14 Orbital and Maxillofacial Injuries

N. Girish Kumar and Sabari Girish Nair

14.1 Introduction

According to the World Health Organization, injury was the cause of 5.8 million deaths worldwide in the year 2000 [1]. Injury is the main cause of death in the age group 5–44 years. in the United States. However, the effect of injury on society cannot be assessed by taking the mortality rate alone. Years of Productive Life Lost (YPLL) and Disability Adjusted Life Years (DALY) should also be considered to understand the implications of injury to society. For every death related to injury, there are an estimated 30 patients seriously injured and another 300 treated for less serious injuries. Nonfatal injuries account for a fifth of diseases being treated. In addition, a large number of injuries are not reported [2].

In 2012, an estimated 1,64,000 people died related to war and conflict, corresponding with about 0.3% of global deaths, and increasing to over 2,00,000 conflict deaths in 2014. These estimates do not include deaths due to the indirect effects of war and conflict on the spread of diseases, poor nutrition and the collapse of health services [3]. Armed violence resulting in injury has become a global health problem. Across the world, approximately 3,00,000 people die annually due to firearms in armed conflict situations, while another 2,00,000 people die every year in non-conflict situations due to firearm injury [4]. They represent a quarter of 2.3 million deaths due to violence, of which 42% are due to suicides, 38% homicide and only 26% war related [5]. At the same time, on the battlefield, 90% of the casualties are due to splinter injuries and only 15–20% due to Gun Shot Wounds (GSW) [6, 7].

The incidence and severity of conflicts are increasing throughout the world today. There is no area, region or country that is immune to terrorist attacks. These may be individual or group events; the degree may vary from a stabbing spree to a bomb blast depending on the situation. In such a scenario, it becomes imperative for every health care professional to know how to diagnose injuries afflicted by such events, the immediate emergency measures required to limit morbidity and mortality and the final definitive management and rehabilitation.

The face is an important part of our body responsible for self-recognition, vision, olfaction, hearing, mastication, breathing, verbal and non-verbal communication. It is the most prone to injuries in assaults and accidents. The psychological impact of facial disfigurement is devastating (Fig. 14.1).

N. G. Kumar (✉) · S. G. Nair (Deceased)
ECHS, Medical College, Trivandrum, India

S. Waikar (ed.), *Ocular Trauma in Armed Conflicts*, https://doi.org/10.1007/978-981-19-4021-7_14

Fig. 14.1 Post-traumatic Facial defects

The brain and the cranial nerves have a close association with the face. The development and use of body armor in conflict situations has led to an increase in injuries to the extremity, head and face. In a study by Shapiro et al., 10.5% of all trauma admissions in a Level I trauma center had a facial fracture [8]. The overall mortality of patients with facial fracture was 8.7%. Even though, face accounts for only 0.035% of the total body surface area, it is commonly involved in traumatic injuries especially in conflict zones as it is left exposed and prominent. Bullet-proof vests and helmets cover most of the areas leaving the face and extremities exposed. In a study by Rai et al., 38% of patients in a conflict situation had multiple injuries leading to polytrauma. Of these, 14.2% had head and neck injuries, 13.3% chest wounds, 13.5% abdominal injury and 59% extremity wounds [9] (Fig. 14.2).

Fig. 14.2 Associated Injuries

Triage of mass casualties with multiple system injuries will have to be done by both military and civilian medical personnel as such situations will overwhelm the existing facilities. For this, all medical personnel should be prepared to provide optimum care that will save lives and morbidity. An understanding of the nature of weapons and the physiological consequences of these weapons of war and terror is essential for prompt and optimal management. The first time is the best time to achieve good results. Any secondary correction will always be suboptimal. To achieve optimal aesthetics and function with minimal morbidity, a multispecialty interdisciplinary team approach is a must.

14.2 Modes of Trauma

The main modes of trauma are blunt trauma and penetrating trauma. Blunt trauma is caused by physical assault with a blunt weapon, road traffic accidents or falls. The forces that lead to blunt trauma are due to sudden deceleration or acceleration where either the victim is in motion and strikes another object or the object is in motion and strikes the victim. Due to this, the victim may suffer a soft tissue injury, a bony injury or a combination of both. Soft tissue injuries may vary from mild abrasion to degloving injury with loss of tissue. It may lead to damage to certain vital structures or organ systems. Bony injuries may vary from an undisplaced fracture to a comminuted displaced fracture with loss of bone.

Penetrating trauma can be grouped into low velocity, medium velocity and high velocity. Examples of low velocity trauma are those due to knife attacks, impalement and low velocity bullets. In these cases, the damage is limited to the track created by the wounding object. In the case of medium velocity trauma, the projectile (high velocity bullets and shrapnel) (Fig. 14.3) enters the tissue to create a permanent cavity and a temporary cavity.

The permanent cavity is the localized area of necrosis along the tract of the bullet. The temporary cavity is a transient lateral displacement of the tissues which is caused by the shock waves generated by the bullet. The damage caused by this depends on the elasticity of the tissues. The entrance wound of a gunshot can be seen as an oval or circular wound with a punched-out clean appearance of the margins (Fig. 14.4). A contusion ring may also be present. Entrance wound

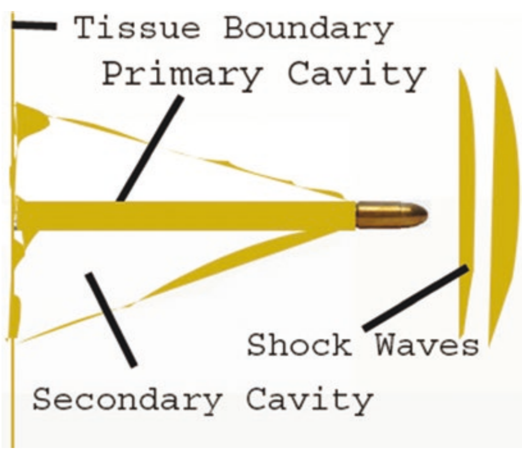


Fig. 14.3 Sketch depicting the primary and secondary cavitation caused by projectiles in the body

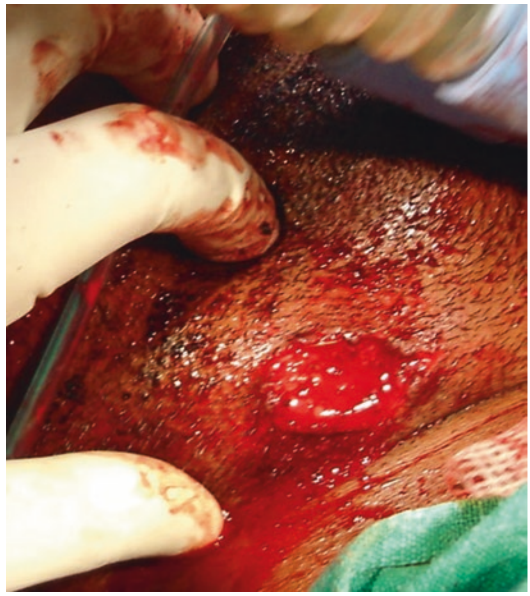


Fig. 14.4 Entrance wound of a bullet

Fig. 14.5 Exit wound of the same bullet

through soft tissue overlying bone is usually stellar in appearance. Exit wounds are usually larger and more irregular. There will be eversion of the margins with irregular skin tags (Fig. 14.5). Shock waves are transmitted to the mandible when a bullet hits it, causing a fracture of the teeth at the cervical margin.

Fig. 14.6 Blast Injury of the face showing the ragged tissue margins, comminution of bone and loss of soft and hard tissue

Blast injuries are caused by bombs and Improvised Explosive Devices (IEDs). These results in the rapid release of enormous amounts of energy, leading to the generation of tremendous amounts of heat and a blast wave that travels outward at supersonic speeds. This blast wave interacts with the body tissues to create stress waves and shear waves. Stress waves create high local forces that are reinforced and reflected at tissue interfaces, thus enhancing the injury potential. Organs containing air or liquids like the lungs, auditory system and intestines are the most affected by these stress waves. Shear waves cause asynchronous movement of tissues resulting in tearing of tissue and possible destruction of attachments (Fig. 14.6). Another set of injuries in the blast trauma were caused by shrapnel released by the explosion. The material may vary from steel particles contained in the IED, automobile parts in a car bomb or fragments of wood, steel or glass from the environment. They typically cause penetrating injuries. They also carry a lot of dirt and contaminants along with them. The fourth type of injury seen is thermal injuries from the heat generated. It depends on the distance of the victim from the blast site.

14.3 Presentation

The presentation of maxillofacial injuries varies depending on the type of force applied, the angle of incidence and the site of occurrence. Generally, maxillofacial injuries appear macabre due to the high vascular supply of the tissues. However, it is not life threatening in most cases. The type of presentation depends upon the nature of force, site of application of the force and the type of tissue acted upon. The type of force may be penetrating or blunt. In penetrating injuries caused by sharp objects, the injury is usually localized and clear cut (Fig. 14.7). The extent of the injuries is clearly visible. In the case of blunt trauma (Fig. 14.8), the extent of injury is not obvious. One has to look for tissue damage in a systematic manner to avoid mistakes and misdiagnosis. In the case shown in Fig. 14.8, even though there are no lacerated wounds, there are panfacial injuries involving the frontal bone, midface and the mandible, as is evident in the three dimensional CT reformatted image (3D-CT).

14.3.1 Clinical Divisions of Face

The face is divided into upper, middle and lower thirds from a clinical point of view (Fig. 14.9). The three regions have their own peculiar features which influence the type of injury seen. The upper third arises from the hairline to the eyebrow and is formed by the frontal bone. Injuries to the upper third are characterized by the involvement of frontal sinuses and orbital roof which dictate the type of treatment required. The middle third extending from the eyebrow to the upper lip is comprised of very thin bones which crumple on impact and thus absorbs a lot of force protecting the eye and the brain except for the vertical and horizontal buttresses. These injuries can cause disturbances in vision, CSF leaks and difficulty in respiration, mastication and speech. The lower third, which extends from the lower lip to chin is the only mobile part and generally fractures at the weakest points, namely angle, the

Fig. 14.7 Penetrating Injury – Clinical and Radiological picture

Fig. 14.8 Blunt Injury – Clinical and Radiological picture. 3D-CT shows fractured frontal bone, fractured maxilla and fractured mandible

parasymphysis region and the subcondylar region. Injuries to this region can also interfere with respiration, mastication and speech.

14.3.2 Upper Third Injuries

The upper third is mainly constituted by the frontal bone which forms the anterior cranial base and is very strong. Any fracture of the upper third is likely to have an associated head injury as the force required to fracture the frontal bone is 200 g (force of gravity) [10]. In addition, the patient may have cervical injury in up to 20% of cases and another life-threatening injury elsewhere in 30% of such cases [11]. Garg et al. suggested a novel classification of frontal bone fractures which had correlation with the severity of the head injury based on CT scan findings [12]. They found that vertical fractures with the frontal sinus and orbital extension, and fractures that penetrated the middle or posterior cranial fossa had the strongest association with intracranial injuries, optic neuropathy, disability, and death ($p < 0.05$). The presentation includes depression of contour, step deformity of the

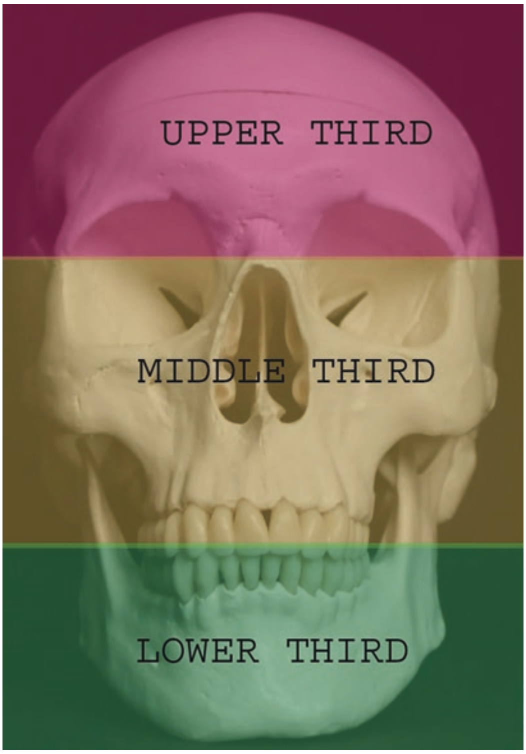


Fig. 14.9 Clinical divisions of the face

supraorbital rims, subcutaneous emphysema and paresthesia of the supraorbital and supratrochlear nerves. Depression of the forehead can be easily missed in the acute presentation due to the accompanying soft tissue oedema. In conscious patients, facial pain is a common symptom. Laceration, contusion, or hematoma to the forehead should make the surgeon suspect frontal sinus injury. In few cases, brain may be seen through lacerations. Cerebrospinal fluid (CSF), rhinorrhea or CSF in the wound can present in as many as one third of patients with frontal sinus fractures. From a surgical point of view, the frontal bone may be classified into medial fractures, lateral fractures and the combination. The medial fractures usually do not involve the cranial cavity and affect the frontal sinus (Fig. 14.10). In severe cases of trauma, both the inner table and the outer table are damaged leading to cranial involvement. For lateral fractures, the orbital roof may be involved and need special consideration (Fig. 14.11). These types of injuries are seen when the patient's head hits an object from the side. Lacrymal gland, which is also located in the region, may be affected. In combination, the trauma is so severe that the whole forehead is involved bilaterally and needs neurosurgical intervention (Fig. 14.12). In cases of gunshot wounds, the brain is usually seen through the wound if the frontal lobe is involved. Gunshot wounds in other areas of the brain may not be seen as they rarely survive. The clinical features are given in Table 14.1.

14.3.3 Middle Third Injuries

The middle third of the face is composed of a complex of bones consisting of the paired maxilla, palatine, zygomatic, lacrimal, inferior conchae and the unpaired vomer and the ethmoid bones. This region is composed of very thin bones supported by vertical and horizontal buttresses (Fig. 14.13). Most of the fractures in this region are termed complex as they involve more than one bone. The most important structure in the middle third are the eyes. They are protected by the orbital rims which are composed of dense cortical bone. The orbital walls on the other hand are usually thin except for the lateral orbital wall composed of the orbital surface of the zygoma and the greater wing of the sphenoid bone. The orbital walls are further weakened by superior and inferior orbital fissures. The floor and medial walls are the ones most frequently fractured sometimes, even without a rim fracture, leading to a blowout fracture. The weakest part of the orbital wall is the region on the floor just medial to the infraorbital groove and is the most common site of blowout fracture. The maxillary sinus and ethmoidal air cells act as airbags to protect the eye. Even though there are a wide variety of classifications of the middle third fractures, from a practical and clinical view point, middle third fractures can be grouped into naso-orbital, maxillary, zygomatic and orbital. Many a time, there may be a combination of the above.

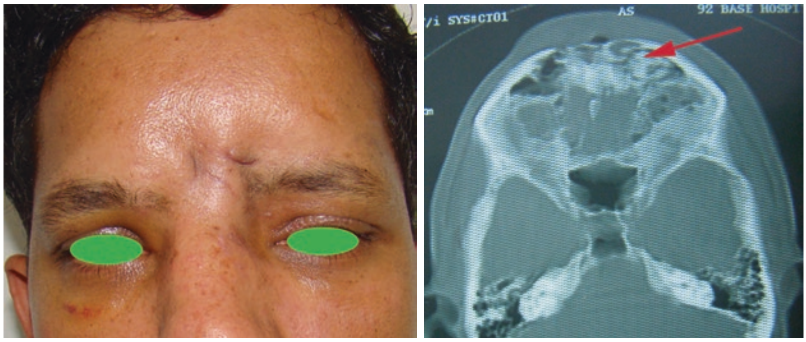


Fig. 14.10 Frontal Bone Medial fractures-clinical and CT picture

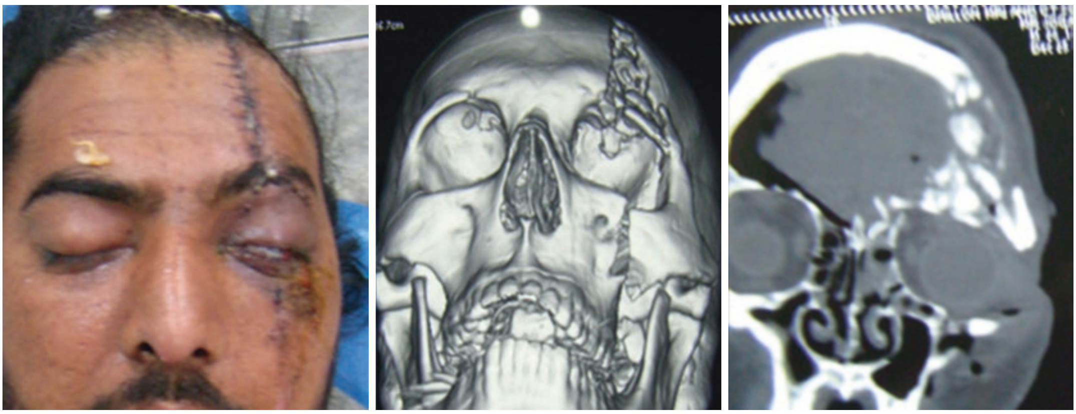


Fig. 14.11 Frontal bone lateral fracture - clinical and radiological picture

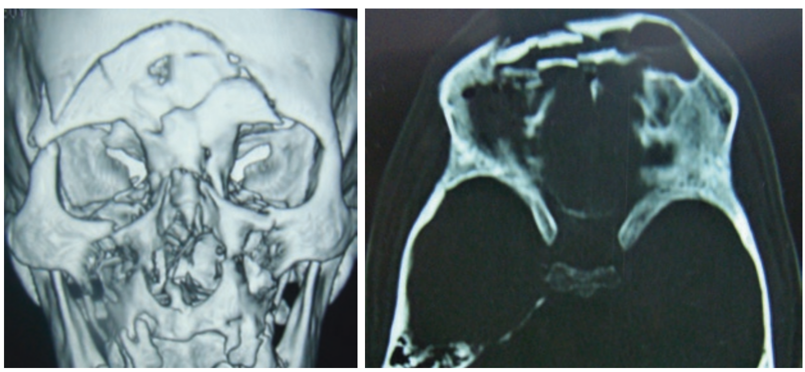


Fig. 14.12 Frontal Bone fracture-combination involving the medial and the lateral

14.3.4 Nasoorbital Fractures

Naso-orbital fractures may vary from a simple nasal bone fracture, which is the most common, to a complex fracture involving the nasal bone, frontal process of maxilla, lacrimal bone and ethmoid. This type of fracture involves the medial orbital wall and leads to disruption of the medial canthal ligament, lacrimal apparatus, fracture of the cribriform plate leading to CSF rhinorrhea and severe epistaxis from the anterior and posterior ethmoidal arteries (Fig. 14.14). The main clinical features associated with this fracture include depression of the nasal bridge, epistaxis,

Table 14.1 Clinical signs and symptoms of facial trauma

Symptoms/ signs	Upper third injuries	Middle third injuries	Lower third injuries
Symptoms	Pain, numbness, fainting, cut, swelling, bleeding, deformity	Pain, numbness, cut, swelling, bleeding, deformity, difficulty in opening eye, loss or diminished sight, double vision, difficulty in closing mouth	Pain, numbness, cut, swelling, bleeding, deformity, difficulty in opening mouth, difficulty in closing mouth, dev
Signs	Laceration, contusion, deformity, oedema, hemorrhage, loss of consciousness, hematoma / ecchymosis, sensory/motor deficit, crepitus, tenderness, step deformity,	Laceration, contusion, periorbital ecchymosis, subconjunctival ecchymosis, hemorrhage, Telecanthus, orbital dystopia, periorbital oedema, difficulty in opening eyes, restriction of eye movement, ocular injuries, enopthalmos/ exophthalmos, epiphora diminished vision, diplopia, epistaxis, subcutaneous emphysema, dystopia, CSF rhinorrhea/ otorrhea, crepitus, tenderness, step deformity, motor/sensory nerve deficit, difficulty in opening mouth/closing mouth, mobility of fractured fragments, elongation of face, dish face deformity, raccoon eyes, palatal hematoma (Guerin's sign), split palate, occlusal derangement	Pain, laceration, contusion, sensory deficit, oedema, hemorrhage, deformity, restriction in mouth opening, deviation of jaw on opening, tenderness/step deformity, deranged occlusion, open bite

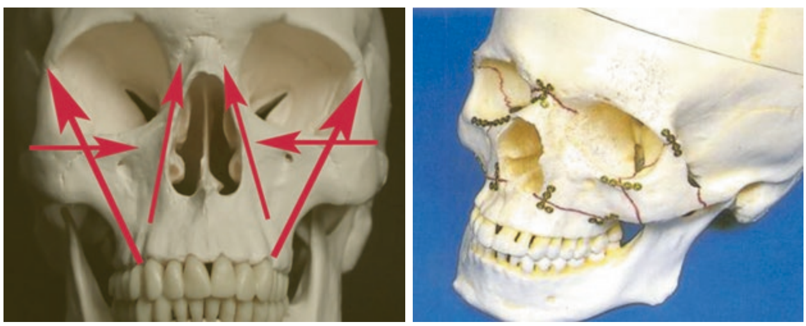


Fig. 14.13 Midface Buttresses (Red arrows) and sites of stabilization

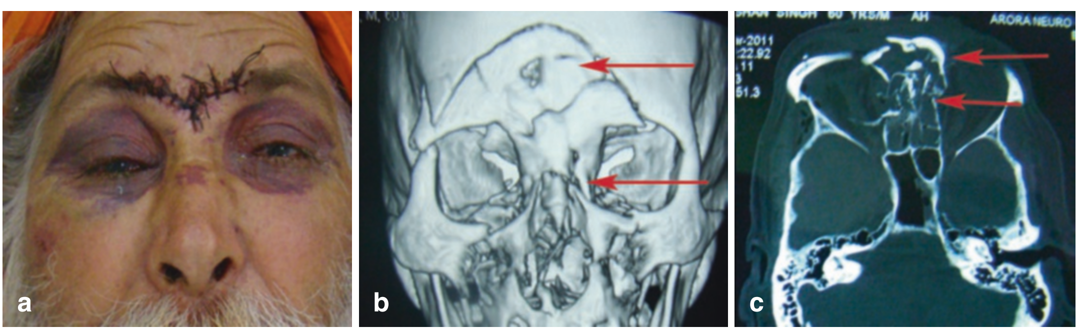


Fig. 14.14 Naso-orbital fracture – clinical and radiologic pictures. (**a**) Showing bilateral circum-orbital ecchymosis. (**b**) 3D-CT showing the nasal bone fracture. (**c**) Axial CT scan showing nasal bone fracture (White Arrow) and ethmoid fracture (Black arrow)

CSF rhinorrhea, telecanthus, shortening of the palpebral fissure, subconjunctival ecchymosis and epiphora.

14.3.5 Maxillary Fractures

The Le Fort series of fractures are those involving the maxilla above the palate and alveolus and extend through the lateral nasal wall and the pterygoid plates and are grouped into I –III depending on the extent of involvement. Le Fort- I involve only the alveolar part of maxilla and the palatine bone and so is a low-level fracture which extends from the pyriform rim backwards and outwards along the buttress and crosses the pterygomaxillary junction to fracture the lower third of the pterygoid plates (Fig. 14.15). In this type of fracture, maxilla is generally mobile and so called the floating maxilla. Sometimes there is a split of the horizontal palatine process leading to an oronasal fistula. Hematoma in the greater palatine foramen region is pathognomonic of Le Fort- I fracture. Le Fort- II fracture is a pyramidal fracture starting from the nasal bone extending laterally to involve the medial wall of the orbit, infraorbital margin around the infraorbital foramen and then down along the zygomaticomaxillary suture to end in the middle third of the pterygoid plates (Fig. 14.16). This produces the

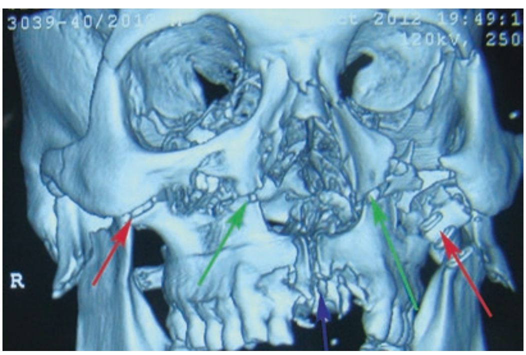


Fig. 14.15 3D-CT showing the line of fracture in Le Fort I. The red arrows show the fracture at the zygomatic buttress, the green arrows at the frontomaxillary buttress and the blue arrow at the midline split of palate

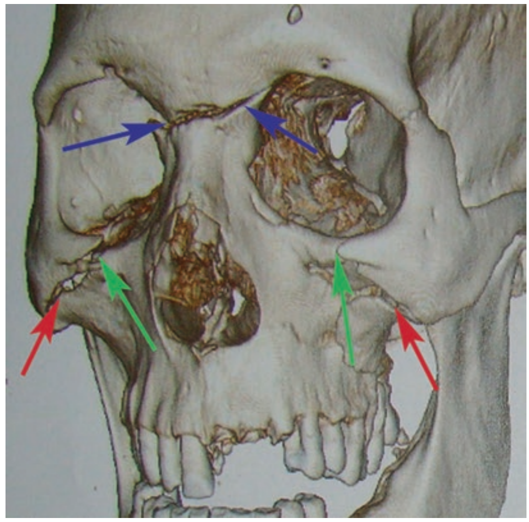


Fig. 14.16 3D- CT showing Le Fort II fracture. Red arrows at the zygomatic buttress, green arrows at the infraorbital margin and blue arrows at the nasal bone fracture

characteristic dish face deformity. In this type of fracture, maxilla is generally displaced downwards and backwards and is most commonly impacted. Hence, there may not be mobility of the fragment and at times it takes considerable force to disimpact the maxilla during reduction. The Le Fort- III fracture is actually a craniofacial dysjunction characterized by the separation of the entire face from the cranium. The fracture starts from the frontonasal suture that extends laterally to involve the frontomaxillary suture, extends posteriorly through the ethmoid bone below the optic foramen through the pterygopalatine fossa and fractures the upper third of the pterygoid plates (Fig. 14.17). The whole face is mobile, leading to lengthening of the face. Although the fractures of the maxilla have been classically grouped into these three types, Patil et al. found that only 24% of the maxillary fractures follow this pattern [13]. In a collective review of maxillary fractures, Phillips and Turco found that Le Fort I, II and III occurred in 16%, 19% and 30% of facial trauma cases. They also found that the majority of these trauma cases were due to motor vehicle accidents [14].

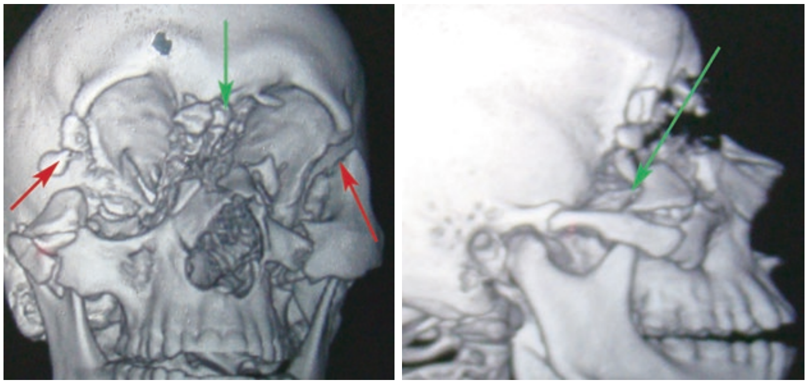


Fig. 14.17 3D CT showing the Le Fort III level fracture frontal and lateral view. The red arrows at the frontozygomatic suture, the blue arrow at the frontomaxillary suture. The green arrow in the picture on the right shows the downward and backward movement of the facial skeleton along the cranial base

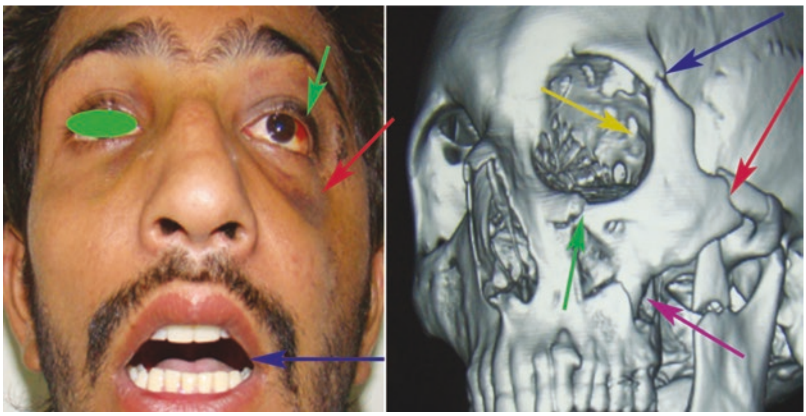


Fig. 14.18 Clinical and radiologic pictures of zygomatic complex fractures. The green arrow on the left picture shows the presence of subconjunctival ecchymoses, the red arrow depicts the malar depression and the blue arrow shows the restriction of mouth opening. The blue, red, purple, green and yellow arrows on the right show the fracture at FZ suture, zygomatic arch, zygomatic buttress, infraorbital margin and spheno-zygomatic suture respectively

14.3.6 Zygomatic Complex Fractures

The lateral group includes fractures of the zygomatic complex, again the term used because of the usual involvement of more than one bone in such fractures. This can vary from a simple fracture of the zygomatic arch to a comminuted fracture of the zygomatic complex. Sometimes the zygoma is pushed inwards and so the fracture line may not be visible in the CT. This is seen when the force is applied from the lateral aspect of the body of the zygoma. If force is applied from the front, in many cases this leads to lateral, outward and downward displacement of the zygoma leading to lowering of the eye level and enopthalmos. Fig. 14.18 depicts the typical clinical and radiological features of fractured zygoma. Any subconjunctival hemorrhage without a visible posterior limit is diagnostic of zygomatic complex fractures. Other key clinical features include restriction in mouth opening, malar depression and tenderness / step deformity in zygomatic buttress, infraorbital and frontozygomatic (FZ) suture regions. If the zygoma is significantly displaced outwards and downwards, lowering of the globe is also seen.

14.3.7 Orbital Blowout Fractures

The orbital fractures usually have some overlap with the above-mentioned middle third fractures

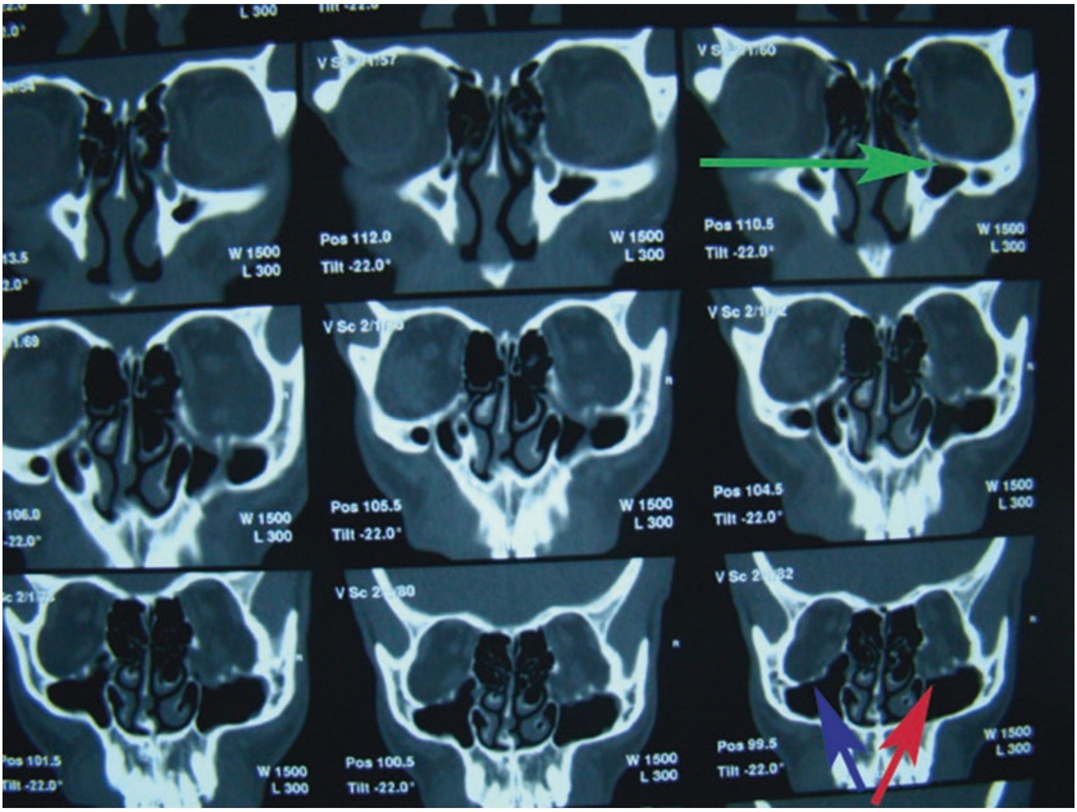


Fig. 14.19 Coronal CT scan showing a 'Blowout' fracture of the orbit. The green arrow shows the intact orbital margin, the red arrow the extrusion of orbital contents into the maxillary sinus through the floor fracture and the blue arrow shows the normal shape of the floor of the orbit at that cross section on the opposite side

as the orbital walls are formed by the zygoma, greater wing of sphenoid, maxilla, ethmoid, lacrimal and the frontal bones. However, there is a unique type of fracture in orbit called the "Blow Out Fracture". A pure blow-out fracture is one in which the orbital wall is fractured without involving orbital margins (Fig. 14.19). Usually this involves the thin upward sloping floor of the orbit leading to entrapment of orbital contents into the maxillary sinus. This may involve orbital fat or extraocular muscle. Clinically this manifests as infraorbital nerve paresthesia/anesthesia and restriction of eye movement. It is important to educate the patient to avoid blowing their nose, as air from the sinonasal tract can be forced into orbit. This can result in an orbital compartment syndrome that can cause blindness [15]. CT scans show the actual extent of the fracture. This type of fracture happens when an object having a diameter larger than the orbit hits the orbit, the eyeball is pushed inwards exerting pressure on the orbital wall which gives way. In fact, there is no clear demarcation between the floor and the medial wall. The floor ascends medially gradually to become part of the medial wall. The medial wall is also formed by thin bone (Fig. 14.19). If the extraocular muscles get entrapped in this fracture, it may lead to restriction in eye movement. This is confirmed by looking for restrictions in eye movement, usually in the upward gaze. To rule out restrictions due to nerve injuries, a forced duction test was also carried out. In some cases, even if there is no muscle entrapment, atrophy of orbital fat due to trauma can cause enopthalmos which will become evident later on. In some patients, diplopia develops and the patient walks with the head turned towards one side or with one eye closed. Even

Fig. 14.20 Rare cases of blow out fractures of the lateral orbital wall. (**a**, **b**) showing the restriction of movement of Lt eye, (**c**) The blowout fracture of the lateral orbital wall without involving the rim, (**d**) The reconstruction of the defect with titanium mesh, (**e**, **f**) the restoration of full eye movement

though it involves the floor mostly, in certain cases it can involve the medial wall and rarely the lateral wall (Fig. 14.20). Occasionally, a "Blow In" fracture may occur. These is due to the fracture of the roof of the orbit in frontal bone fractures. The roof of the orbit is made of very thin bones which are easily fractured in frontal bone injury. Pure blow-out fractures are seen in 4–16% of all facial fractures while those involving the orbital rims comprise 30–55% of all facial fractures [16].

The globe is held in place in the horizontal axis by the Lockwood's suspensory ligament which is attached medially to the posterior aspect of the lacrimal bone and laterally to the medial aspect of the frontal process of the zygomatic bone at the Whitnall's tubercle located 1 cm below the frontozygomatic suture and 3–4 mm posterior to the lateral orbital margin. The shape and location of the palpebral fissure is determined by the attachment of the canthal tendons. The medial canthal tendon is attached to the anterior and posterior lacrimal crests. The lateral canthal tendon is also attached to the Whitnall's tubercle. Any disturbance in this arrangement can lead to telecanthus and dystopia. If the medial canthal attachment is detached, it will lead to telecanthus (Fig. 14.21). If the zygomatic complex is displaced downward and outward, it will lead to lowering of the globe on that side (Fig. 14.21).

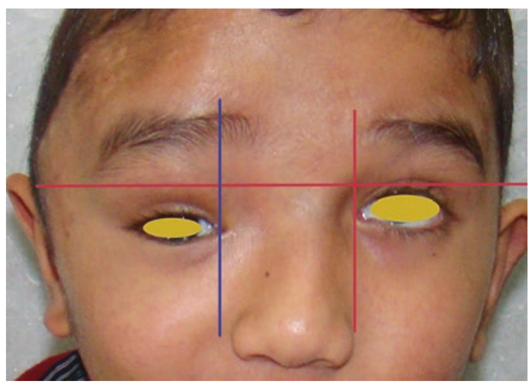


Fig. 14.21 Orbital dystopia showing the lowering of Rt Globe and telecanthus

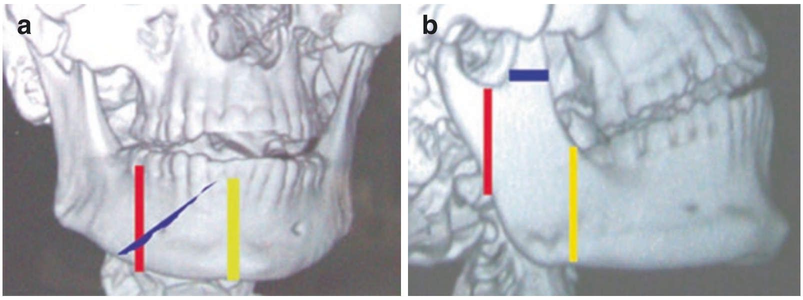


Fig. 14.22 Common sites of fracture mandible. (**a**) 3D-CT showing body fracture (red), parasymphysis fracture (blue) and symphysis (yellow). (**b**) 3D-CT lateral view showing subcondylar fracture (red), coronoid fracture (blue) and angle (yellow)

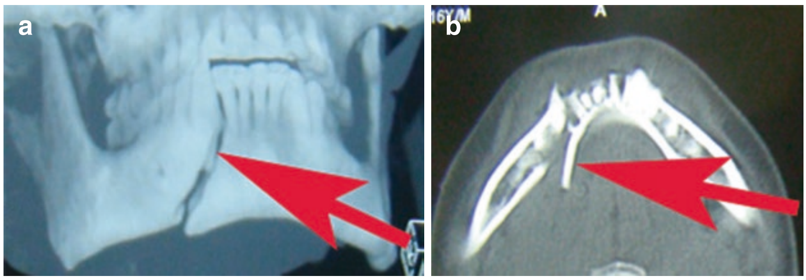


Fig. 14.23 (**a**, **b**) Fracture mandible Rt parasymphysis

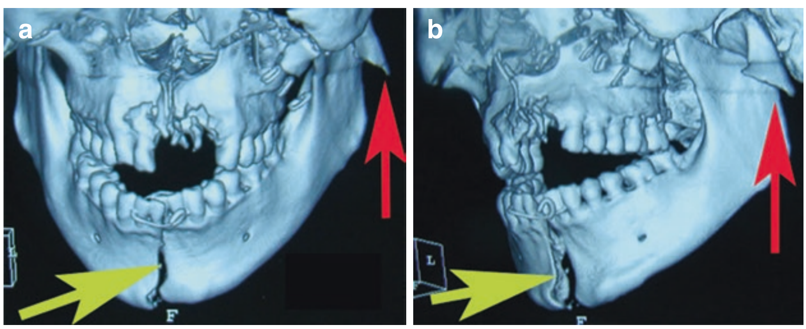


Fig. 14.24 3D-CT showing fractured mandible symphysis and subcondylar. (**a**) frontal view and (**b**) lateral view. Red arrows show the laterally displaced subcondylar fracture and the yellow arrows the torsional displacement of the symphyseal fracture

The clinical features of the middle third fractures are given in Table 14.1.

14.3.8 Lower Third Injuries

Mandible is the only movable bone in the outer facial skeleton and being very prominent in most individuals is commonly involved in maxillofacial trauma. Due to the U shape, multiple fractures are seen in more than 50% of cases. The most common fractured area depends on the type of trauma. The common sites of fracture are parasymphysis, angle, subcondylar and body (Fig. 14.22). Mild to moderate impact often causes fractures of mandible parasymphysis (Fig. 14.23). In automobile accidents and falls, subcondylar and parasymphysis fractures are commonly seen (Fig. 14.24). Assaults more often cause angle fractures (Fig. 14.25). The most common associated injuries include head injuries (39%), head and neck laceration (30%), midface fractures (28%), ocular injuries (16%), nasal fractures (12%), and cervical spine fractures (11%) [17]. Common clinical features include pain, swelling, hemorrhage, step deformity, tenderness, and difficulty in opening/closing the mouth, deviation on opening jaw, occlusal

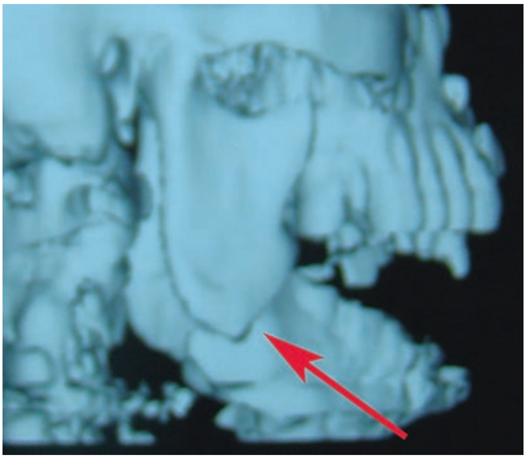


Fig. 14.25 3D-CT showing fractured angle of mandible

derangement and nerve deficit. Lingual hematoma is a pathognomonic sign of fracture mandible. Tongue blade bite test is also a useful test for detecting fracture mandible. The clinical features are given in Table 14.1.

Of 929 isolated facial fractures, the most common fracture type was a nasal bone fracture (164), followed by orbital floor (150), ZMC (76), maxillary sinus (75), mandibular ramus (48), and nasoethmoid orbital (46) [18]. In patients with orbital fractures, associated ocular injuries are present in up to 29% of the patients [19].

In high velocity injuries due to motor vehicle accidents (MVA), all three regions of the face may be involved and thus they are called panfacial trauma. It is mostly due to blunt trauma (Fig. 14.8). There may or may not be a laceration or visible injury. There are fractures in the upper third, middle third and lower third.

Similarly, Gun Shot Wounds (GSW) produce its own peculiar feature. The exact clinical picture is unpredictable. If it is due to a low velocity bullet, the bullet may enter the body and after hitting a bone may be deflected and lie without causing significant damage. Sometimes it may get deflected by bone or teeth and then take an unpredictable course inside the body. For example, in one case the bullet had entered the cheek on the right side from the front, hit the mandible and was found lying under the skin in the posterior triangle of the neck on the right side without causing any significant injury on the right side. The bullet was removed without any difficulty from the right side. Even though it had crossed over to the right side through the neck, it did not cause any major vascular injury. Arteries generally get deflected due to the resilience of the wall. For high velocity gunshot wounds, there is usually a small entry wound and a large exit wound (Fig. 14.4 and 14.5). There is extensive destruction of both hard and soft tissues along the route, causing the comminution of the bone and many a time, loss of soft tissue. However, blast injuries typically show a massive entrance wound with multiple bony fragments and foreign bodies lodged in the tissues (Fig. 14.6). There is usually a significant loss of tissue- both hard and soft. The actual extent of tissue trauma is much beyond visible as it leads to considerable micro trauma resulting in avascular necrosis of adjacent tissue which will be presented later on.

14.4 Management

Maxillofacial injuries can occur in isolation or along with injuries elsewhere. It produces local as well as systemic effects. Local effects include an inflammatory response leading to pain, tenderness, swelling and decreased function. Systemic effects include biological and psychological stress reactions. The biological reaction is affected mainly by the release of the endogenous catechol amines while the psychological reaction is of denial, shock, fear and an increased sense of vulnerability. These factors should be taken into consideration before attending to the patient.

The care received in the "golden hour" of trauma determines the final outcome. In cases of airway compromise, this take even minutes, while in patients with unstable hemorrhage, like pelvic fractures, it can take several hours. Approximately 60% of the all trauma related hospital deaths occur during this important hour. Avoidable deaths due to inadequate assessment and resuscitation contribute to the 35% of these deaths [20]. A 2016 National Academy of Science report estimated a civilian trauma Preventable Death Rate (PDR) of 20% or about 30,000 deaths per year [21]. In order to promote greater implementation of effective, affordable, and sustainable trauma systems globally, the World Health Organization (WHO) and the International Association for Trauma Surgery and Intensive Care (IATSIC) have worked collaboratively in the past to produce Guidelines for essential trauma care, which defined the core essential trauma care services that every injured person in the world should realistically be able to receive, even in the lowest income setting. In order to ensure the availability of these services, the publication went on to propose the minimum human resources, physical resources, and administrative mechanisms that should be in place in the range of health care facilities globally. The publication and the related prehospital trauma care systems have considerably catalyzed improvements in trauma systems in many countries since their release several years ago [22].

Uncontrolled hemorrhage is the most common cause of mortality in the first 48 h. With the advances in prehospital care and efficient transport, more severely injured patients are now capable of reaching hospital. The development of trauma centres has led to an increase in survival of such patients who will require reconstruction of devastating facial injuries. The craniofacial team should ideally include the anesthetist who is the first responder, neurosurgeon, ophthalmologist, maxillofacial surgeon, otorhinolaryngologist and the radiologist. A reconstructive surgeon and a pediatric surgeon can be included if required. Advances in managing severely injured patients are permitted early and definitive primary fracture treatment. The management of such cases can be considered under three heads – primary survey and resuscitation, secondary survey and definitive management.

14.4.1 Primary Management and Resuscitation

Primary management of severe maxillofacial injuries should follow the protocol advised by Advance Trauma Life Support (ATLS) to prevent loss of life and morbidity. The goals of primary management are to identify and treat threats to life, limb and eye sight, to prevent exacerbation of existing injury and to restore function to normal levels. Time is of the greatest significance. The role of a well-trained multispecialty interdisciplinary team in achieving this goal is very significant. In conflict situations, these patients have multiple penetrating injuries with severe tissue destruction. They also have profound acidosis, hypothermia and coagulopathy. In such patients, time consuming procedures for repair of all identified injuries has led to death in many cases. Today for such patients, "damage control surgery" is an option. This involves abbreviating laparotomy with rapid and precise control of hemorrhage and contamination with temporary packing if necessary, followed by physiologic resuscitation. Once the patient is stabilized, the patient can be taken up for definitive repair of all injuries, including abdominal closure.

An important point to be kept in mind is that maxillofacial trauma rarely causes hemorrhagic shock even though it appears to be very severe. In such cases, one should look for any occult hemorrhage in the thorax or abdomen or even a closed injury of the extremity. The risk of death due to maxillofacial injury is only because of airway obstruction. In many cases with severe injuries even in GSW or blast injuries, the patient is conscious and prefers to sit up in a forward position rather than lie down to maintain the airway. If such patients are made to lie down, they cannot maintain the patency of the airway. Awake fiber optic intubation is the ideal method of intubation in such patients. However, it may not be possible because of the heavy hemorrhage associated with facial injuries.

The facial soft tissue is highly vascular and bleeds from both sides. In addition, certain arteries like anterior ethmoid arteries, posterior ethmoid arteries and the internal maxillary arteries are not easily accessible for control. In such cases, packing the nose and pharynx can control the hemorrhage. There are many methods of packing. Initially, anterior and posterior packing with gauze was the only option which was difficult and time consuming. A wide variety of materials are available now. The most widely used and

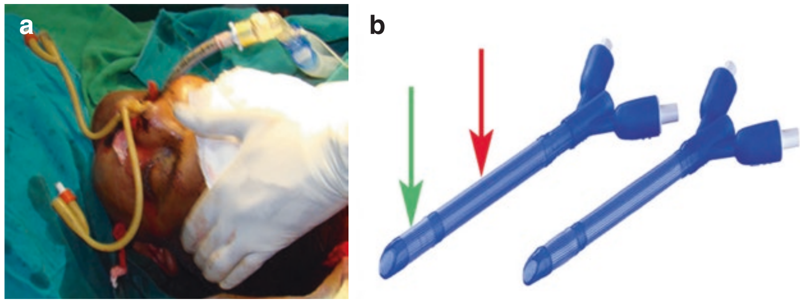


Fig. 14.26 Management of hemorrhage by packing. (**a**) Use of Foley's Catheter as a nasal pack. (**b**) Epi-Max Catheter with anterior cuff (Red Arrow) and posterior cuff (Green Arrow)

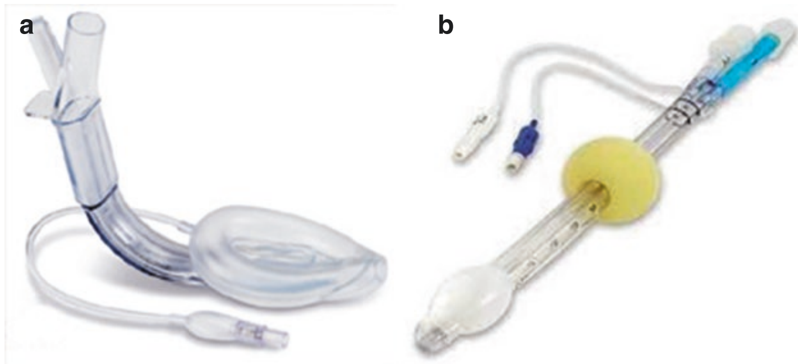


Fig. 14.27 Airway for difficult intubation in trauma. (**a**) Laryngeal mask, (**b**) Combitube

the easiest to use is the epistaxis catheter to achieve anterior and posterior nasal pack (Fig. 14.26). The lubricated epistaxis catheter is inserted through the nostril after cleaning the nasal cavity of foreign bodies and blood clot in such a way that the posterior balloon extends into the nasopharynx. The posterior cuff is inflated with 4–8 mL of air. The catheter is then pulled out gently until it engages the posterior choanae to form the posterior seal. Then the anterior cuff is inflated with 10–25 mi of air and the catheter taped to the nose. An oral tube is then passed as early as possible. Once the patient's condition stabilizes, the oral tube can be changed to a nasal tube so that occlusion can be obtained by inter-maxillary fixation. In mandibular fractures, hemorrhage from the fractured fragment can be controlled by temporarily stabilizing the fracture.

The American Society of Anesthesiologists (ASA) has come out with a Practice guideline for management of difficult airway [23]. In case of difficulty in vision due to excessive hemorrhage, oral intubation under direct laryngoscopy should be attempted. Once the patient's condition is stabilized, it can be converted to nasal intubation or submental intubation. Other options for control of the airway in the emergency setting are the use of laryngeal mask airway and Combitube (Fig. 14.27). The use of intervention radiology to arrest such deep hemorrhage by embolization is also being studied. Planned tracheostomy can be carried out once patient's condition stabilizes where the need for prolonged intubation is expected postoperatively. In a study by Beogo et al., it was found that tracheostomy was required in 22.4% of all Le Fort fractures and 43.5% of all Le Fort -III fractures [24].

Once the patient's condition is stabilized, the secondary survey is carried out. A head to toe examination is done to note all injuries obvious and otherwise. The potential for missing an injury or failing to appreciate the significance of an injury is great, especially in an unresponsive or unstable patient. A detailed ophthalmic examination should be carried out at the earliest as it may not be possible later on due to lid edema. Examination of the face should start from the upper third, then middle third and then the lower third in a systematic manner. Soft tissues are examined to detect any asymmetry, swelling, hemorrhage, contusion, laceration and avulsion. Any bleeding from the ear and nose should be noted. Hearing and acuity of vision should be checked. Jaw movements are checked for restriction/ deviation. Restrictions can be due to an angle fracture, subcondylar fracture or a Le Fort-II fracture. Deviation of the jaw to the same side occurs in unilateral subcondylar fracture. An open bite or inability to close mouth fully can be seen in bilateral subcondylar fractures as well as Le Fort-II fractures of the maxilla (Fig. 14.28 and 14.29). All bony margins are palpated to look for tenderness, step deformity and crepitus. The presence of crepitus in the soft tissues suggests the involvement of the paranasal sinus. Both sensory and motor nerves are checked for deficit at this stage and recorded clearly as changes may occur in their status after surgical treatment. The intraoral examination should reveal the presence of step deformity, occlusal derangement, unilateral or bilateral open bite, soft tissue laceration/ hematoma and the fracture of teeth (Fig. 14.28, 14.29 and 14.30). Missing teeth to be noted. Any mobile anterior teeth in the maxilla may be dislodged accidentally during intubation. Intrafragmentary movements, if any, should be noted. Mobility of the maxilla is assessed by placing the head securely against a headrest, grasping the upper teeth and alveolus and moving it gently but purposefully in all directions. In the case of a mandible the mandible is pushed down while the mouth is open. Any fracture of the mandible if present, will cause pain. In the case of symphyseal fractures, the fracture fragments will be distracted upon opening the jaw. It can also be checked by gently pushing both angles inwards when patient will experience pain in the symphysis. Split palate can lead to an oronasal fistula.

14.4.2 Imaging

The primary imaging modality of maxillofacial trauma today is CT scan. Previously, the PNS view of the skull was a basic radiograph of the middle and upper third fractures. Due to the multiple bones involved and their overlap, a two-dimensional radiograph in middle third and upper third fractures led to many fractures being missed. In addition, the severity of the fracture and the degree of involvement of the cranial and orbital cavities cannot be assessed with a conventional two-dimensional radiograph. Today, the coronal section of the facial bone gives the surgeon enough idea about the actual extent of the middle

Fig. 14.28 Clinical presentation of fracture mandible. (**a**) step deformity seen in fractures of parasymphysis and angle of the mandible. (**b**) step deformity seen in the fractured body of the Mandible Rt. (**c**) Anterior open bite seen in bilateral subcondylar fracture

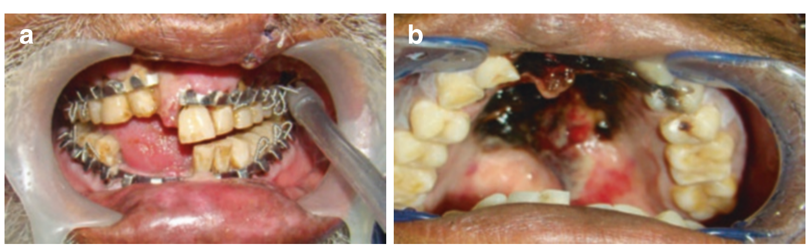


Fig. 14.29 Clinical presentation of fractured maxilla Le Fort I. (**a**) step deformity due to vertical displacement of maxillary fragments. (**b**) Horizontal displacement due to split palate

Fig. 14.30 Fracture maxilla Le Fort II clinical picture showing elongation of face, anterior open bite and downward and backward displacement of maxilla

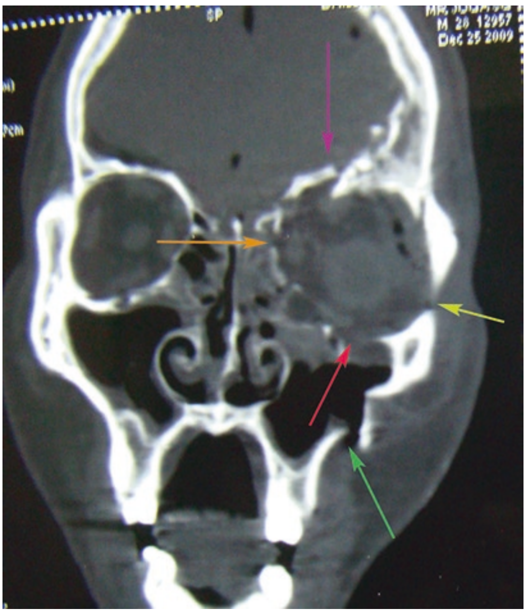


Fig. 14.31 Coronal section CT showing the involvement of all four walls in the orbit

third fractures (Fig. 14.19). For frontal bone fractures, it is important to know the anteroposterior involvement of the fracture. An axial section of the region will clearly show the involvement of the anterior as well as the posterior table of the frontal sinus which is an important information required for planning the type of surgery required (Fig. 14.10 and 14.12). A good coronal section of the same region will give a clear idea of the involvement of the orbital roof (Fig. 14.31). A CT scan is equally important for fractures involving orbit to assess the degree of reconstruction required. In fact, the requirement of reconstruction of the orbital floor can be easily predicted after visualizing a coronal section which gives a clear idea about the anteroposterior and the transverse width of the floor defect. This will clearly show the entrapment of the soft tissue in the orbital floor fracture. In maxillary fractures also, coronal sections give a clear idea of the type of fracture and the involvement of the maxillary sinus and the orbital floor which is important to plan surgical management. The axial sections give a clear idea of the involvement of the pterygoid plates in the fracture as well as the type of fracture of the horizontal palate. Even though Orthopantomograph gives a good picture of pure mandibular fractures, in fractures involving the condylar region, a CT scan is an essential diagnostic modality. The CT scan will clearly show the type of fracture which is important in deciding the approach to the fracture as well as the difficulty in management. Today with the availability of 3D modeling and manufacture of patient specific implants, CT scans have a greater role to play [25, 26]. This is also true with the increasing use of interventional radiology in controlling hemorrhage from deep seated tissues like internal maxillary artery. An MRI may be required in select cases to explore the possibility of nerve injury as well as ocular injuries.

14.4.3 Definitive Management

The face has several important functions like nutrition, respiration, vision, taste and communication. The importance of these functions can be understood by the fact that 11 of the 12 cranial nerves supply the face. Its proximity to the vital structures of the head and neck is also of great significance. It is responsible to a great extent for the personality of the individual and any disfigurement will lead to considerable psycho-social problems. The earlier definitive treatment is started, the better the result will be. This is due to rounding of bony ends with time leading to difficulty in approximation later on. It is especially important in the middle third fractures as the bone fragments are too thin in most of the regions and it is difficult to realign the structure if these bones are lost. Three dimensionally restoring the middle third when there is multiple fragmentation as seen in severe trauma is a big challenge. Soft tissue contracts with time and it becomes difficult to approximate the tissues leading to dehiscence postoperatively. The best time to achieve good results is the first attempt. Any compromise in the quality of primary repair will lead to secondary deformity which is very difficult to correct at a later stage.

The goal of definitive management is to establish form and function through:

- Anatomic reduction of fracture fragments after achieving occlusion followed by stabilization.
- Preservation of width, projection and height of the face.
- Preservation of vital structures of the face like facial nerves, parotid ducts, lacrimal ducts, eyeballs, cranial nerves.
- Early return to function.

14.4.4 Soft Tissue Repair

Soft tissue wounds may be cleaned, contused or punctured wounds, or any combination of these three. The first step in wound management is wound debridement. This is done by exploring the wounds by placing incisions where necessary, followed by thorough debridement with diluted chlorhexidine and a brush to remove all dirt and foreign bodies to prevent tattooing. After this the wound is irrigated copiously with saline followed by antibiotics. It should be remembered that glass particles may not be easily visible and have to be looked for. Then necrotic tissues are excised conservatively. With face being very vascular, excision is limited to tags of loose, dead skin or mucous membrane at the edge of the wound. No area should be allowed to dry. Placement of wet gauze in between procedures will prevent the desiccation of the soft tissue flaps. Wherever possible, primary closure must be done. This is true even for gunshot wounds and blast injuries, unlike other areas of the body where it is best to leave it open due to excessive contamination and contusion. Where there is extreme loss of tissue and facilities for harvest of flaps to cover the defect is not available, skin can be sutured to mucosa to limit the contraction of the wound. Care should be taken to preserve vital structures like parotid duct and the facial nerve during debridement, especially in injuries involving the cheek. Once the soft tissues are debrided properly, the hard tissues must be restored to its original form before closing primarily. In facial regions, generally drain placement is not necessary. However, if the wound is extensive and tissues appear traumatized, a suction drain can be placed. Primary closures can generally be obtained by giving adequate release incisions. The cleansed wound is first loosely assembled, in order for an assessment of any tissue loss to be made. In the face, approximately 5 cm advancement can be obtained by releasing incisions. Where advancement will lead to excessive tension, local or regional flaps may be used to achieve closure. No bones should ideally be left exposed. Lingual mucosa is notorious for giving away in the postoperative period. To prevent that, some reduction of bone level can be attempted to reduce tension. For severe injuries, it is best to start with landmarks easily identifiable like corner of mouth, eyebrow, eyelid, vermillion border and angle of the eye to achieve reasonable esthetics (Fig. 14.32). Tetanus toxoid should be administered if indicated.

14.4.5 Hard Tissue

The principles of hard tissue management are wide exposure of all the fractures, mobilization, reduction and stabilization. Management of hard tissue injuries involves the mobilization, reduction and stabilization of fracture fragments. In tooth bearing areas, occlusion must be ensured before stabilization of the fractures.

14.4.6 Approaches to the Facial Skeleton

There are numerous methods for exposure of the facial skeleton [27]. As far as possible, incisions

Fig. 14.32 Preoperative and postoperative photos showing restoration of form with direct primary closure

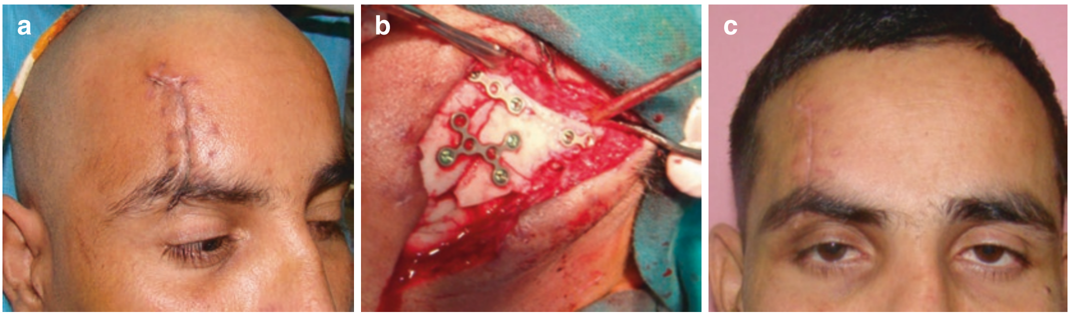


Fig. 14.33 Approach through existing lacerations. (**a**) Existing laceration. (**b**) Intra-operative exposure. (**c**) Postoperative appearance

should not be placed in the face to avoid disfiguration as well as injury to the facial nerve branches. The exception to this rule is when there are existing lacerations (Fig. 14.33) and it is possible to get adequate exposure of the fracture either through the laceration or by very little extension to it. However, in the naso-orbital region, even in the presence of a laceration, it would be better to approach through a coronal incision to get enough advancement of the tissue for closure without tension and to avoid an ugly scar in the most prominent part of the face. The selection of the method depends to a large extent on the part to be exposed, the type of fracture (degree of fragmentation and stability) and the training, skill and comfort level of the operating surgeon. Intra-oral incisions are used wherever possible.

The best approach to upper third fractures is the coronal or hemicoronal incision which gives adequate exposure, does not leave visible scars, minimizes the risk of facial nerve injury and helps the management of complex fractures (Fig. 14.34). Among the middle third fractures, the fractures of the nasoorbital complex and Le Forte III fractures of the maxilla are again approached from the coronal incision which gives the best results. For the maxillary, Le Forte II fractures intra oral incision along with an incision in the

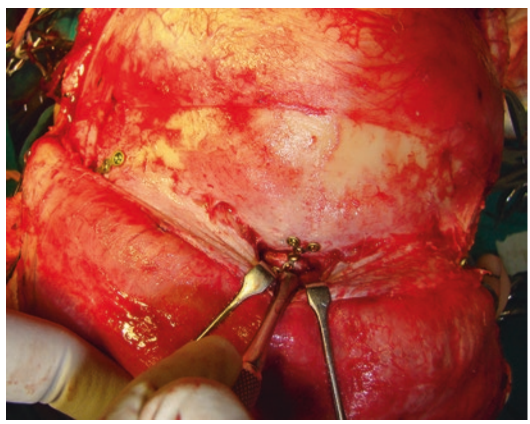


Fig. 14.34 Coronal approach for upper third and middle third fractures

infraorbital region will give optimum results. The incision in the infraorbital region can be transconjunctival, subciliary, midpalpebral or infraorbital. Each has its own advantages and disadvantages. In the hands of a good surgeon all these incisions give good results. For fractures of the zygomatic complex and Le Forte I fracture of maxilla, an intra-oral vestibular incision gives wide exposure for mobilization, reduction and stabilization of the fractures. In the case of zygomatic complex fractures additional incision in the lateral brow, infraorbital region or a hemicoronal incision may be required depending on the extent of fragmentation and the resultant stability of the reduced fractures. Accordingly, one point, two point, three point and four point fixation is planned. For mandibular fractures involving the angle, body and parasymphysis, intraoral vestibular incision is good enough. For subcondylar fractures, Hind's retromandibular incision gives the best access.

14.4.7 Upper Third Fractures

Once all fracture fragments are exposed through a suitable incision, the next step is the mobilization of all fractures. In the upper third fractures, the fragments are very difficult to mobilize. Burholes may be required to mobilize fracture fragments in frontal bone fractures. In some cases where the posterior table is not involved, it may be wise to do camouflage surgery by applying a titanium plate over the depressed fracture without mobilizing the anterior table for reduction. The main consideration in frontal bone fractures involving the frontal sinus is the management of the frontal sinus to prevent infection. The frontal sinus is ideally obliterated to prevent infection of the nasal cavity. If the bone pieces are too small and are not attached, it may be better to remove them and replace them with a titanium mesh/plate.

14.4.8 Middle Third Fractures

The middle third is composed of multiple very thin bones and few strong vertical and horizontal buttresses. The horizontal buttresses include the supraorbital margin, the zygomatic arch, the infraorbital margin and the piriform rim. The vertical buttresses are the zygomatico-fronto-maxillary and the fronto-maxillary buttresses. So, during reduction, these areas are best to reassemble as well as stabilize.

The fracture at the frontozygomatic suture is usually a dysjunction and not a true fracture. However, in some cases of direct hit, fragmentation of this region is also encountered. Similarly, in naso-orbital fractures, usually the medial canthal tendon is detached along with a piece of bone which can be refixed. In zygomatic complex fractures, if there is no dysjunction at the fronto-zygomatic suture, one-point fixation at the zygomatic buttress will provide stability. If there is dysjunction at the fronto-zygomatic suture, a two-point fixation at the buttress and the fronto-zygomatic suture is good enough (Fig. 14.35). However, when there is severe fragmentation, it may be advisable to stabilize the fractures at the buttress, frontozygomatic suture and infraorbital margin (Fig. 14.36). If the zygomatic arch is also comminuted, a four-point fixation through a hemicoronal approach may be required (Fig. 14.37). In rare instances, direct hits at the lateral orbital rim cause an isolated fracture of the lateral orbital wall, which is difficult to manage as there is usually a collapse in the orbit at that point (Fig. 14.38). Reducing it requires considerable force, which if not controlled will lead to avulsion of the fragment.

The management of orbital blow-out fractures is controversial; some advocate late intervention if symptoms do not improve [28] while others advocate early (less than 2 weeks) intervention, the rationale being that late intervention leads to a compromised result [29]. Indications for immediate surgical intervention are diplopia present with CT evidence of an entrapped muscle or periorbital tissue associated with a nonresolving oculocardiac reflex (bradycardia, heart block, nausea, vomiting, or syncope), "White-eyed blow-out fracture", Young patients (< 18 years)with history of periocular trauma, little ecchymosis or edema (white eye), marked extra-ocular motility vertical restriction, and CT

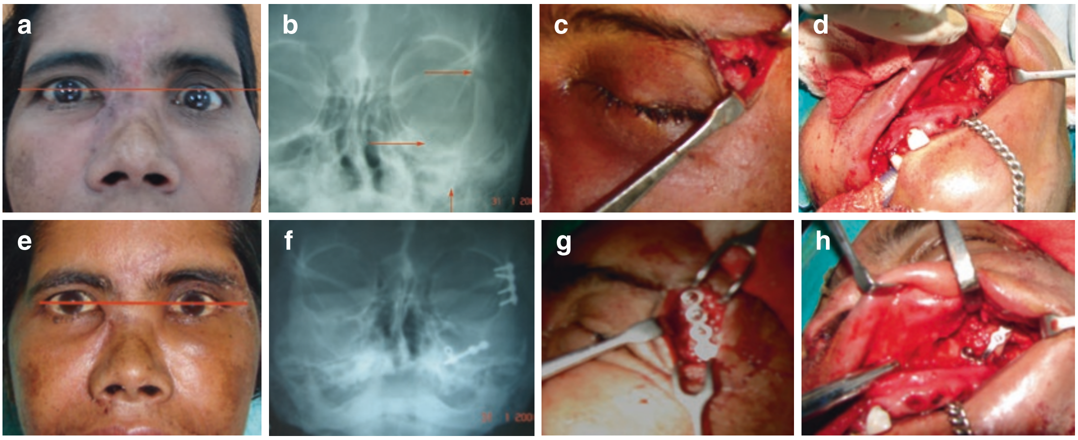


Fig. 14.35 Two point fixation of Zygomatic complex fractures. (**a**) Preoperative photo showing the lowering of the left eyeball due to downward and outward displacement of Lt Zygomatic complex. (**b**) Preoperative PNS View Xray showing the frontozygomatic dysjunction and downward displacement at zygomatic buttress and infraorbital margin. (**c**) Intraop photo showing the frontozygomatic dysjunction. (**d**) Intraop photo showing the downward displacement at zygomatic buttress. (**e**) Postoperative photo showing the restoration of eye level. (**f**) Postoperative X ray PNS view skull showing the two point fixation. (**g**) Intraop photo showing the reduction and stabilization at FZ suture. (**h**) Intraop photo showing reduction and stabilization of the buttress

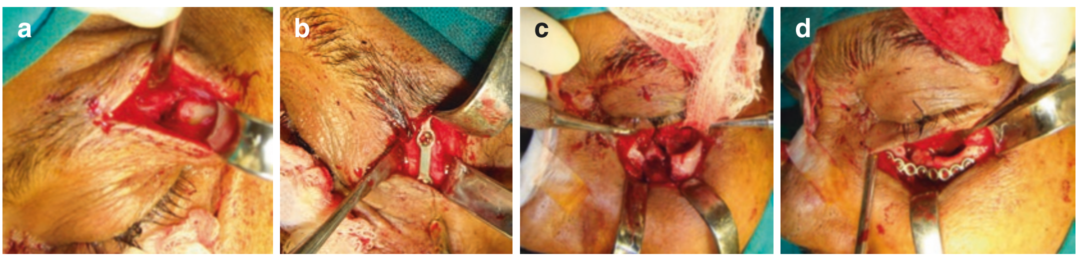
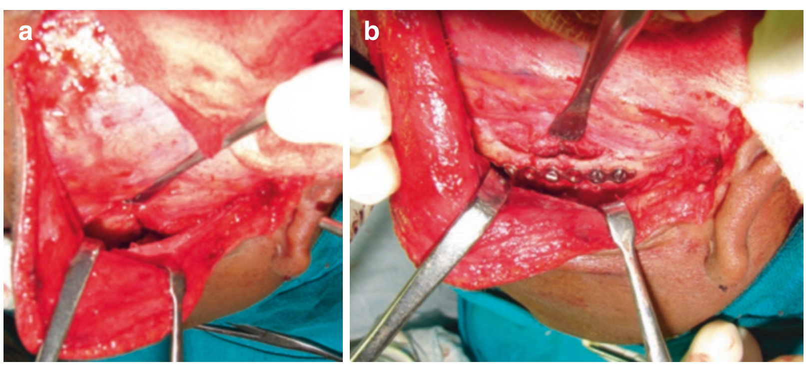


Fig. 14.36 Three point fixation of zygomatic complex fracture. (**a**) Fracture displacement at FZ suture. (**b**) Reduction and stabilization. (**c**) Fracture displacement infraorbital margin. (**d**) Reduction and stabilization

Fig. 14.37 Four point fixation. (**a**) a depressed fracture of the zygomatic arch. (**b**) reduced and stabilized



examination revealing an orbital floor fracture with entrapped muscle or perimuscular soft tissue and early enopthalmos/hypoglobus causing facial asymmetry [30].

Brucoli et al. found that the incidence of diplopia, enopthalmos, and infraorbital nerve dysfunction is decreased by immediate intervention and early surgical repair of the orbital blow-out fractures. Patients who had surgery within 2 weeks of trauma have a lower risk to develop postoperative complications; this study supports an early surgical treatment of orbital blow-out fractures, when it is indicated [31]. Early surgery minimizes progressive fibrosis and contractures of the prolapsed tissues and fat atrophy and gives the best results. Other authors report the same data [32, 33]. The most common surgical approach reported was a preseptal transconjunctival approach (32.0%), followed by the subciliary (27.9%) and postseptal transconjunctival (26.2%) approaches. The most commonly reported implants for orbital reconstruction was titanium (65.4%), followed by Medpor (43.7%) and composite Medpor and titanium (26.4%) [34] (Fig. 14.39).

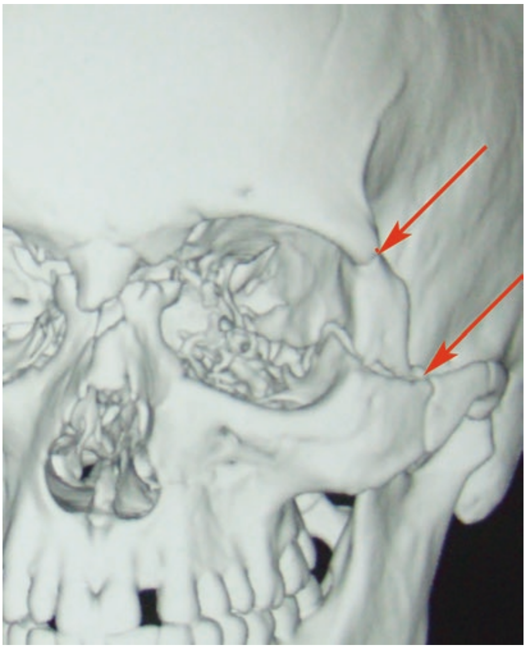


Fig. 14.38 Isolated fracture of the lateral wall of the orbit

Regarding orbital floor fractures, reconstruction of orbital floor defects of more than 2 cm requires the use of an autogenous graft or alloplasts. The commonly used autogenous grafts are the calvarial graft, mandibular symphysis grafts (Fig. 14.40) and iliac bone graft. The alloplastic materials that have been successfully used are the titanium mesh and porous polyethylene sheets. Currently, patient specific implants are available manufactured as per the patient's specification using CAD/CAM based on CT scans. This gives better results as the orbital floor anatomy is com-

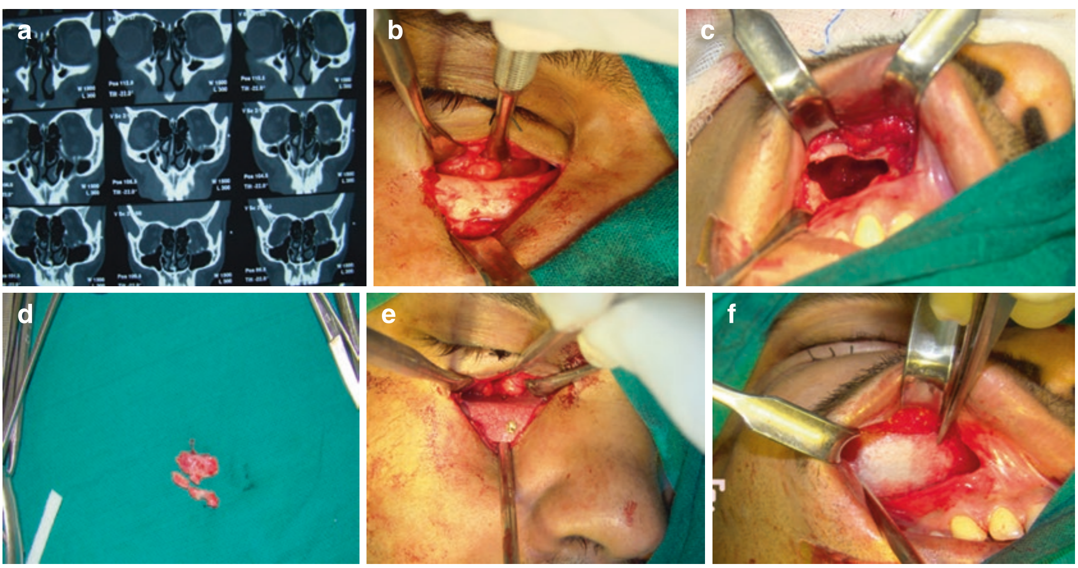


Fig. 14.39 Blowout fracture of orbit. (**a**) Coronal section CT shows blowout fracture of Rt Orbit. (**b**) Intraop photo showing entrapment of orbital tissues in the fracture. (**c**) Tissues cannot be disengaged from the fracture site without further traumatizing. Caldwell Luc approach was used to remove interfering bony spicules. (**d**) Bony fragments interfering with reduction removed. (**e**) Orbital floor reconstructed with Medpore Sheet. (**f**) Caldwell approach closed with Medpore sheet

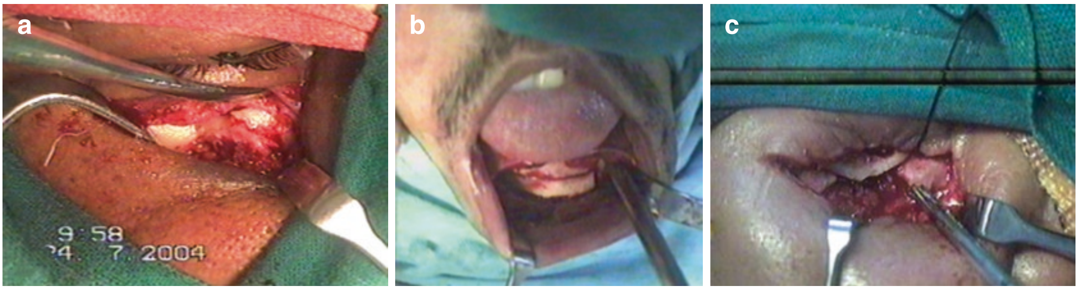


Fig. 14.40 Orbital floor reconstruction with Mandibular Symphysis graft. (**a**) Orbital floor defect. (**b**) Mandibular symphysis graft harvested. (**c**) Reconstruction of orbital floor with graft

Fig. 14.41 Intermaxillary Fixation using arch bars to achieve occlusion

plicated with depression followed by an upward slope which is difficult to recreate manually. In CAD/CAM, it is possible to recreate the exact defect by mirror imaging [25, 26].

In Le Fort fractures, after mobilization of the fractures, occlusion is achieved before reducing the other fractures. This was achieved by approximation of the upper and lower jaw using wires and elastics (Fig. 14.41). Another point in complex fractures to be noted is that the fracture reduction should start from the inner to the outer. Without mobilizing all the fractures, it may not be possible to achieve correct reduction. In cases with gross comminution, small bone fragments with attachment loss are better removed to prevent their necrosis and infection in the postoperative period. Either bone grafts or titanium plates can be used to bridge the gaps. Once the bone fragments are reduced, they are stabilized with miniplates and screws. In the infraorbital margin, even micro plates and screws can be used. In a few cases, especially with associated fracture mandibles, it may be advisable to perform open reduction and fixation of the palate also to ensure restoration of the width of the alveolar arch. Otherwise, the mandible will also be restored with greater width leading to deformity as well as functional problems. Phillips found that 60% of the Le Fort fractures required open reduction and internal fixation (ORIF), while 30% required conservative management and 10% no treatment. The majority of Le Fort – I fractures were managed using an intraoral vestibular incision, while Le Fort –II and III required an additional infraorbital (transconjunctival/sub ciliary) incision along with lateral brow/coronal incisions (Fig. 14.42). Minimally invasive techniques have recently been introduced for the management of isolated zygomatic complex fractures and orbital fractures. However, they are not of use in severe maxillofacial injuries. Le Fort I, II, and III fractures had mortality rates of 0%, 4.5%, and 8.7%, respectively [33]. Le Fort fractures are associated with significant morbidity, including the development of visual problems (47%), diplopia (21%), epiphora (37%), difficulty with breathing (31%), and difficulty with mastication (40%) [35]. Satisfactory outcomes with regards to function and aesthetics were achieved in 89.1% of patients, while long term infection, temporary temporomandibular joint stiffness, or facial deformity were seen in 10.9% of patients [36].

14.4.9 Lower Third Fractures

Compared to upper third and middle third fractures, lower third fractures are complicated by severe muscle pull displacing the fracture frag-

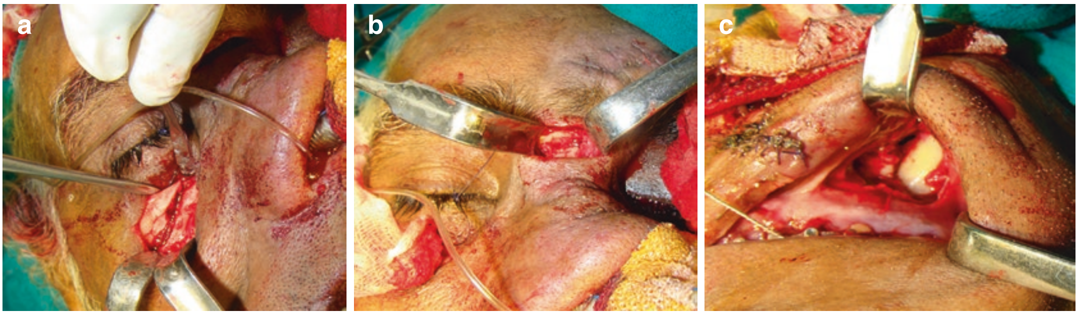


Fig. 14.42 Fracture maxilla – approaches. (**a**) Infraorbital incision. (**b**)'W' incision. (**c**) Vestibular incision

Fig. 14.43 Approaches to Mandible. (**a**) Vestibular incision for parasymphysis fractures. (**b**) Vestibular incision for angle fractures. (**c**) Hind's approach for subcondylar fractures

ments. The most common fractures of the mandible are parasymphysis, body, angle and subcondylar. In most cases there is more than one type of fracture depending on the nature of the force acted upon. These multiple fractures may be unilateral or bilateral. Commonly associated with multiple fractures are parasymphysis and angle/subcondylar, bilateral subcondylar and bilateral body. Once the fracture fragments are mobilized, occlusion is achieved by intermaxillary fixation. Then the fragments are reduced and stabilized starting from the dentate portion (Fig. 14.43). The stabilization is achieved using the miniplates and screws as described by Champy et al. [37]. In cases of severe loss of bone, a reconstruction plate is used.

14.4.10 Panfacial Fractures

In Panfacial fractures, management becomes more difficult as there is no stable base. The situation is similar to solving a jigsaw puzzle. Look for the easiest part to align first. It is impossible to reduce such fractures anatomically without mobilizing all fracture fragments. Different approaches have been advocated – inside out or outside in. in a clinical situation, all fractures are exposed and mobilized first. If mandible and maxilla are fragmented, mandible is fixed first anatomically. Then the maxilla is fixed based on mandible. If frontal bone is intact or stable, zygoma is aligned to the frontal bone and stabilized. Then the rest is arranged as if you are doing a jigsaw puzzle.

14.4.11 Blast Injuries and GSW

The management of gunshot and blast injuries requires more experience and skill. In GSW, the tract of the bullet should be carefully explored to get a complete picture of the injury. The entry wound and the exit wound may not be in a straight line. Usually, GSW is easier to manage to achieve a reasonable restoration of form and function (Fig. 14.44). Important vessels tend to escape

Fig. 14.44 Blast injury of mandible

Fig. 14.45 Blast injury of maxilla

injury in most cases. Blast injuries have a different set of problems. They include loss of hard and soft tissues, contamination of the wound by multiple types of foreign bodies and lastly the contusion effect. The contamination may be soil, wood and metal splinters or even glass particles. The viability of the adjacent tissues cannot be ascertained immediately. They suffer contusion due to the shock waves and the vitality of these tissues will become evident only after a week or so. In blast injuries with severe loss of hard and soft tissues in US and UK, an external Jackson's crib is used to prevent infection at the fracture site [38, 39]. In India, direct fixation with bone plates and screws have been used to get good results [40] (Fig. 14.44 and 14.45).

14.5 Rehabilitation

Rehabilitation of patients with maxillofacial injuries with secondary deformities is very challenging. Optimum primary management is the best way to avoid such deformities. This is due to the fact that there is significant soft tissue contraction during healing which will increase the defect as well as make the tissue fibrotic leading to difficulty in advancing the flaps for closure of the defect. In

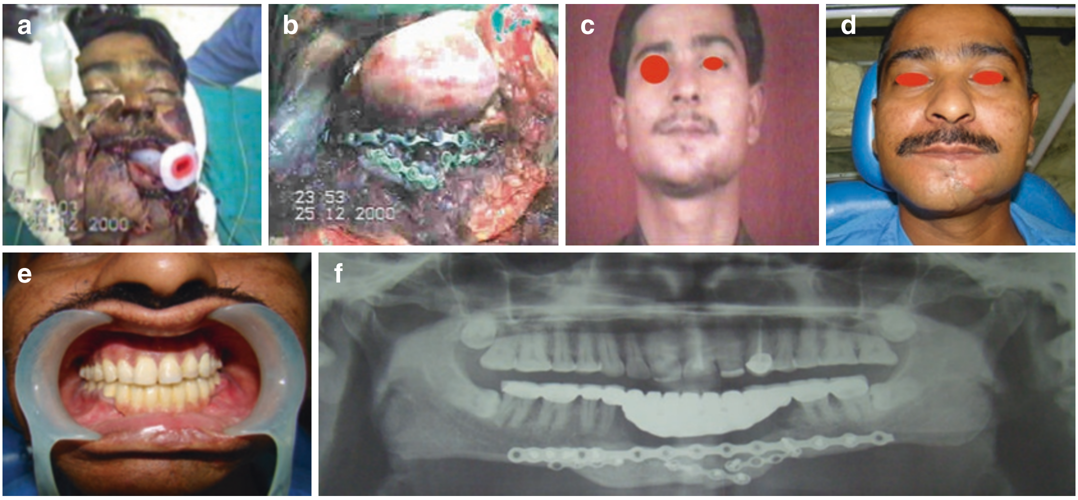


Fig. 14.46 Rehabilitation of GSW. (**a**) Preop. (**b**) Intraop showing the fixation of multiple bone fragments with titanium plates and screws. (**c**) Postop photo 3 months. (**d**) Postop photo 16 years. (**e**) Provision of Fixed Prosthesis immediately after surgery helped hold mandible in place avoiding the collapse of the arch in comminuted symphysis fractures due to the strong muscle pull. (**f**) OPG 16 years. postop showing the multiple bone fragments held in place with titanium miniplates and good bony healing

addition, due to scarring, vascularity of the soft tissue is compromised leading to increased incidence of dehiscence postoperatively. The most difficult to correct are the deformities involving the orbit. Enopthalmos take almost a month to settle down and be visible. It is almost impossible to assess the volume replacement required to achieve correction because of the 3-dimensional nature of the defect. To prevent this, it is always advisable to explore the orbital floor whenever the CT scan shows the presence of defects irrespective of the fact whether signs and symptoms are present. In severe fragmentation of bone, virtual surgical planning and fabrication of patient specific implants will give the best results. For blast injuries in the mandible where there is significant loss of bone in the symphysis region, it is ideal if a dental fixed prosthesis is placed replacing the missing teeth at the earliest (Fig. 14.46). Otherwise, due to the muscle pull, even the screws placed in the reconstruction plates can come out leading to collapse of the arch. In addition, the reconstruction plate bridging the gap is replaced with a bone graft for consolidation. This can be an iliac crest bone graft if the defect is less than 8 cm. For bony defects greater than 8 cm, a free fibula bone graft is the best option. Dental implants can be placed on this bone graft to restore mastication.

14.6 Conclusion

Maxillofacial trauma is an increasingly common phenomenon leading to significant morbidity, YPLL and DALYS. Optimal primary management by a multispecialty interdisciplinary team will minimize mortality and morbidity as well as restore function at the earliest. Any disfigurement of the region can have very serious psychosocial consequences. Correction of secondary deformities is very challenging and leads to compromised results. With the recent advances in materials, technology and techniques, it is possible to restore optimum function as well as esthetics if handled by an expert team in the first attempt.

References

1. Peden M, Mcgee J, Krug E, editors. Injury: a leading cause of the global burden of diseaes-2000. Geneva: World Health Organization; 2002.
2. Krug E, Etienne G. Injury—a leading cause of the global burden of disease. Geneva: World Health Organization; 1999.
3. WHO. Health in 2015: from MDGs to SDGs.
4. Cukier W. Firearms/small arms: finding common ground. Can Foreign Policy. 1998;6:73–87.

5. Krug EE, editor. World report on violence and health, vol. 360. Geneva: World Health Organization; 2002. p. 1083.
6. Reza A, Mercy JA, Krug EE. Epidemiology of violent deaths in the world. Inj Prev. 2001;7:104–11.
7. World Health Organization (WHO). Small arms and global health. Paper prepared for SALW talks. Geneva: WHO; 2001.
8. Shapiro A, Johnson R, Miller S, McCarthy MC. Facial fractures in a level I trauma Centre: the importance of protective devices and alcohol abuse. Injury. 2001;32:353–6.
9. Rai KM, Kale R, Mohanty SK, Chakrabarty A, Waghray MR, Kumar R, Prasad D, Lahiri AK. Treatment of casualties in a forward hospital of Indian Army: nine years experience. Med J Armed Forces India. 2004;60:20–4.
10. Pappachan B, Alexander M. Biomechanics of craniomaxillofacial trauma. J Maxillofac Oral Surg. 2012;11(2):224–30.
11. Bentley RP. Craniofacial trauma including management of frontal sinus and nasoethmoidal injuries. In: Langdon JD, Arnold H, et al., editors. Operative oral & maxillofacial surgery. London: CRC; 2017. p. 513.
12. Garg RK, Afifi AM, Gassner J, et al. A novel classification of frontal bone fractures: the prognostic significance of vertical fracture trajectory and skull base extension. J Plast Reconstr Aesthet Surg. 2015;68(5):645–53.
13. Patil RS, Kale TP, Kotrashetti SM, Baliga SD, Prabhu N, Issrani R. Assessment of changing patterns of le fort fracture lines using computed tomography scan: an observational study. Acta Odontol Scand. 2014;72(8):984–8.
14. Phillips JB, Turco LM. Le fort fractures: a collective review. Bull Emerg Trauma. 2017;5(4):221–30.
15. Boyette JR, Pemberton JD, Bonilla-Velez J. Management of orbital fractures: challenges and solutions. Clin Ophtalmol. 2015;17(9):2127–37.
16. Kim HS, Jeong EC. Orbital floor fracture. Arch Craniofac Surg. 2016;17(3):111–8.
17. Yuen HW, Hohman MH, Mazzoni T. Mandible fracture. [updated 2019 Oct 30]. In: StatPearls [internet]. Treasure Island, FL: StatPearls Publishing; 2020.
18. Erdmann D, Follmar KE, Debruijn M, et al. A retrospective analysis of facial fracture etiologies. Ann Plast Surg. 2008;60(4):398–403.
19. Kreidl KO, Kim DY, Mansour SE. Prevalence of significant intraocular sequelae in blunt orbital trauma. Am J Emerg Med. 2003;21(7):525–8.
20. Jeroukhimov I, Cockburn M, Cohn S. Facial trauma: overview of trauma care. In: Thaller SR, WS MD, editors. Facial trauma. New York: Marcel Dekker; 2004. p. 1–17.
21. National Academies of Sciences [NAS]. A national trauma care system: integrating military and civilian trauma systems to achieve zero preventable deaths after injury. 2016. http://www.nationalacademies.org/hmd/Reports/2016/A-National-TraumaCare-System-Integrating-Military-and-Civilian-Trauma-Systems.aspx.
22. WHO. Guidelines for trauma quality improvement programmes 2009.
23. Practice Guidelines for Management of Difficult Airway. An updated report by the American Society of Anesthesiologists Task Force on Management of Difficult Airway. Anesthesiology. 2013;118(2):1–20.
24. Beogo R, Bouletreau P, Konsem T, Traore I, Coulibaly AT, Ouedraogo D. Wire internal fixation: an obsolete, yet valuable method for surgical management of facial fractures. Pan Afr Med J. 2014;17:219.
25. Vignesh U, Mehrotra D, Dichen Anand A, Howlader D. Three dimensional reconstruction of late post traumatic orbital wall defects by customized implants using CAD-CAM 3D stereolithographic models. A case report. J Oral Biol Craniofac Res. 2017;7:212–8.
26. Parthasarathy J. 3D modeling, custom implants and its future perspectives in craniofacial surgery. Ann Maxillofac Surg. 2014;4(1):9–18.
27. Ellis E III, Zide MF. Surgical approaches to the facial skeleton. 3rd ed. Philadelphia: Wolters Kluwer; 2018.
28. Matteini C, Renzi G, Becelli R, et al. Surgical timing in orbital fracture treatment: experience with 108 consecutive cases. J Craniofac Surg. 2004;15:145–50.
29. Putterman AM, Stevens T, Urist MJ. Nonsurgical management of blow-out fractures of the orbital floor. Am J Ophthalmol. 1974;77:232–9.
30. Burnstine MA. Clinical recommendation for repair of isolated orbital floor fracture. Opthalmology. 2002;109:1207–13.
31. Brucoli M, Arcuri F, Cavenaghi R, Benech A. Analysis of complications after surgical repair of orbital fractures. J Cariofac Surg. 2011;22(4):1387–90.
32. Hossal BM, Beatty RL. Diplopia and enophthalmos after surgical repair of blow-out fracture. Orbit. 2002;21:27–33.
33. Jin HR, Lee HS, Yeon JY, Suh MW. Residual diplopia after repair of pure blow-out fracture: the importance of extraocular muscle injury. Am J Rhinol. 2007;21:276–80.
34. Christensen BJ, Zaid W. Inaugural survey on practice patterns of orbital floor fractures for American Oral and maxillofacial surgeons. J Oral Maxillofac Surg. 2016;74(1):105–22.
35. Girotto JA, MacKenzie E, Fowler C, Redett R, Robertson B, Manson PN. Long term physical impairment and functional outcomes after complex facial fractures. Plast Reconstr Surg. 2001;108(2):312–27.
36. Jarupoonphol V. Surgical treatment of Le Fort fractures in Ban Pong hospital: two decades of experience. J Med Assoc Thail. 2001;84(11):1541–9.
37. Champy M, Lodde JP, Schmitt R, Jaeger JH, Muster D. Mandibular osteosynthesis by miniature screwed plates via buccal approach. J Maxillofac Surg. 1978;6(1):14–21.

38. Gokel T. Improvised explosive devices and the oral and maxillofacial surgeon. Oral Maxillofac Surg Clin North Am. 2005;17:281–7.
39. Gibbons AJ, Breeze A. The face of war: the initial management of modern battlefield ballistic facial injuries. J Mili Veteran Health. 2011;19(2):15–8.
40. Girish Kumar N, Vijaya N, Jha AK. Blast injuries of mandible: a protocol. J Maxillofac Oral Surg. 2012;11(2):191–4.