lacrimal duct obstruction can be managed with a dacryocystorhinostomy.

Scars

- Wounds kept moist heal faster than those exposed to air:
  - Keratinocytes migrate sooner.
  - Prevents hypoxia which drives angiogenesis and retention of growth factors.
  - Affords protection against exogenous organisms.
  - Retains water and proteolytic enzymes, which debride the wound.
- Silicone sheeting has been shown to aid in keeping moisture in and keeping out bacteria. The sheets are permeable, which allow some oxygen to enter the wound. In addition, they control tension on the wound to prevent stretching and irritation. They have also been shown to suppress fibroblast activity and decrease capillary activity and collagen deposition leading to decreased dermal thickness (decreases scarring). They are to be used after epithelialization has occurred.
- Hypertrophic scars develop within the borders of the wound. Keloids are scars that extend outside of the wound borders. Treatment includes intralesional steroids that can be started at 1 month post-op (e.g. Triamcinolone 40 mg/ml, 0.2 ml given every 3 weeks for 3 months). Aggressive injections can lead to significant atrophy.
- Silicone sheeting, flashlamp-pumped pulsed-dye laser 585 nm or 1064 nd:YAG non-ablative laser, dermabrasion at speed of 35,000 rpm with diamond fraise burrs of medium course can also be used.
- Radiotherapy, 15–20 Gy over 6 sessions, should be considered for refractory cases.
- Scar can take up to 1 year to mature as collagen remodels. It is imperative to allow adequate time to healing. A delay of at least 6 months is recommended.

Ear

- Fluoroquinolones are prudent for injuries that involve the cartilage to cover *Pseudomonas aeruginosa*. However, it is toxic to developing cartilage and should not be given to patients under 18 years of age. If perichondritis develops, assume it is from this pathogen.
- The ear is extremely vascular and only requires small pedicle for revascularization.
- Elastic cartilage found in the ear, which is relatively avascular, is not commonly sutured as this may devitalize the area. If suture is required, then a fine chromic suture is recommended.
- If there is partial avulsion, classically the Mladick technique (retroauricular pocket) is performed: de-epithelize amputated auricle, perform anatomic cartilage reattachment, and bury into retroauricular pocket. The second stage (2 weeks later) is cartilage elevation and split thickness skin graft.
- The Baudet technique for ear repair [14]: amputated auricle's posterior surface is de-

epithelized, cartilage fenestrated, retroauricular pocket raised, and anterior pinna skin sutures placed. Second stage: ear elevation and split thickness skin graft.
- Temporoparietal fascia flap may be used to cover denuded cartilage and a split thickness skin graft.
- Auricular hematoma (usually from blunt trauma) can lead to cartilage destruction and replacement with fibrous tissue. Early treatment with needle evacuation (incision and drainage for late treatment). A bolster dressing should be left in place for 7 days.

Nasal Hemorrhage
- Exam should be performed after achieving profound anesthesia and vasoconstriction for visualization. Anesthesia and vasoconstriction for exam can be achieved with 4–10% cocaine topical solution (max 1 mg/kg for infant or 2–3 mg/kg for adult). Another option is utilizing local anesthesia with oxymetazoline-soaked neuro sponges.
- Septal hematomas are drained with small mucosal incision or needle drainage. Nasal pack or septal stent secured with a multiple pass 4-O suture technique is utilized to prevent recurrence.
- Nasal bleeds are more commonly anterior (from Kiesselbach area aka Little's area), where posterior bleeding is commonly from the sphenopalatine artery and the posterior pharyngeal artery (Woodruff's plexus) (Fig. 7.8).
- Control of an anterior bleeding may include [15]:
  - Finger compression for 10 minutes.
  - Topical vasoconstrictors.
  - Silver nitrate application.
  - Nasal sponge cut to 4–6 cm (from 10 cm sponge) coated in petroleum jelly removed in 48 hrs.
  - 1/2 inch petroleum jelly soaked gauze removed after 48 hrs.
  - Balloon tamponade coated with Sodium Carboxymethylcellulose, e.g., Rapid Rhino © (to aid in gel coat and to encourage platelet aggregation) soaked 30 seconds in sterile water (not normal saline as it may interfere with hydrocolloid fabric). Fill the bladder of the rhino with air from a syringe and monitor tactile feedback of pilot cuff (cuff becomes rounded and feels firm). Remove in 24–72 hours.
- Control of a posterior bleed is most commonly managed with the use of a 14 French Foley catheter with a 30 ml balloon. Fill it

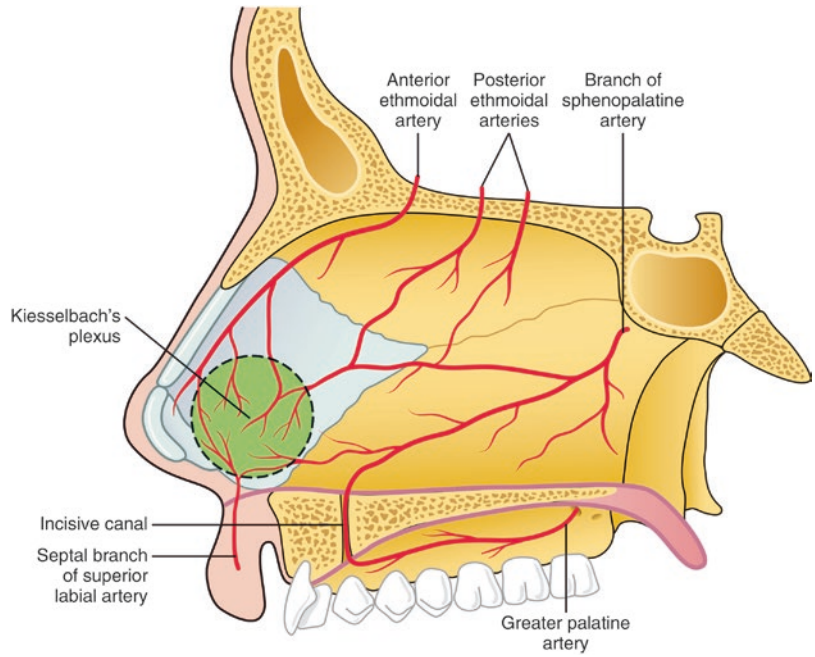

Fig. 7.8 Arterial supply to nasal septum. (Reprinted with permission from Waldman S. Chap. 147 – Neuradenolysis of the Pituitary: Needle-Through-Needle Technique. Fourth Edition. Atlas of Interventional Pain Management. Elsevier Inc.; 2015)

with 10–15 ml saline. Retract the Foley so the balloon is wedged and add 3–5 ml of more saline. Remove in 3 days. Of note, some doctors use air versus saline due to aspiration risk if the catheter were to rupture. On the contrary, leakage of air renders the catheter ineffective.
- Nasopulmonary reflex – mediated by trigeminal and vagal nerves. Can be seen in patients with COPD, advanced pulmonary or cardiac conditions. Nasal packing can cause a 15 mm Hg drop in arterial oxygen pressure [15].
- If packing measures fails, then consider endoscopic sphenopalatine artery ligation (EPSAL) for a posterior bleed or anterior ethmoid artery ligation for anterior bleed. Extensive bleeding may require ligation of both regions.

Lip Laceration
- Defects of up to 25% of the width of the upper lip can be closed primarily, and 30% of the lower lip.
- Misalignment of 1 mm of the vermillion border can be detected by the human eye.
- Intermediate defects up to 2/3 of the upper or lower lip can be reconstructed with either the Abbe flap or the Estlander flap.
- Larger defects may require Karapandzic flap, Gilles flap, or a Webster-Bernard flap.

Pediatric Maxillofacial Trauma

Nasal Fractures

- Common fractures in the pediatric population.
- Edema frequently masks the fracture.
- Diagnosis is usually made by clinical exam but a plain film or CT scan can be used.
- Clinical exam must include ruling out other associated fractures and ruling out the presence of a septal hematoma. If a septal hematoma is noted, it must be drained as in the adult patient.
- Treatment is usually observation or closed reduction. Rarely is open reduction necessary.
- Growth disturbances can occur and be associated with premature ossification of the septovomerine or nasoethmoid suture. This may lead to a restriction in midface growth.

Naso-Orbital-Ethmoid Fractures

Rare injuries but have significant effects on growth when displacement occurs and is not repaired. Premature ossification or obliteration of the frontoethmoidal, frontolacrimal, frontomaxillary, nasomaxillary, or ethmoidomaxillary may result in midface hypoplasia in the vertical and anterior/posterior planes.

- If the fractures are nondisplaced, then observation is acceptable.
- If displaced, precise reduction and fixation must be performed (consider resorbable plating systems).
- If there is telecanthus, then the canthal ligament must be resecured. If the location of the disruption is unclear, then it must be secured in a more superior and posterior position. Ideal treatment is within the first 4 days of injury.

Orbital Fractures

- The pattern of orbital fractures may be influenced by the changing craniofacial ratio of the growing child.
- Signs of globe injury such as asymmetric pupils, hyphema, torn bulbar conjunctiva, and corneal damage warrant a prompt evaluation by an ophthalmologist.

Fronto-Orbital Injuries (Orbital Roof Fractures)
- Occur primarily in children <7 years of age.
- Secondary to a proportionally larger cranium and a lack of rudimentary sinuses present.
- Orbital roof fractures have a greater likelihood of associated neurocranial injuries.
- Non-displaced orbital roof fractures may be observed.
- Neurosurgical consultation is advised as these fractures may extend into the frontal bone.

- If the bones are displaced, extraocular muscle movements are affected, or intracranial injury is confirmed, then an open approach is indicated via a coronal incision.
- Consider using a resorbable plating system.

Lower Orbital Fractures (Orbital Floor and/or Medial Wall)

- Occur primarily in children >7 years of age.
- Increased vulnerability of the face due to growth and pneumatization of the paranasal sinuses.
- Clinical signs include ecchymosis, diplopia, restricted upward gaze (entrapment), enophthalmos, hypoglobus, loss of globe support, and loss of orbital volume.
- Trapdoor fractures are linear, medially hinged, minimally displaced, and run along the infraorbital nerve canal.
- Assess for the presence of "white eyed" orbital floor fractures (no subconjunctival hemorrhage or overt signs of orbital trauma is seen) that can result in muscle necrosis of the inferior rectus muscle due to entrapment. The oculocardiac reflex may be seen in this patient population (intractable nausea and vomiting, bradycardia, and occasionally syncope.)
- Early intervention is crucial (2 days maximum).
- The consequence of late detection and treatment is muscle ischemia and permanent gaze restriction.
- Resorbable mesh or Gelfilm ® are adequate materials for the reconstruction of most orbital floor/wall fractures.
- If there is a large defect, a calvarial bone graft may be necessary.

Zygomatic Complex Fractures

- Clinical findings similar to that of the adult patient; periorbital ecchymosis and edema, bony step offs, paresthesia associated with the infraorbital nerve (V2) on the side affected, and subconjunctival hemorrhage.
- Ophthalmology consult required if orbital components involved.
- Minimal or non-displaced fractures can be observed.
- Displaced fractures require an open approach and one-point fixation is usually adequate for the non-comminuted pediatric zygomatic complex fracture.
- Access can be achieved with the transconjunctival, buccal, upper bleph, or lateral brow approaches.
- Comminuted fractures may require a coronal approach.
- Maxillary tooth buds are still present in children under 6 years of age and must be taken into account when fixating a fracture from the maxillary vestibule approach.

Maxillary Fractures (LeFort)

- Rare fractures in children. Prevalence increases after age 12 when sinuses have pneumatized.
- Open reduction and internal fixation is the preferred technique for management.

Mandible Fractures

- Mandible fractures account for 5–50% of all pediatric facial fractures.
- Children's mandible fractures have a high tendency to have greenstick fractures secondary to the fibroelastic properties of the bone during its development. Displaced and comminuted fractures are rare.
- Attention to the age and state of development of the dentition is necessary. At 6 months of age the first deciduous incisors erupt. By age 2.5 most children have a full complement of deciduous teeth. Root resorption of the primary teeth occurs between the ages of 5–9, and between 9–12 years of age mixed dentition is present.
- The high vascular supply to the periosteum by the inferior alveolar nerve and high osteogenic potential is the reason for early fracture healing (2–3 weeks) in the pediatric mandible fracture patient.
- Treatment of mandible fractures is dictated by fracture location, patient age, stage in development, severity of injury, and the presence of displacement or comminution.

  - Infants less than 1 year of age should be observed. Diet modification is not required.
  - For mandible fractures in young children that are not displaced and occlusion is stable, conservative management, close observation, and soft/liquid diet is appropriate treatment.
  - Displaced fractures need to be stabilized and immobilized.
  - Open reduction and internal fixation (ORIF) should be used only for fractures significantly displaced or comminuted.
- Techniques for stabilization and immobilization in pediatric patients include maxillomandibular fixation, fabrication of a lingual or occlusal splint, open reduction internal fixation, or a combination of these techniques.
- If maxillomandibular fixation (IMF) is used, closure for 2–3 weeks is adequate for children less than 12 years of age. Less time, 1–2 weeks, is appropriate, if the fracture involves the condylar process.
- In a patient without adequate dentition to secure arch bar placement skeletal fixation with wires at the circum-mandibular, circum-piriform, circum-orbital, and circum-zygomatic regions can be used to attain maxillomandibular fixation.
- Acrylic splints can be fabricated to provide stability to the mandible. They can be used when no deciduous or permanent teeth are present or fabricated on the occlusal or lingual aspects of those teeth that are present. They require taking impressions, pouring diagnostic models, cutting the models at the regions of fracture and restoring the segments to proper occlusion with wax. An acrylic splint is then fabricated off of these models and secured to the patient's mandible with wires (either circumdentally or circum-mandibular).
- A Risdon cable can also be used as a substitute to bulky arch bars that will not conform to the small deciduous teeth. The technique which entails twisting a long 24-gauge wire together and is secured to the posterior molars with additional 24-gauge wires was described by Risdon.
- Titanium plates and screws may be used although may require a secondary surgery for removal in patients 2–3 months after the initial placement. This is secondary to concerns regarding migration of the titanium plates and inhibition or alteration of growth. This is controversial, as some surgeons believe a secondary surgery may further lead to disturbances in growth. The author of this section (J.P.) typically removes titanium plates and screws in patients less than 13 years of age 2 months after the initial placement.

Symphyseal and Parasymphyseal Fractures

- Can be treated with IMF or ORIF.

The canine region is important to evaluate as the permanent canine may be at different stages of development and susceptible to injury at multiple regions including the inferior border if the tooth bud is still present. Placement of screws in this region should be avoided if ORIF is used.

Angle, Body, and Ramus Fractures

- Less susceptible regions for fractures and growth disturbances.
- Can be treated conservatively with IMF, traction, or with ORIF.
- If a greenstick fracture is present, observation is a reasonable choice of management.
- Circum-mandibular wires are useful at times to hold and provide stability to a distracted mandibular body fracture.

Condylar Fractures

- Laceration or ecchymosis of the chin should give rise for suspicion for a condylar fracture.
- Fractures of the condyle are one of the most frequent types of mandible fractures. These are also the most commonly missed and undiagnosed fractures.
- Generally categorized as extracapsular (low or subcondylar fractures extending toward the ramus) or intracapsular (fracture of the condylar head or high condylar neck above the sigmoid notch).
- With bilateral condyle fractures, clinical presentation is loss of projection and an anterior open bite.

- Based on the development of the mandible, children less than age 6 are more likely to have intracapsular fractures and those older than 6 years of age are more likely to have condylar neck or extracapsular fractures. The marrow within the condylar unit has an abundance of osteogenic progenitors, which could lead to an exuberant osteoblastic response, and hence ankylosis.

Management of Condylar Fractures

- Those condylar fractures with no evidence of malocclusion with a reproducible bite can be treated with observation and soft diet. Strong consideration should be made for intracapsular fractures due to the high risk of ankylosis.
- If the fracture is immobilized in IMF, 7–14 days is generally adequate. Elastics guidance can be used to promote the function of the joint after this time frame. This is usually followed by physical therapy to regain maximal opening and to help shape the remodeling of the new condyle. This also helps to reduce the possibility of ankylosis.
- Indications for ORIF of condylar fractures are few and include:
  - Condylar head fractures avulsed from the capsule and fossa.
  - Condylar fractures that have been displaced intracranially.
  - Bilateral condyle fractures with comminuted midfacial fractures.
  - Unacceptable occlusion after a closed technique trial has failed.

Metallic Plates and Screws

Advantages

- Superior mechanical handling.
- Greater resistance against torsional forces and allowance of compression.
- Titanium is biocompatible, hypo-allergenic, and inert.

Disadvantages

- Passive migration of metal plates in children.
- Distortion of future MRI or CT scans.
- Possible need for secondary surgery for subsequent removal.
- Growth disturbance.
- Thermal sensitivity.

Biodegradable Plates and Screws

Advantages

- Does not require additional surgery for removal.
- Blunt and non-penetrating biodegradable screw tip avoids potential odontogenic injury.
- Decreased potential obstruction to tooth eruption.

Disadvantages

- Time-consuming and technique-sensitive process of plate adaptation.
- Complex bending of the plates requires a heat source to allow the polymer chains to bend and not fracture. This may present a problem when fixating regions that require more complex shaping.
- Higher rate of visible or palpable hardware postoperatively due to greater thickness than metal.
- Foreign body reaction or sterile abscess may occur during the biodegradation and absorption process.
- Polyglycolic acid (PGA) and pure poly-L-lactic acid (PLLA) have caused adverse reactions during degradation.
- Unable to be re-sterilized.
- Limited shelf life.

Examples of Resorbable Plates Currently on the Market

- Inion CPS® system, Tampere, Finland.
- Zimmer-Biomet Lactosorb® (Lorenz Plating System).
- DePuy Synthes Rapidsorb® Rapid Resorbable Fixation System.

- Stryker Delta System®.

Management of Dentoalveolar Trauma

- Clinical Manifestations – malocclusion, mobile teeth and/or alveolar bone, gingival soft tissue lacerations, fractured teeth, missing teeth, pain with chewing or biting, and dentures not seating properly.
- Physical Exam.
  - Evaluate for any lacerations or soft tissue wounds intraorally.
  - Evaluate for any bony steps or malocclusions.
  - Evaluate dentition for fractures, mobility, or displacement of teeth.
  - Percussion and pulp test teeth.
- Radiographic Imaging – Panorex and/or CT scan.
  - Evaluate for presence of root fracture.
  - Determine degree of extrusion or intrusion.
  - Pathology.
  - Evaluate root development and pulp chamber/root canal.
  - Evaluate for jaw fractures.
  - Evaluate for tooth fragments or foreign bodies.

Classification

- Crown Crack – crack or incomplete fracture of enamel without loss of tooth structure.
- Ellis Fracture Classification.
  - Class I – Confined to the enamel.
  - Class II – Enamel and dentin involved.
  - Class III – Enamel, dentin, and exposed pulp involved.
  - Class IV – Root fracture.
- Tooth Displacement.
  - Intrusion or Extrusion.
  - Labial, Lingual, or Lateral displacement.
- Avulsion.
  - Complete displacement of tooth from its socket.
- Alveolar Process Fracture.
  - Fracture of alveolar bone with or without tooth involvement.

Treatment

- Most crown cracks and/or fractures that only involve enamel/dentin can be treated with dental restorations.
- If the pulp is exposed, then pulp capping or pulpotomy may be indicated.
- Root and/or crown fractures that extend past the gingival crevice usually require removal. Orthodontic extrusion or crown lengthening may be an option depending on apical extent of injury.
- No acute treatment is recommended for sensitivity. Although, removing occlusal contacts may help relieve pain.
- Intrusion.
  - Orthodontic assisted eruption is favored: must be done slowly over 3-4 weeks and once in position must be stabilized for 2-3 months.
  - Endodontic treatment is based on follow-up findings.
  - If a deciduous tooth is intruded, it may be extracted if it is impeding eruption of permanent tooth.
- Extrusion.
  - Usually can be repositioned and splinted for 1–3 weeks.
  - Endodontic treatment is usually needed, and patient should be evaluated at follow-ups.
- Displacement
  - Reposition tooth and alveolus and splint.
  - Repair any gingival lacerations.
  - Follow up to determine the state of pulp and periodontal damage to determine further treatment.
- Avulsion.
  - Rinse tooth immediately with patient's saliva or saline and replant immediately.
  - Try to limit contact with root surface.
  - If patient cannot replace tooth, then it should be placed in storage medium (HANKS Balanced Salt Solution or milk). Do not scrape walls of socket or root sur-

face, as this will destroy viable periodontal tissue.
  - Semi rigid splint for 7–10 days.
  - Strict follow up to evaluate for root resorption and ankylosis as well as need for endodontic treatment.
- Alveolar Fractures.
  - Place segment into proper position.
  - Stabilize for 4 weeks using arch bars or acrylic/composite splint.
  - Teeth in segment may need endodontic treatment.

Stabilization Periods (Table 7.5)

Table 7.5 Dentoalveolar stabilization periods

Dentoalveolar injury	Duration of stabilization
Mobile tooth	7–10 days
Tooth displacement	2–3 weeks
Replanted tooth (mature)	7–10 days
Replanted tooth (immature)	3–4 weeks

Case Example

You are paged by the ED about a 51-year-old male that was involved in an MVC with rollover. The patient was a restrained driver with airbag deployment and prolonged extrication. There was loss of consciousness and the patient was intoxicated with ethanol. ATLS has been completed and the patient is stable per vital signs. Secondary survey reveals that the patient's injuries were isolated to the maxillofacial region. You see the patient at the bedside the next morning. Ophthalmology has already evaluated the patient and has ruled out globe injury (Fig. 7.9).

Fig. 7.9 Frontal photograph of panfacial patient. (Images are courtesy of Drs. Aaron Figueroa and Damian Findlay)

- *How do you want to proceed?*
  Get a thorough history from family members, trauma team members, chart review, and witnesses if available. Next, conduct a thorough head and neck physical exam.
  Exam reveals the following:
  - *Middle-aged male with male pattern baldness. Bilateral periorbital edema, temporal subconjunctival injection, and ecchymosis. Pupils are reactive to light. Frontal edema with appreciable depression. Steps noted at the left frontozygomatic articulation and left orbital rim.*
  - *Mobility of the nasal bones; there are tagging sutures in the nasal dorsum region.*
  - *Intraoral exam reveals left upper vestibular ecchymosis with mobility of the maxilla. Dentition is intact. A left posterior open bite and mobility at the left mandibular angle are appreciated. The fracture involves the mesial periodontal space of tooth #17. Orogastric tube placed due to excessive emesis due to oropharyngeal bleeding.*

- *What do you want to do next?*
  Get a maxillofacial CT with 3D reconstruction.

- *What do you see on the provided radiography* (Fig. 7.10)*?*
  1. Left unfavorable mandibular angle fracture.

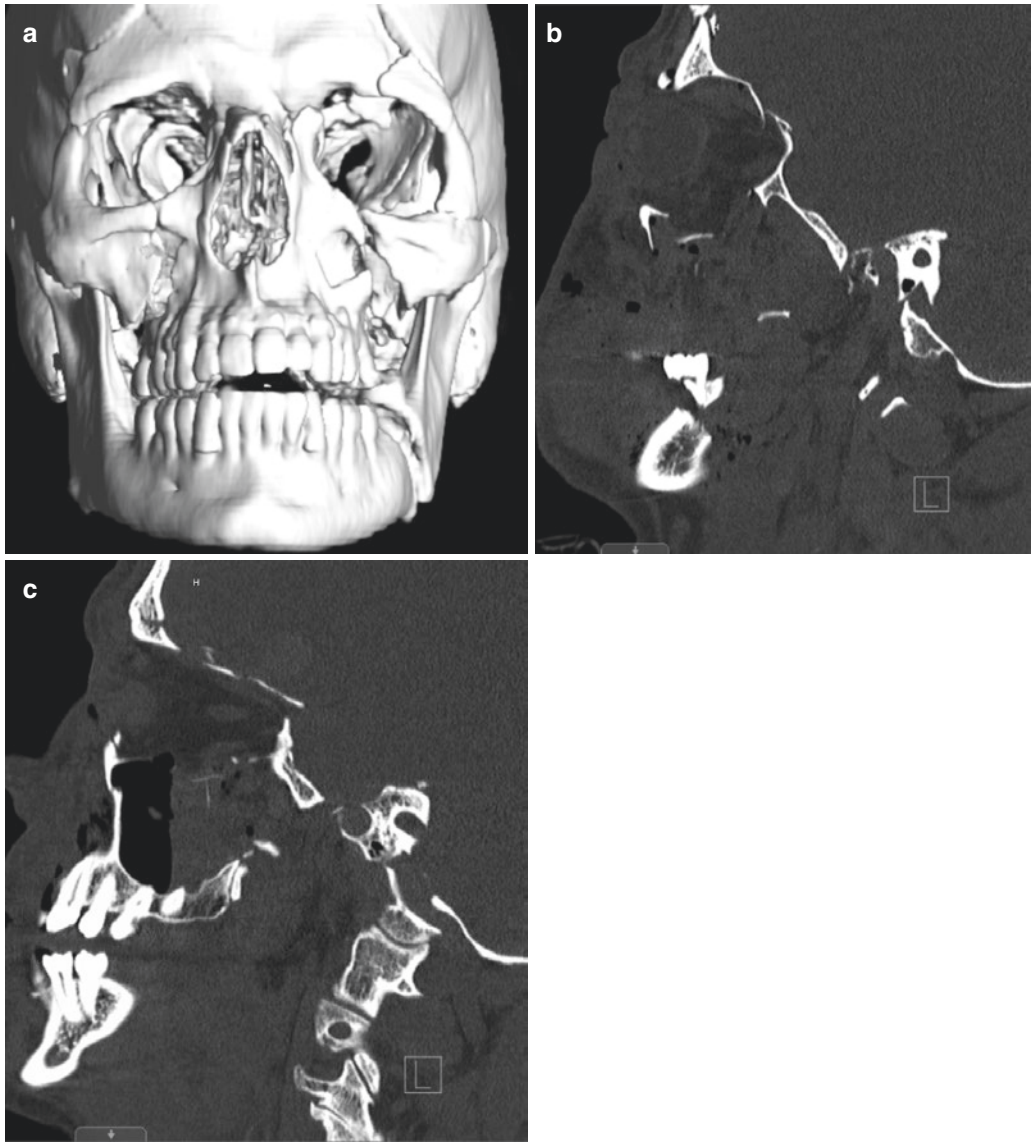

Fig. 7.10 Clinical case example of panfacial fracture from blunt trauma. (**a**) 3-D reconstruction of panfacial fracture. (**b**) CT scan without contrast sagittal view at the level of left orbit. (**c**) CT scan without contrast sagittal view at the level of right orbit. (Images are courtesy of Drs. Aaron Figueroa and Damian Findlay)

2. Left displaced ZMC fracture with involvement of the buttress and rim.
3. Right minimally displaced ZMC fracture with buttress and rim involvement.
4. Nasal bone fracture.
5. Depressed frontal bone region.
6. Bilateral Orbital floor fractures.

- *What's your diagnosis?*
  1. Depressed frontal bone fracture.
  2. Bilateral LeFort II fractures.
  3. Left displaced open mandibular angle fracture.
  4. Nasal bone fracture.

- *Can you describe the LeFort fracture patterns?*
  LeFort I (Horizontal Fracture) – extends above the apices of the maxillary dentition across the nasal septum and maxillary sinuses. Posteriorly it extends through the pyramidal process of the palatine bone and the pterygoid

processes of the sphenoid bone. It also may involve the fracture of the palate.
LeFort II (Pyramidal Fracture) – extends from the nasofrontal region down through the medial orbital wall, crossing the inferior orbital rim and zygomatic buttresses. Posteriorly similar to a LeFort I fracture.
LeFort III (Complete Craniofacial Disjunction) – fracture lines extend through the nasofrontal junctions, zygomaticofrontal articulations, zygomaticomaxillary suture, temporozygomatic suture, pterygomaxillary junction, medial and lateral orbital walls, and superior articulation of the nasal septum.

- *How would you approach this fracture?*
  My approach would be a bottom-up approach. I would first establish occlusion to allow for stability and provide a stable base for horizontal and vertical relationships to build on.
  - *Apply Erich arch bars and place the patient in maxillomandibular fixation.*
  - *Access fractures sites* via *Risdon approach, coronal, bilateral subconjunctival, and maxillary vestibular approaches.*
  - *I would begin fixation at the angle of the mandible using a reconstruction plate at the inferior border. Next I would fixate zygomaticomaxillary buttress followed by the infraorbital rims with miniplates. The frontal bone would then be reduced and secured with multiple low profile miniplates. The orbital floor fractures would be reconstructed with Medpor ® orbital reconstruction implants. The nasal bones with be reduced and stabilized with internal and external splinting.*

  **Author's Note*. It is easy to go down the rabbit hole of overwhelming detail. Allow the examiner to guide you down this hole if they wish to. A brief description normally suffices.

- *What comprises the lateral retinaculum?*
  Lateral horn of the levator aponeurosis, lateral check ligament, Lockwood's inferior suspensory ligament, lateral canthus.

- *How would you manage the tooth in the line of fracture if a vertical root fracture appreciated?*
  I would remove this non-restorable tooth as it poses a risk for infection.

- *Where is the nasofrontal ostium located in relation to the frontal sinus?*
  Its location is in a medial posterior position. The majority of the time, it is not a true duct but a recess.

- *How can patency of the duct be assessed?*
  With the frontal duct exposed, injection of sterile solutions such as propofol or methylene blue can be done into the ostium and evaluated for its passage into the nares.

- *If the duct is found to be non-patent, what is your treatment?*
  My choice would be for plugging of the duct/recess and obliteration of the sinus. This would involve carefully removing the remaining sinus mucosa. At the level of the duct, bone is used to plug the duct and covered with a pericranial flap.

- *What other materials may be used to obliterate the sinus?*
  Muscle such as a temporalis flap, fat, autogenous bone or alloplastic materials such as glass ionomer cement or hydroxyapatite.

- *What is Guerin's sign?*
  Ecchymosis in the maxillary vestibule denoting a zygoma fracture.

- *What is the earliest sign of enophthalmos in the acute traumatic setting?*
  Deepening of the supratarsal crease.

- *You are seeing your patient post-op day #2 from ORIF. The patient is tolerating a diet. He complains of intense ocular pain and a decrease in visual acuity. Exam reveals a proptotic and tense globe. What do you think is going on and how do you manage it?*

Fig. 7.11 Trauma complication. (Courtesy of Dr. Tirbod Fattahi)

A retrobulbar bleed. Perform a lateral canthotomy or remove the transconjunctival sutures to decompress the globe. Get an ophthalmology consult.

- *What is the condition seen below and how do you manage it* (Fig. 7.11)*?*
  Nasal septal hematoma. Managed by inserting a 27-gauge needle and aspirating the blood. A nasal packing should be placed for several days to prevent recollection of blood.

References

1. Champy M, Lodde JP, Schmitt R, Jaeger JH, Muster D. Mandibular osteosynthesis by miniature screwed plates via a buccal approach. J Maxillofac Surg (Elsevier). 1978;6:14–21.
2. Powers D. Classification of mandibular condylar fractures. Atlas Oral Maxillofac Surg Clin North Am. 2017;25(1):1–10.
3. Zide MF, Kent JN. Indications for open reduction of mandibular condyle fractures. YJOMS. 1983;41(2):89–98.
4. Bevans S, Moe K. Advances in the reconstruction of orbital fractures. Facial Plastic Surg Clin NA. Elsevier Inc; 2017;25(4):513–35.
5. Lin TKY, Tingey DP, Shingleton BJ. 10.17 – Glaucoma associated with ocular trauma. Fifth Edition. Ophthalmology. Elsevier Inc; 2019; 9853.
6. Gossman DG, Archer SM, Arosarena O. Management of frontal sinus fractures: a review of 96 cases. Laryngoscope. 2006;116(8):1357–62.
7. Bell RB. Management of frontal sinus fractures. Oral Maxillofac Surg Clin North Am. 2009;21(2):227–42.
8. Rodriguez ED, Stanwix MG, Nam AJ, St Hilaire H, Simmons OP, Christy MR, et al. Twenty-six–year experience treating frontal sinus fractures: a novel algorithm based on anatomical fracture pattern and failure of conventional techniques. Plast Reconstr Surg. 2008;122(6):1850–66.
9. Karnad D. Tetanus. 1st ed. Conn's Current Therapy 2019. Elsevier Inc Philadelphia, PA, 2017. 4.
10. Stefanopoulos P. Management of facial bite wounds. Oral Maxillofac Surg Clin North Am. 2009 May;21(2):247–57, vii.
11. Bullard-Berent J. Chapter 123 – Rabies. Ninth Edition. Rosen's Emergency Medicine. Elsevier Inc Philadelphia, PA, 2018. p. 14634.
12. Jackson AC. Rabies. 1st ed. Conn's Current Therapy 2019. Elsevier Inc Philadelphia, PA, Elsevier Ltd; 2017. p. 3.
13. Van Sickels J. Management of parotid gland and duct injuries. Oral Maxillofac Surg Clin NA (Elsevier Ltd). 2009;21(2):243–6.
14. Costa-Ferreira A, Reis J, Rebelo M, Natividade-Silva P, Amarante J. "Non-microsurgical" ear replantation – Baudet's technique revisited. J Plast Reconstr Aesthet Surg. 2007;60(3):325–7.
15. Savage S. Chapter 78 – Management of epistaxis. Third Edition. Pfenninger and Fowler's procedures for primary care. Elsevier Inc Philadelphia, PA, Mosby, Inc; 2011. p. 7.