VI. Fractures of the Maxilla

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Introduction

Restoration of occlusion and facial profile are the most important aspects of treating Le Fort fractures. Following treatment of other facial fractures (zygoma, orbital complex, or medial maxillary), there should be no alteration of preinjury occlusion. The distinguishing feature of Le Fort fractures is the mobile upper dental arch. Le Fort fractures, like mandible fractures, can result in malocclusion, and if fractures of both dental arches occur concomitantly, then restoration of premorbid occlusion requires even greater diligence.

Facial skeletal contours also must be restored. Loss of facial symmetry is possible with all midface fractures, but not to the degree seen with Le Fort fractures. Facial profile also can be more difficult to re-establish if a Le Fort fracture occurs in combination with a mandible fracture. Le Fort fractures can result in other functional disorders, such as alterations in nasal breathing, lacrimation, and facial sensation.

Prior to the era of precise rigid internal fixation of facial fractures, long-term morbidity resulting from fractures of the maxilla was a significant problem. Now, good exposure and knowledgeable application of rigid internal fixation devices results in favorable outcomes for most of these patients.

Le Fort Classification

In 1901, Monsieur Rene Le Fort presented the results of the cadaveric experiments he had performed in an effort to determine whether or not there was a pattern to midfacial fractures.[1] These experiments consisted of striking supported and unsupported cadaver heads with a wooden club, or dropping them from a height of several stories onto the pavement in front of his research facility. Three classic fracture patterns emerged from these studies.

Originally, Le Fort described the three fracture levels as I, II, and III, with the Le Fort I representing craniofacial disjunction, and Le Fort III representing supra-alveolar fracture. In common usage, the Le Fort classification associated with these two fracture levels has, for some reason, become reversed from his original description (Figs 1A and

1C). Thus, Le Fort I fracture, which was first described by Guerin in 1866, is a low transverse fracture crossing the supra-alveolar and submalar maxilla and nasal septum, resulting in separation of the palate from the body of the maxilla.[2] The fracture line passes along the floor of the nose, pyriform aperture, canine fossa, and lateral wall of the maxilla. Le Fort I fractures traverse the inferior aspect of the pterygoid plates. The septum is often fractured at the level of the floor of the nose in Le Fort I fractures. Clinically, these fractures result in what is generally termed a *floating palate.*

The Le Fort II, or pyramidal fracture, crosses the nasal bones, descends steeply down the frontal process of the maxilla and lacrimal bone and then crosses the orbital rim, being the only Le Fort fracture to do so (Fig 1B). The fracture line terminates by passing through the lateral wall of the body of the maxilla and into the pterygoid plates at the base of the skull. A high septal fracture also is usually noted with this fracture pattern. The clinical correlate of this fracture pattern is that of a *floating maxilla.*

The most severe fracture of the maxilla, the Le Fort III, results in craniofacial disjunction. After fracturing the nasal bones and septum, the Le Fort III fracture line sequentially traverses the frontal process of the maxilla, lacrimal bone, lamina papyracea (and ethmoid air cell system), and orbital floor (posterior to the inferior orbital fissure) before bifurcating into two distinct limbs. One of these limbs extends across the lateral orbital wall, at the level of the sphenozygomatic junction, and often terminates by crossing the zygomatic arch (Fig 1C). The second limb follows a more posterior course across the posterior aspect of the body of the maxilla, crossing into the infratemporal fossa, and ending by passing through the superior aspect of the pterygoid plates at the level of the basisphenoid. The main fracture line often traverses the perpendicular plate of the ethmoid bone, with a consequently greater chance of sustaining dural tears and cerebrospinal fluid leaks than with either the Le Fort I or II fracture patterns.

In his original description of fractures of the maxilla, Le Fort acknowledged that his three great fracture lines often occurred in combination, and were often associated with any of a number of different, non-classified fracture lines.[1] Thus, common nomenclature will refer to "pure" Le Fort fractures, when the fracture lines follow Le Fort's classic description, and "impure" Le Fort fractures, when there are other fracture lines present or when there is incomplete separation across Le Fort's three lines of weakness. Furthermore, although Le Fort fractures are usually bilateral, they are commonly asymmetrical.

Le Fort's classification system provides the surgeon with a useful starting point from which to organize a valid treatment plan; however, it does not provide a full description of the degree of displacement or comminution that may be present. It also ignores other frequently noted fracture patterns in the maxilla, namely, medial maxillary, palatal parasagittal, dentoalveolar, and anterior maxillary fractures. These are often referred to as non–Le Fort fractures.

Medial Maxillary and Other Non–Le Fort Midface Fractures

Fractures of the medial maxilla, usually resulting from an oblique-force trajectory applied against the side of the nose and medial wall of the maxilla, involve the ascending process (of the maxilla) and the orbital rim. Clinically, these fractures result in a classic C-shaped nasal configuration simulating a simple depressed nasal fracture. Injuries to the infraorbital nerve and lacrimal apparatus are not uncommonly seen with this fracture pattern. The medial maxillary fracture that extends from the alveolus to the nasofrontal suture and involves the anterior lacrimal crest is classified as a type I nasoethmoid fracture.

Palatal fractures are generally parasagittal, rather than sagittal, because of the firm midline support provided by the attachment of the vomer to the nasal aspect of the hard palate. Most palatal fractures are comminuted and are occasionally associated with overlying mucosal disruption. Failure to appreciate the nature of these fractures or to fixate them inappropriately may result in significant long-term morbidity in the form of oronasal fistulae and malocclusion. Dentoalveolar fractures are most often noted in the older edentulous patients. This is secondary to the alveolar bone atrophy, and hence weakening, that follows loss of the dentition. These fractures are commonly isolated and usually result from a local limited-force application.

As outlined, the anterior face of the maxillary antrum may be involved as part of a Le Fort fracture pattern, or it may be an isolated injury. Specific complications resulting from maxillary sinus injury include infraorbital nerve dysfunction, mucocele and mucopyocele formation, and rare overlying soft tissue retrusion with significant unrepaired anterior wall disruption.

Incidence of Le Fort Fractures

Fractures of the maxilla are relatively common, comprising approximately 15% to 20% of all fractures of the maxillofacial region.[3] The vast majority are noted to occur in males (male:female ratio 5:1), due to motor vehicle accidents, assaults, and falls. The overall incidence of these injuries has significantly decreased with the availability of air bags, shoulder seat belt restraints, and collapsible dashboards and steering columns. Le Fort I fractures make up approximately 30% of all Le Fort fractures; Le Fort II about 50%, and Le Fort III about 20%. These fractures can occur in any combination with different fractures present on either side of midline. Also, it is fairly common to have a Le Fort II or III fracture in combination with a zygoma fracture. Combination of a Le Fort fracture with a subcondylar fracture may pose significant difficulty in achieving proper midface projection (Fig 2).

Principles of Management

Maxillary Buttresses

The key to understanding fractures of the maxilla is the realization that the maxilla is maintained in normal anatomic position, between the mandible and the skull base, by a series of four supporting pillars, commonly referred to as vertical buttresses (Fig 3). These buttresses represent load paths for the distribution of the powerful vertical forces of mastication. In the human maxillofacial skeleton, there are three paired vertical buttresses: the nasomaxillary, the zygomaticomaxillary, and the pterygomaxillary; and a single midline buttress, the nasoseptum (vomer, crista galli, perpendicular plate of the ethmoid bone, and the cartilaginous septum). The thin pterygomaxillary (posterior) buttress running from the maxillary tuberosity, through the pyramidal process of the palatine bone and the medial plate of the pterygoid bone, to end at the basisphenoid, is not of much surgical importance since fixation cannot routinely be applied at this level.[4]

The alveolus, hard palate, inferior orbital rim, zygomatic arch, and frontal bar constitute the primary horizontal supports (or horizontal buttresses) that serve as a foundation for the vertical buttresses.

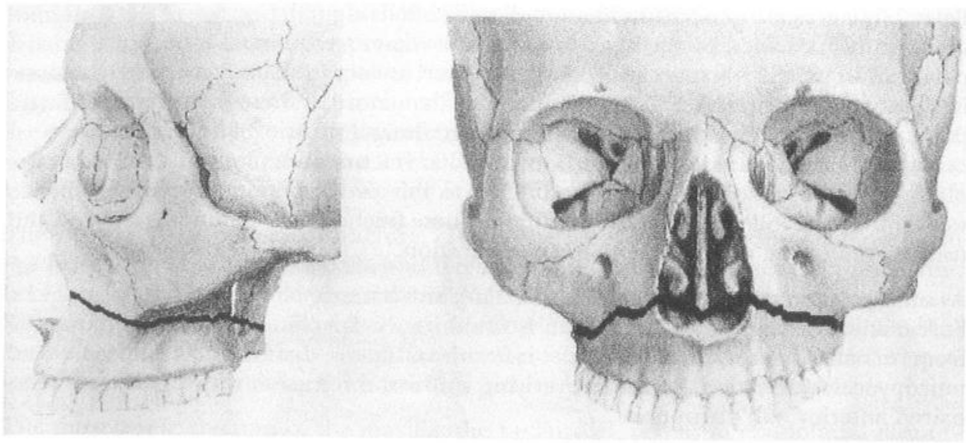


Fig 1A.—Le Fort I fracture.

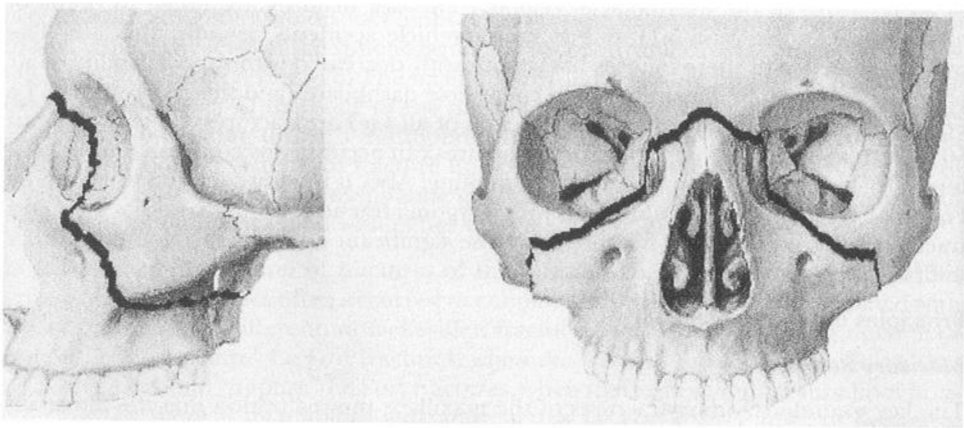


Fig 1B.—Le Fort II fracture.

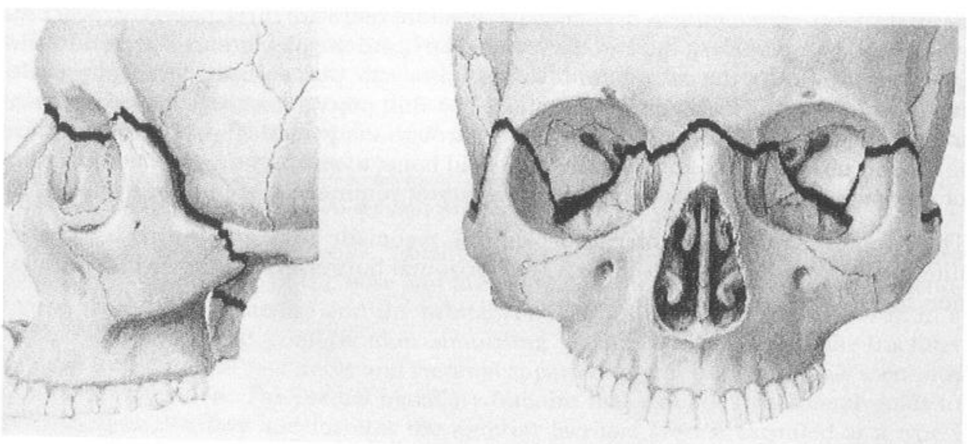


Fig 1C.—Le Fort III fracture.

Mechanism of Injury

It is helpful to note the nature of the injury and consider the direction of the force causing the midface fracture. As a result of the presence of strong vertical buttresses, the maxilla is somewhat tolerant to vertically oriented force vectors, but will readily fracture when exposed to laterally or obliquely directed force vectors.

Nahum[5] studied the magnitude of force required to experimentally elicit fractures in the human maxillofacial skeleton. The conclusions of this trial revealed that the force required to generate a fracture of the maxilla was relatively low in comparison to most other facial bones. In fact, the bony integrity of the maxilla was generally disrupted with only one third the force necessary to fracture the mandible, and one fifth the force required to produce a fracture of the frontal sinus area.[5] From the standpoint of evolutionary self-preservation, the ability of the maxilla to fracture with relative ease allows it to function as a midfacial "shock-absorber," significantly decreasing the amount of force allowed to progress posteriorly to the central nervous system and eye.

The midface attachment to the basisphenoid is normally angulated at approximately 45 degrees. Traumatic breakdown of the buttresses leads to a release of the maxilla from its bony attachments. This allows the lateral pterygoid muscles, attached to the posterolateral aspect of the maxilla at the level of the pterygoid plates, to pull the fractured maxilla posteroinferiorly along the skull base (altering the normal 45-degree angulation), leading to the classic anterior open-bite deformity noted in these patients. This rotation of the maxilla will also lead to elongation and flattening of the midface. Thus, severe trismus and pain are common patient complaints. The alveolar neurovascular bundles may be disrupted as they course to the upper dentition. This disruption causes early paresthesias of the upper dentition and may lead to late devitalization of the teeth.

Historical Perspectives of Management

Principles of treatment of Le Fort fractures have evolved rapidly in the last two decades based on what is known of untreated fractures or incompletely treated fractures. If left untreated, Le Fort fractures tend to heal because of the excellent vascularity of the face. However, they tend to heal with malunion because of impaction of the fracture segments and the posteroinferior rotation described above.

Historical treatment was intermaxillary fixation after disimpaction. This treatment prevented the malocclusion; however, it was noted that patients often developed a long face deformity. This may be caused by the effects of gravity or the downward pull of the pterygoid muscles in Le Fort I and II, and pterygoid and masseter muscles in the case of Le Fort III fractures. Thus, many surgeons promoted suspension of the midface as a means to prevent elongation. Conventional treatment for many years consisted of circumzygomatic wires for Le Fort I or II fractures and circumfrontal wires for Le Fort III fractures. Closed management in this manner had the disadvantage of needing prolonged intermaxillary fixation. Furthermore, reduction was not precise because of the inability to visualize and reduce the fractures, often resulting in inadequate projection of the midface skeletal elements.

Secondary late deformity was common after employment of this fixation method. While unsuspended Le Fort fractures healed with midface elongation, treatment with wire suspension commonly resulted in midface compression and retrusion. Midface shortening arises as a result of compression of comminuted vertical buttresses with subsequent loss of height. Retrusion is not unexpected, as the pull of the suspension wires is in a predominantly superior direction, making the establishment of normal anterior projection

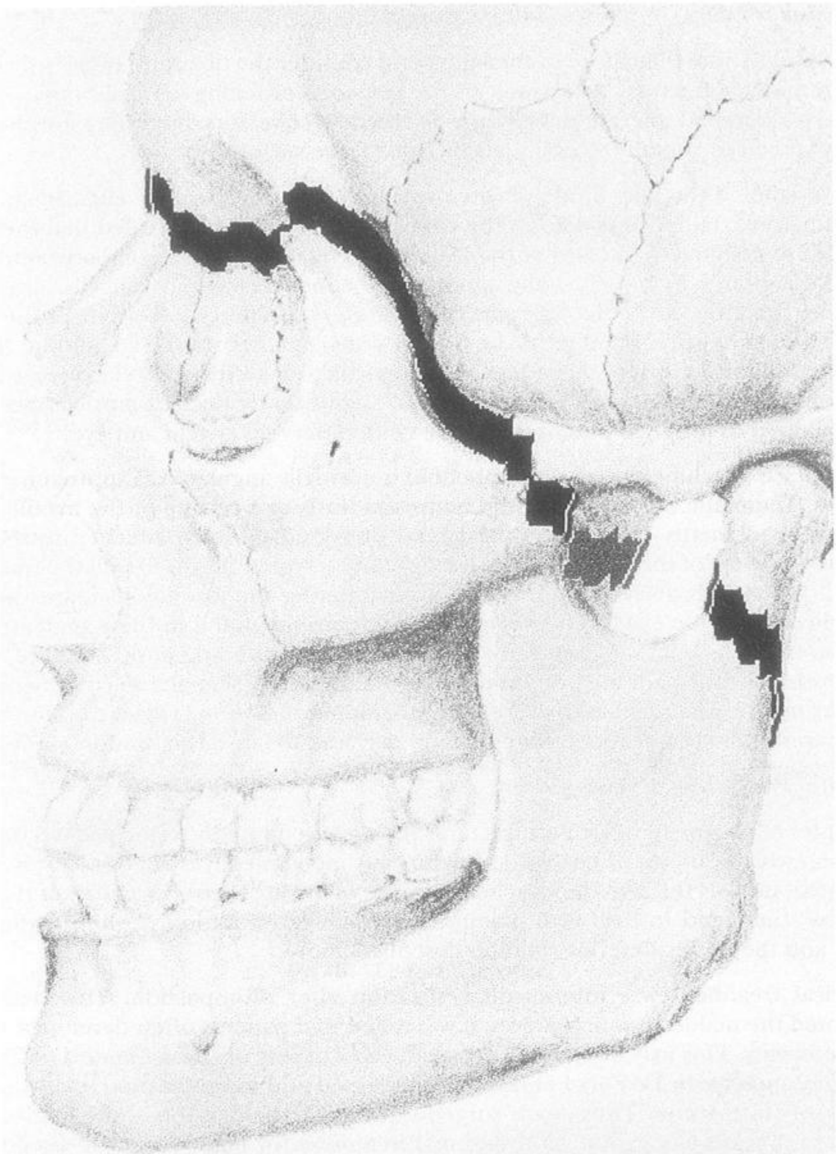


Fig 2.—Le Fort III fracture and subcondylar fracture.

almost impossible. This lack of anteroposterior projection can also compromise the depth of the nasopharynx. More than 60% of Le Fort fractures treated with craniofacial suspension techniques can be expected to heal with the maxilla in a cosmetically and functionally unfavorable posterosuperior position.[6]

Fig 3.—Facial swelling caused by maxillary fracture.

In an effort to overcome this lack of anterior projection and loss of vertical height, external fixation devices were used. Proper application of these devices was difficult. Continual required adjustments over the necessary 6- to 8-week period of utilization and the sheer bulkiness of the device made it quite uncomfortable for the patient to tolerate. Moreover, adjustments of the frame are difficult to judge and, more often than not, are based on rough estimations of what "looks right" rather than on firm anatomic landmarks. Finally, external frames do not provide absolutely rigid fracture fixation. The role of external fixation today is extremely limited, but may have some use in establishing a good occlusal relationship in the patient with severely comminuted combined fractures of both the midface and the mandible, or where there has been a large amount of bone loss with soft tissue injury.

The development of computed tomographic (CT) imaging, which allows precise definition of the fracture pattern, and the widespread application of the principles of rigid plate fixation have together revolutionized the management of facial fractures. The critical features in the treatment of Le Fort fractures are re-establishment of premorbid occlusion and premorbid facial profile. While there are rare cases in which closed reduction or interosseous wire fixation may be feasible, open reduction and internal fixation with miniplates is the preferred approach.

Evaluation of Fractures of the Maxilla

Once the injured patient has been fully stabilized, evaluation for facial fractures can be performed. Wound exploration should be done before any facial lacerations are closed because step-offs or bony fractures can be palpated through the wound, which is typically at the point of impact.

Le Fort fractures should be suspected in the presence of marked facial swelling, ecchymoses, pain, crepitus, or malocclusion. On occasion, gross midface instability can be demonstrated by asking the patient to bite down on his/her mandible, resulting in upward movement of the upper jaw. This phenomenon may occur secondary to the lack of vertical buttress support required to counteract the strong masticatory forces.

Determining the presence of a Le Fort fracture can be performed by grasping the upper incisors/maxillary alveolar ridge between the thumb and forefingers in one hand, while the frontal skull is stabilized in the other hand. Motion of the palate at the level of the anterior nasal spine when the skull is held immobile is diagnostic of a Le Fort fracture with these caveats: 1. There may be an alveolar fracture that is mobile rather than the entire palate. This can be determined by checking for continuity and movement of the entire hard palate and maxillary arch. A split palate also can occur, indicating unilateral Le Fort fracture. 2. Occasionally, a novice examiner may think there is midface motion when, in fact, the skull is rotating under the immobilized soft tissue and scalp. The mobility of a Le Fort fracture typically is not a subtle finding, and movement can be appreciated in the soft tissues of the face. 3. Severe impaction (which should be evident on examination) may limit mobility.

Once true hard palate mobility is determined, the next step is to attempt to classify the level of Le Fort fracture. Again, clinically, there is often a combination of fractures, but on physical examination, a Le Fort I, II, or III can be roughly determined (Table 1). If the skull is indeed fixed and the alveolar ridge is grasped, a determination is made whether there is motion at the nasal bridge/middle one third of the face, or at the malar eminence. If the palate alone moves, then a Le Fort I fracture is present. If the palate and nasal pyramid move, then a Le Fort II fracture has occurred. A Le Fort III

TABLE 1

PHYSICAL DIAGNOSIS TO DIFFERENTIATE LE FORT FRACTURES

	Le Fort I	*Le Fort II*	*Le Fort III*
Palate	**Mobile**	Mobile	Mobile
Nasal bridge*	**Stable**	**Mobile**	Mobile
Malar eminence	Stable	**Stable**	**Mobile**
Skull	Stable	Stable	**Stable**

*Nasal bridge mobility may be difficult to determine if nasal or nasoethmoid fractures are present.

fracture can be suspected if the hard palate, nasal pyramid, and malar eminence all move while the skull is stabilized.

Associated Facial Injuries

Blunt injury alone can cause significant facial fractures, but often there are concomitant soft tissue lacerations, abrasions, or avulsions present.

Nasoethmoid fractures often are associated with Le Fort II or III fractures. Traumatic telecanthus is a sign of significant nasoethmoid injury, although this is sometimes difficult to determine with soft tissue swelling. The lid traction test is very helpful to determine if detachment of the medial canthus has occurred. Continued observation for possible cerebrospinal fluid leak from the ear or nasal cavities is important, especially in Le Fort III fractures. Nasal and septal injuries, especially mucosal lacerations, are commonly seen.[7,8]

In any case of midfacial fracture, documentation of visual status is mandatory prior to exploring any associated orbital fractures. If there is fracture extension to the level of the orbit, a range of ophthalmologic findings may be present. These can include relatively minor periorbital edema, ecchymosis, chemosis or, more serious, anterior or posterior chamber hemorrhage, retinal detachment, globe disruption, and optic nerve injury. With Le Fort II or III fractures, damage to the optic nerve is possible because of the injury or as a result of fracture reduction.

In a Le Fort II fracture, there will be a fracture at the orbital rim, and this often can be palpated. In addition, fracture patterns often may result in expansion of orbital volume which, if not recognized and treated, will lead to enophthalmos. Early post-injury edema may mask this problem. Therefore, close clinical follow-up (with Hertel ophthalmometry) and CT evaluation of orbital volume is important.

Periorbital edema and/or extraocular muscle entrapment may limit globe movement. A standard-forced duction test will differentiate between edema and entrapment (usually of the inferior oblique muscle). The lacrimal drainage system also may be disrupted. Generally, acute repair over a Silastic stent needs only to be considered in the obviously transected canalicular system.[9] A Le Fort II fracture also may involve disruption of the infraorbital nerve, leading to paresthesias or anesthesia of the upper lip and cheek.

Radiological Evaluation of Midface Fractures

The diagnosis of fractures of the maxilla is made by the history and physical examination. The diagnosis is confirmed with ancillary radiologic investigations. Simple dentoalveolar fractures are best visualized with a Panorex or dental periapical examination. High-quality plain films are very helpful in evaluation of midface fractures.

However, bone-window CT is certainly the standard of care for evaluation of midface fractures. Most patients get a head CT scan as part of their evaluation for a closed head trauma. Usually this does not extend inferiorly through the maxilla far enough to be completely adequate for fracture evaluation, but frontal sinus fractures or disruption at the frontozygomatic suture can be seen on these films. It is possible to ask the radiologist to continue through the midface acutely if the patient is otherwise stable. CT scanning, in the coronal and axial planes, offers a clear delineation of the degree of displacement and comminution that may be present. It also allows for visualization of critical areas that are generally not well seen on plain films, such as the orbital apex. Axial cuts show fractures of the posterior wall of the antrum, pterygoid plates, hard palate, and dentoalveolar segments. Coronal images are most useful for demonstrating fractures of the anterior maxilla, inferior orbital rim, palate, and orbital floor.

Three-dimensional CT scans are not very helpful for acute treatment. There is often volume averaging in which thin bony areas may be represented as bony defects by the reproduction. They may be helpful for planning late reconstructions but have little utility in management of acute facial trauma. Magnetic resonance imaging has limited use because bony details are not apparent, but it may have some role in demonstrating herniation of orbital fat, as well as intraorbital and intracranial injury.

Management of Le Fort Fractures

Indications for Repair

Prior to embarking on surgical stabilization of a midface fracture, one needs to first determine whether or not surgical intervention is appropriate. A clinically and radiologically nondisplaced fracture usually can be managed conservatively with a soft pureed diet for 4 to 6 weeks to reduce the masticatory load. If there is clinical and/or radiologic evidence of complete healing at the end of this trial period, advancement to a normal diet may be attempted. In edentulous patients who display a small amount of fracture displacement, but where the fracture appears to be able to withstand modified (soft diet) masticatory forces, strong bony union is usually the result of conservative treatment alone.[10] Later modification of the patient's dentures to reflect the new spatial relationship between the upper and lower jaws will restore function.

For patients suffering from such severe systemic or cerebral injury that the chance of survival is low, surgical intervention for repair of midface fractures should not be attempted early. With intracranial hypertension, one should postpone surgery because of the significant increase in intracranial complications (including exacerbation of edema and intradural hemorrhage) that could result.[11] If the patient's condition allows, consideration should be given to at least disimpacting the maxilla, if required, and applying intermaxillary fixation. At a later date, complications of malunion, malocclusion, or enophthalmos can be treated. In the stable patient with significant fracture comminution, displacement, or instability, the midface needs to be explored and the fractures anatomically reduced. Occasionally, fractures with limited mobility and without comminution can be treated with 4 weeks of maxillomandibular fixation alone.

Timing of Repair

After careful preoperative evaluation, repair of the fractures can be planned. There is no universally accepted time-frame for the treatment of fractures of the midface. Typically, closure of lacerations, repair of concomitant mandible fractures, and intermaxillary fixation (which may require disimpaction) could be addressed immediately if the patient is taken to the operating room emergently for some other cause, for example, if there is a long bone fracture or otherwise stable intracranial injury. If the patient will not be in the operating room for another reason, any open mandible fractures are repaired within 1 to 2 days, often delaying definitive midface repair until the facial swelling goes down.

Some surgeons do propose that the definitive repair be done immediately in all cases. They suggest that the wound milieu is more conducive to soft tissue and bony healing if tissues are repaired as quickly as possible. There may be several advantages to this approach, but these are outweighed by the disadvantages.

Massive facial swelling which usually accompanies significant facial trauma makes the repair more difficult. It is also difficult to retract swollen tissues, and periorbital swelling particularly makes it hard to evaluate nasoethmoid fractures or approach the orbital floor. Comprehensive ophthalmologic evaluation is also hindered by extensive swelling. While one might not think visualization or palpation of the facial profile to ensure symmetry is necessary with open reduction procedures, having that ability is an important extra "data point" which is valuable in comminuted fractures. Also, non–emergent-associated injuries, such as closed head trauma, thoracic or abdominal injury, possible cervical spine injury, or ophthalmologic injury, may require prolonged periods for evaluation and resolution. Thus, repair of midface fractures often is delayed until a significant reduction of edema has occurred (usually 3 to 7 days after injury).

On occasion, as a result of patient medical instability or logistical problems, definitive fracture treatment is delayed for extended periods. Early bone healing will occur within 2 weeks, so osteotomies may be necessary in repairs delayed beyond 14 days. Irreversible soft tissue contraction will begin to occur if fracture repair is delayed beyond 2 weeks from the time of the injury.[12] These problems are managed as well as possible, understanding that the final outcome will be suboptimal.[13] In the stable patient, it is recommended that fracture reduction and stabilization be carried out within 10 days of the injury.

TABLE 2

PREOPERATIVE CHECKLIST

☐ -Airway, circulation stable
☐ -Cervical spine cleared
☐ -Ophthalmology evaluation
☐ -Neurovascular evaluation

Whether repair is immediate or delayed, a preoperative evaluation must be complete and documented (Table 2). Documentation of facial numbness, visual changes, and condition of the teeth is important. A careful informed consent in trauma care is necessary. If the patient is unable to give consent, it should be obtained from a family member or guardian. In the patient who has poor dentition, dental splints can be made. This is very helpful in re-establishing premorbid occlusion, particularly if there is concomitant mandible fracture, alveolar fractures, broken or lost teeth, and/or a split palate. In the case of combined fractures of the midface and bilateral subcondylar fractures, the anteroposterior dimension of the midface and vertical height are very difficult to re-establish. In this instance, it may be helpful to have family members bring in pictures of facial profile so the degree of anteface or retroface profile can be re-established. Model surgery for combined upper and lower jaw fractures also can be helpful in certain situations.

Perioperative Airway Management

In the patient with mandible and Le Fort fractures, airway management is very important. Depending on their initial presentation, patients often may be intubated or already have a tracheotomy. An intubated patient can be switched to tracheotomy at the time of the definitive procedure. Because intermaxillary fixation is usually required intraoperatively for Le Fort fractures, tracheotomy has the advantage of securing the airway without having an orotracheal tube.

Alternatively, nasotracheal intubation is possible in certain circumstances. Intracranial passage of the endotracheal tube from an attempted nasotracheal intubation is highly unlikely, even with severe midface trauma. However, if there is significant nasoethmoid, nasal, or skull base injury, nasotracheal intubation would interfere with reduction and potentially be hazardous with possible disruption of any fractures that may be present in the floor of the anterior cranial fossa. This may lead to new or further dural tears and result in a cerebrospinal fluid leak. Moreover, the stasis of nasal and paranasal sinus secretions induced by the presence of a nasal tube may increase the risk of intracranial contamination should communication exist between the intracranial and extracranial compartments. Thus, in severe Le Fort II or III fractures, tracheotomy is the best option. In Le Fort fractures without comminution or associated nasal or nasoethmoid fractures, perioperative nasotracheal intubation is an alternative.

Oral intubation may have a role in very select patients. If the patient has not had a mandible fracture and presents with a simple, noncomminuted Le Fort I fracture (and does not have significant nasal or nasoethmoid injuries) oral intubation is possible. Satisfactory occlusion can be ensured by placing the tube behind the molars. Great care must be taken to be sure that centric relation is maintained during this maneuver.

Operative Management of Le Fort Fractures

Open reduction/internal fixation with miniplates is the preferred surgical management in almost all cases; however, there are limited indications for open management of these fractures using interosseous wiring instead of miniplates. There is no role for dynamic compression plating in midface fractures.

Operative Management with Interosseous Wires

The role of wires in the fixation of fractures of the maxilla has largely been relegated to temporary intraoperative use to facilitate application of rigid fixation devices, and to bring numerous comminuted fracture fragments together prior to fixating these larger segments with plates. Interosseous wiring has the disadvantage of requiring prolonged intermaxillary fixation because the wires do not fixate the fracture rigidly. This same feature of wire fixation (lack of rigidity) is also a reason to use fixation if there is such significant comminution and poor dentition that premorbid occlusion and adequate reduction cannot be confidently established. Intermaxillary fixation and interosseous wiring will allow the fracture segments to come into reduction over time and are more forgiving than plates. In general, if a fracture is plated out of position, it will stay out of position.

Prolonged intermaxillary fixation tends to result in some temporomandibular joint dysfunction and ankylosis. Patients in intermaxillary fixation tend to lose weight, which can affect wound healing because of the catabolic state of significant trauma. Open reduction and miniplate fixation allow the most precise reduction of the fractures and eliminate or shorten the duration of intermaxillary fixation.

Operative Management with Miniplate Osteosynthesis

Numerous investigators have reported excellent success with the use of miniplate systems for the treatment of midfacial fractures.[14,15] Surgical principles of exposing the fracture, reducing the fracture, and fixating the fracture will be reviewed for each Le Fort classification. Surgical access to each type of Le Fort fracture, in combination with other fractures, is shown in Table 3. Often, an existing laceration or scar can be used to give direct access to the fracture. This is used whenever possible.

General Principles of Management of Le Fort Fractures

Exposure

Le Fort fractures often include lower maxillary fractures, which are best approached via a sublabial incision. A lateral brow incision or, preferably, an upper blepharoplasty incision, can be added to access the frontozygomatic suture. The floor of the orbit can be examined through either of these orbital incisions by sliding a probe under periorbita along the rim and palpating the orbital floor. If necessary, a transconjunctival incision can be added. Floor disruption should generally be appreciated by careful analysis of preoperative imaging studies. The orbital floor can be explored, and the orbital rim can be plated through the transconjunctival exposure. If a significant nasoethmoid fracture is present in the case of Le Fort II or III, then a bicoronal approach (or bilateral external ethmoidectomy incision) with a sublabial incision will be required. All the necessary access incisions should be opened prior to the application of rigid internal fixation

TABLE 3

EXPOSURE OF LE FORT FRACTURES

Le Fort I	Sublabial
Le Fort II	Sublabial
With NE	Bicoronal or external ethmoid
With orbital floor	Transconjunctival (+/- canthotomy) or subciliary
Le Fort III	Bicoronal, lateral brow, Lynch, or upper blepharoplasty
With NE	Bicoronal or external ethmoid

NE=nasoethmoid.

devices, and these incisions should not be closed until all midface fractures have been fully repaired. This will allow for ongoing evaluation of all of the fracture sites during manipulation and fixation of any of the fracture segments.

Knowledge of the neurovascular supply to the maxilla is important in allowing the surgeon to plan safe surgical approaches. In the case of major degloving of soft tissue and concomitant release of the soft palate attachments to the maxilla, care must be given to preserve any remaining attachments during surgical exploration. Maxillary devascularization would be detrimental to subsequent healing and increase susceptibility to infection.

Reduction

After exposure of all fractures, precise reduction of these fractures can now proceed. To put the patient into intermaxillary fixation, disimpaction of the midface may be necessary. Whether done initially or at the time of definitive repair, disimpaction can be done with Rowe forceps (Fig 4). The midface can be distracted inferiorly and then

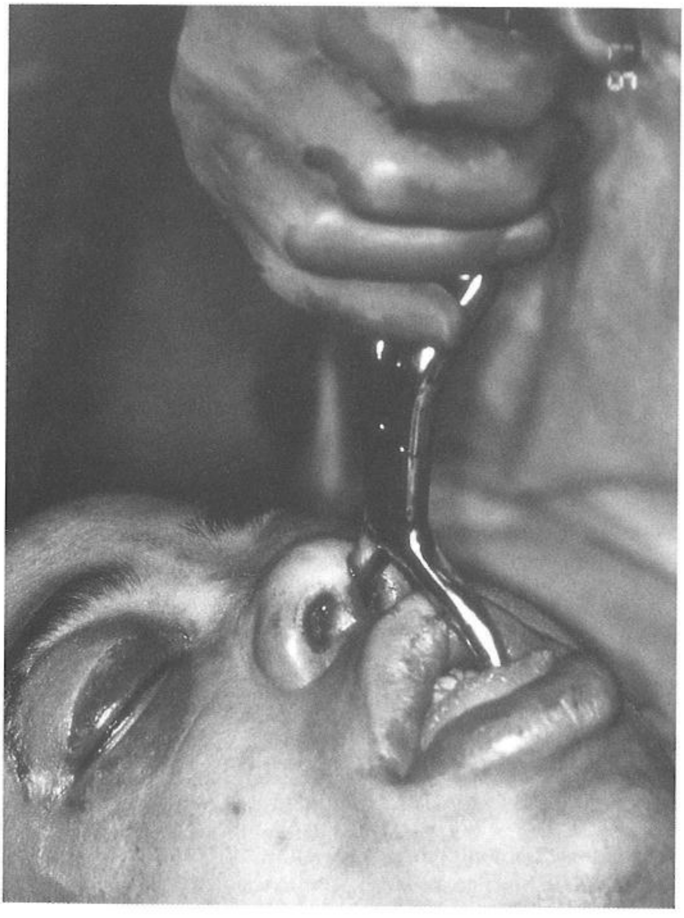


Fig 4.—Placement of Rowe disimpaction forceps.

anteriorly. This technique also can be used to ensure precise reduction after the fractures have been exposed. Often, a large elevator, such as a Cobb or Boies, may be used to reduce bony segments. A small elevator, such as a Freer, will be helpful to work segments apart to achieve optimum reduction.

Fixation

After gross disimpaction and reduction of segments, bony continuity is re-established, usually with the patient in intermaxillary fixation. This is best done by working from a stable area toward an unstable area. In the case of frontozygomatic suture involvement, it is best to start with reduction and partial temporary fixation of this suture to establish the vertical height for the maxilla (Fig 5). By incompletely fixating the fracture across this suture line, it allows for continued three-dimensional adjustments of the midface at lower levels. If there are concomitant nasoethmoid fractures present, the intercanthal distance should be established first (prior to frontozygomatic suture fixation) to prevent lateral displacement of orbital skeletal fragments hindering optimal intercanthal distance re-establishment. If the mandible is intact and intermaxillary fixation is successful, then the hard palate position should be correct. The vertical buttresses must be reconstructed (Figs 6A and 6B). Once the alignment of the vertical buttresses is confirmed, the frontozygomatic suture can be more rigidly plated. Attention also must be paid to the septum. The septum is almost always fractured in Le Fort fractures. Because of the septum's critical role in maintenance of dorsal support, reconstruction of the septum is an important measure for long-term support. Likewise, testing for centric occlusion *after* reduction and fixation is important.

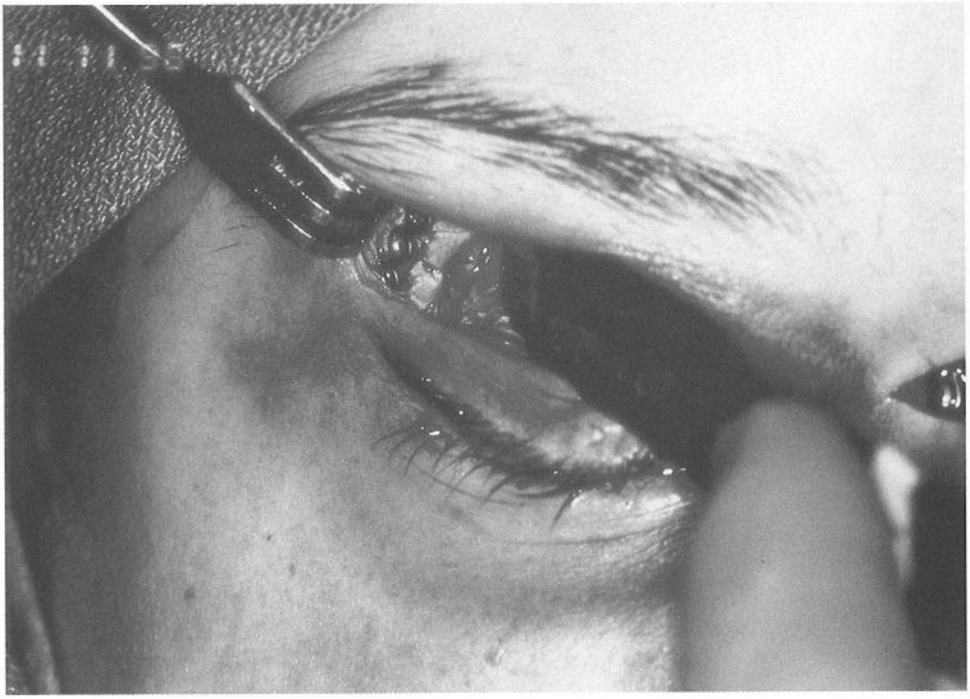
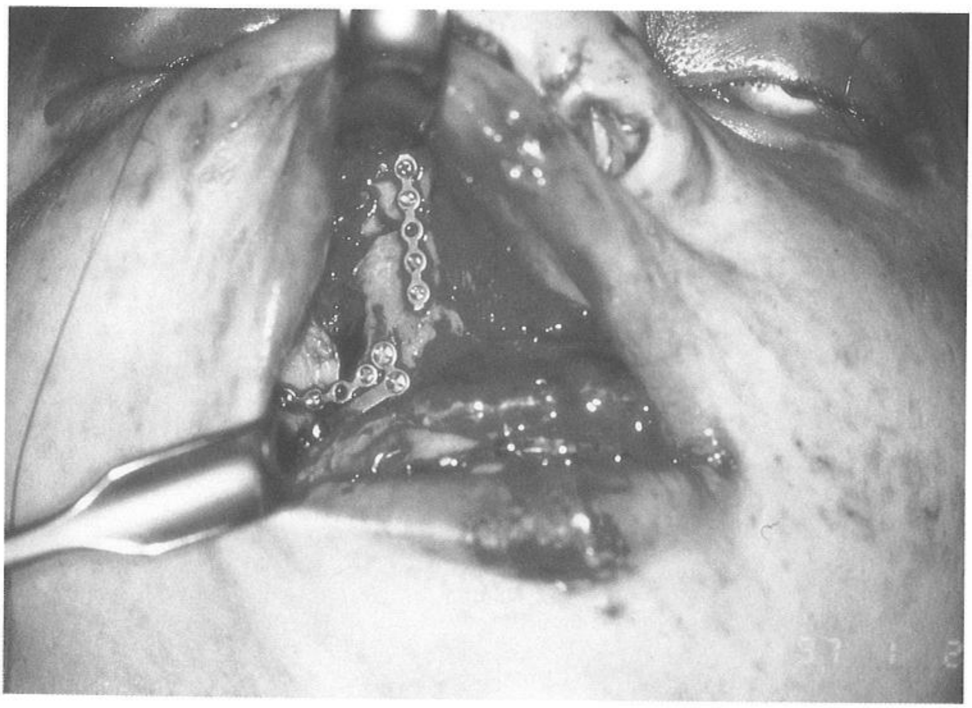


Fig 5.—Fixing superior zygomatico-frontal fracture line.



Figs 6A and B.—Reconstructing vertical buttress with plates.

Le Fort I

Exposure of Le Fort I fractures is by the sublabial or maxillary vestibular approach to access the anterior maxilla. Reduction is achieved by disimpaction and intermaxillary fixation. A minimally unstable fracture may be adequately treated with just intermaxillary fixation, especially if the mandible is intact. Any palatal fractures should be reduced and rigidly fixated prior to the application of intermaxillary fixation. This may be accomplished with a small low-profile plate (X, square, or straight) placed either across the fracture site or on the face of the maxilla above the alveolus.

The fractures are fixated with miniplates. At least two screws need to be placed on either side of the fracture line. While unlikely with correct use of monocortical screws, one should be careful to avoid the tooth roots when fractures extend inferiorly in the zygomaticomaxillary buttress. The use of L-shaped plates is invaluable for allowing placement of enough screws on the inferior aspect of the fracture, while still avoiding the tooth roots. Generally, one or two plates are required to rigidly fixate each buttress. In order to better absorb the masticatory load, use sturdier miniplates (usually 1.7 mm or 2.0 mm) in buttress reconstruction. When there is bone loss greater than 1 cm within one of the vertical buttresses, it should be bridged by the use of bone grafts. If there is not sufficient autologous bone available from the maxillary fracture site, then a split outer table calvarial graft can be harvested. The use of iliac crest or rib grafts is also acceptable. The key to preventing resorption of these bone grafts is rigid in situ fixation. Bony gaps of less than 1 cm can be safely bridged with miniplates (and postoperative maxillomandibular fixation) without the need for interpositional bone grafting. When all four anterior vertical buttresses are comminuted, correct repositioning can be accomplished only by aligning the contours of the bone fragments and relying on aesthetic norms for midface proportion (middle third of face = upper third = lower third of face). When bone grafting is required for buttress reconstruction, or when the reduction is not absolutely rigid, maxillomandibular fixation should be maintained postoperatively. If severe comminution is present, elastic trainers may need to be maintained for 2 to 4 weeks after release of intermaxillary fixation.

If the mandible is stable, midface reconstruction is easier with repair proceeding superiorly. On the other hand, if midface comminution is accompanied by multiple mandible fractures, then working inferiorly from the skull base is important to re-establish proper relationships between the upper and lower jaws.

Le Fort II

The initial exposure and sequence of repair for Le Fort II fractures is as described for Le Fort I fractures. A simple noncomminuted Le Fort II fracture also can be treated with only a sublabial incision, which also can be used to explore the orbital rim from below. However, if there is significant nasoethmoid injury, a Lynch incision or bicoronal flap will be required to give adequate exposure. If the orbital floor needs to be repaired, a transconjunctival incision is preferred. Subciliary approaches are also acceptable.

Reduction of simple Le Fort II fractures is similar to Le Fort I, with disimpaction, if necessary, and intermaxillary fixation. The lateral buttresses are an important guide for anatomic reduction, and may serve as the sole landmark for reduction in simple, noncomminuted fractures. If there is significant comminution, or other fractures are present (nasoethmoid, zygoma), then additional exposure and reduction will be required.

Fixation of Le Fort II fractures entails plating the hard palate to the malar eminence laterally with the use of one or two miniplates. Fractures of the rim are best repaired with wires or low-profile miniplates (1.0 or 1.2 mm). Sturdier plates are not required as this is not a major load-bearing area of the maxillofacial skeleton. If there is bone loss at the level of the inferior orbital rim, it may need reconstruction to prevent significant postoperative cosmetic deformity. Often, small pieces of bone from comminution around this site are available for reconstruction. Hydroxyapatite also is an option that may be considered.

With a Le Fort II, as with an isolated zygoma fracture, there will always be a fracture through the floor of the orbit. The degree of comminution or displacement of the floor fracture will determine the need for intervention. The size of the floor defect usually can be determined by CT scanning. If no significant defect exists, then exploration is not mandatory and fractures through the orbital rim can be repaired from the sublabial approach. On occasion, significant bony disruption can occur without herniation of orbital fat. In such a case, the patient may do well without exploration. However, orbital floor exploration during concomitant fracture repair has little morbidity and will help avoid postoperative complications of enophthalmos or entrapment.

The size of the orbital floor defect will determine the method of reconstruction. For defects less than 1 cm, simple application of Gelfilm will suffice. For larger defects, titanium foil or mesh, polyethylene, cartilage, or bone graft may be utilized. Whatever the material used for floor reconstruction, it needs to be fixated to the inferior rim with either a permanent suture (e.g., Prolene), screw, or miniplate (Fig 7). This is necessary to prevent posterior migration or displacement of the reconstruction material toward the orbital apex, placing the optic nerve at risk. Fixation will also prevent anterior extrusion through the lid. Before closure, a standard forced-duction test should be repeated to confirm that the orbital contents have been fully released.

Le Fort III

With a pure Le Fort III fracture (rarely seen), exposure with a bicoronal approach will allow access to both frontozygomatic and nasofrontal sutures. Lateral brow incisions, or upper blepharoplasty type incision, in conjunction with a Lynch incision, would also be acceptable. If there are significant lacerations already present, these may be utilized. A midforehead incision hidden in a prominent rhytid also may be used. The so-called "open sky" approach across the glabella should generally be avoided because of the poor aesthetic outcomes.

A Le Fort III on physical diagnosis may, in fact, be a Le Fort II with bilateral zygoma fractures. This would give complete craniofacial dissociation but include the orbital rim and orbital floor fractures seen with Le Fort II or with isolated zygoma fractures. In this case, a sublabial incision and a transconjunctival (or subciliary) incision also may be necessary for accurate fixation. As mentioned previously, various combinations of these fractures are typical, so exposure must be based on physical examination, CT findings, and evaluation of fractures as they are exposed.

Initial reduction of the frontozygomatic suture will re-establish the vertical height of the zygoma. Drill holes can be placed for wire fixation or plate fixation. The holes can be drilled into the thick bone of the lateral orbital rim. If the holes are too deep, intracranial penetration can occur, usually beginning 18 mm above the frontozygomatic suture. It often is best to wire the frontozygomatic suture initially so it can be rotated as needed when the maxillary fractures are visualized. Then one may reduce the maxillary fractures and rigidly fixate the frontozygomatic suture. The wire could be left in

Fig 7.—Titanium mesh repair of orbital floor.

position if it is not touching the plate, but the wire should be removed if it is in contact with the plate because electrolysis in the screw hole may occur if two different metals are in contact.

If the Le Fort III occurs with a significant nasoethmoid fracture, then a bicoronal approach incision provides the best exposure. The nasal bridge often is severely collapsed in this fracture pattern (Fig 8). Fixation of the ascending processes of the maxilla and nasal bones to the frontal bar is of critical importance (Fig 9). Anterior repositioning of the nasoseptal complex with the use of Asche reduction forceps and resuspension of the dislocated upper lateral cartilages will allow for aesthetically and functionally acceptable restoration of nasal projection. Dorsal augmentation with bone grafts at the time of initial repair may be required (Fig 10). Open septorhinoplasty may be required to adequately repair these fractures and facilitate graft placement. This is generally delayed.

Other Maxillary Fractures

When repairing medial maxillary fractures, wires may be preferable since even low-profile plates may be visible through the thin skin present in this area of the face. If the use of miniplates is required for fracture stabilization, they will often have to be removed at a secondary procedure 3 to 6 months after fixation. Low-profile 1.0 mm plates may work quite well, but they can complicate later osteotomies that may be required for secondary nasal reconstruction.

Fig 8.—Severely collapsed nasal bridge.

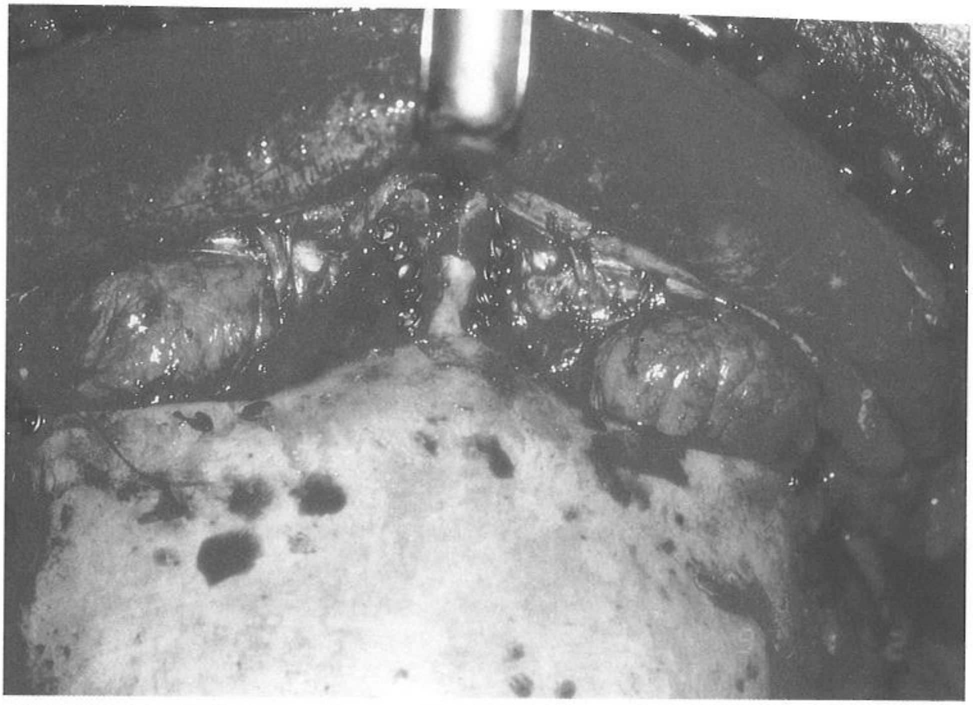


Fig 9.—The nasal and maxillary bones are fixed to the frontal bar.

As outlined, palatal fractures are treated with miniplates prior to the application of maxillomandibular fixation. Palatal splints may, however, be required in very severely comminuted fractures of the palate.

Maxillary Fractures in Children

The treatment of maxillary fractures in children deserves special mention. Fractures of the maxilla make up approximately 10% of all fractures of the pediatric facial skeleton.[16] The infant's face is small relative to total head size, with the midface being especially flat in the vertical dimension. The small child's suture lines are somewhat more flexible, and the maxillofacial skeleton is more prone to the development of greenstick-type fractures than its adult counterpart. This tendency for sutures to deform with incomplete fracture will make precise three-dimensional reduction of fractures difficult. Together with a relative lack of paranasal sinus pneumatization, all of the previously mentioned factors contribute to the relative resistance of the pediatric midface to traumatic disruption. However, when a fracture of the maxilla occurs in the child, it is often the result of a substantial amount of force. Hence, concurrent central nervous system and serious multisystem injury are more commonly noted compared with the adult population suffering from a midfacial fracture. Dental development and the presence of tooth buds may make identification of fracture lines from plain X-rays more difficult in children. Thus, if skeletal disruption is suspected in the maxilla, one should proceed

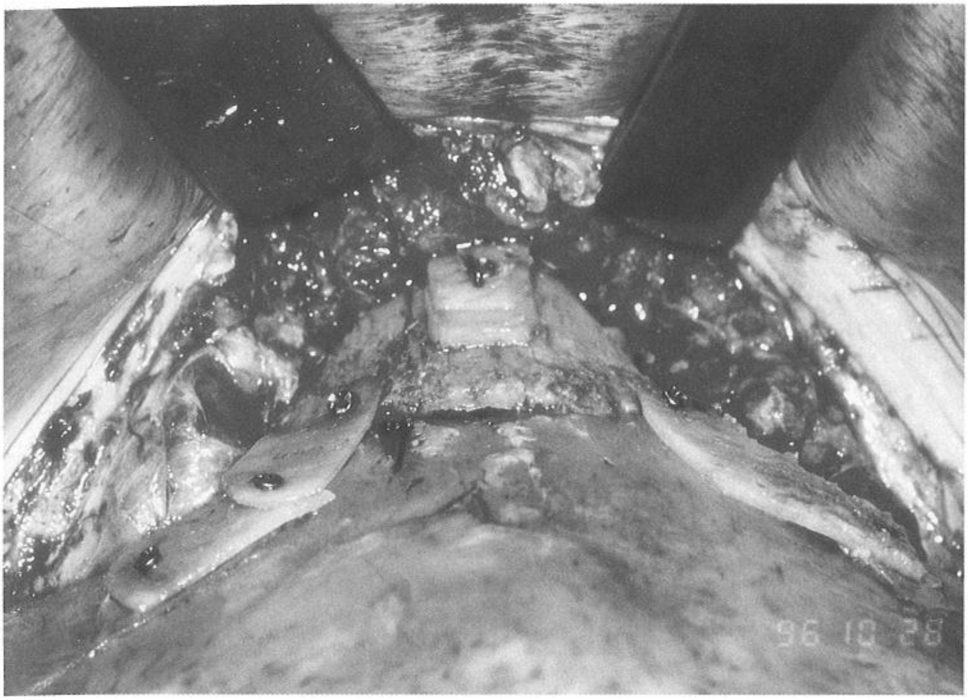


Fig 10.—Bone graft augmentation of nasal root.

directly to CT scanning. Bony union occurs at a much quicker pace in the pediatric population, so reduction and fixation should be carried out within 1 week, if possible. Placing too many plates in the young midface may disrupt growth centers. The basic principles of reconstruction are the same as for adults. If plates are utilized, they should be removed in 3 to 6 months. If maxillomandibular fixation is required, it does not need to be continued beyond 3 to 4 weeks, because of the more rapid bone healing. Resorbable plating systems may have a significant role to play in children.

Postoperative Care

Treatment of midface fractures can take several hours if significant comminution is present. As a result, postoperative swelling can be significant. Intraoperative steroids can reduce edema postoperatively. The head of the bed should be elevated and ice packs applied. Visual checks are routinely done. Antibiotics are continued postoperatively for at least 48 hours or until nasal packing is removed. Even if there are no mucosal lacerations present, the surgical approaches to these fractures violate the mucosal barrier. The risk of infectious complications is likely decreased by the routine use of such antibiotics.[17] It is unclear whether perioperative antibiotics have any beneficial effect on the occasional late development of chronic maxillary sinusitis. A first-generation cephalosporin with metronidazole is usually recommended for this purpose.

Nutrition usually can be maintained by oral intake. If the patient has delayed oral intake, then nutritional support will be required because of the catabolic state of significant trauma. If a tracheotomy has been done, the patient should be decannulated as soon as possible. The tracheostomy may, however, make anesthetic management easier for any procedures that may be required in the first 4 to 6 weeks.

Arch bars and intermaxillary fixation are continued for 4 to 6 weeks if the repair was done with interosseous wiring or if there was significant comminution present at the level of the buttresses. If miniplate fixation was used and solid bone-to-bone contact was achieved in the buttresses, the patient can be taken out of intermaxillary fixation immediately postoperatively. If there is any question as to the occlusion, elastics can be used for 2 to 4 weeks postoperatively. The patient should be on a liquid or soft diet during this time. Occasionally, a new anterior open-bite deformity may develop in the second or third day postoperatively, if the patient is not in intermaxillary fixation. This might be caused by posterior soft tissue swelling. If there is a shift in occlusion, then a return to intermaxillary fixation for 2 weeks and elastics continued for a further 4 to 6 weeks may be necessary. If a lid incision (either transconjunctival or subciliary) has been done, routine use of a Frost stitch for 24 hours postoperatively may prevent the acute edema from initially drawing down the lid. Patients should be instructed to massage the lower lid upward and laterally for several weeks to try to prevent ectropion.

Postoperative films are routinely taken. If there is suboptimal positioning, the best time to correct the alignment is in the immediate postoperative period. It is much easier to reposition a plate than to do osteotomies at a later date. Diplopia caused by edema should resolve within a few weeks.

Complications

Complications following maxillary fractures are uncommon, largely as a result of the maxilla's excellent blood supply. Malunion and malocclusion may occur as a result of improper technique, delayed therapy, or the development of infection. Severe comminution of midfacial buttresses associated with bone loss makes rigid stabilization more difficult. Malunion is uncommon with the use of rigid fixation techniques. Where malunion has occurred, corrective osteotomies and re-fixation may be required. Both trauma and fracture of the mandibular condyles at the time of maxillomandibular fixation may lead to late temporomandibular joint problems and malocclusion. It is not unusual to have minor malocclusion postoperatively after repair of major midfacial trauma. Acceptable outcomes can be achieved with spot grinding of malaligned tooth facets and/or orthodontia. Close coordination of care with the patient's dentist is often quite beneficial.

Persistent diplopia on upward gaze may be a sign of entrapment of the inferior oblique muscle. Thus, one should always perform forced duction testing after repair of all midfacial fractures to verify that entrapment is no longer present. Neuromuscular injury also may give rise to limitation of upward gaze, but with a normal forced-duction test. There is a variable amount of fat atrophy because of the trauma. Therefore, even with appropriate orbital floor reconstruction, patients may develop enophthalmos 4 to 6 weeks postoperatively. Late repair can be done if the deformity is significant.

Patients who have had midfacial fractures have about a 30% incidence of sinusitis after their injury. This is secondary to ostial disruption at the time of the initial trauma or during the repair of fractured segments in the area. Drainage of the maxillary sinus by antrostomies does not need to be routinely performed. Most late postoperative infections are attributable to screw or plate loosening. Hardware removal is required in these cases.

Epiphora from disruption of the lacrimal drainage system occurs in 4% of Le Fort II and III fractures.[10] Interestingly, the most frequent indication for dacryocystorhinostomy in adult males is dacryostenosis resulting from midfacial trauma.[11] Late diagnosis of lacrimal injuries is commonly made many weeks after the initial injury. The presence of recurrent dacryocystitis, with medial canthal edema and tenderness, or recurrent purulence at the medial fornix especially noted upon awakening in the morning, are clues to this diagnosis.

Aesthetic deformity from improper anterior positioning of the maxilla may occasionally be noted. Incomplete maxillary disimpaction creates midfacial flattening and shortening with a decrease in the maxillary incisor show. It also may lead to an anterior openbite deformity caused by premature posterior molar contact. Soft tissue problems may occur as a result of repair of midfacial fractures. Careful resuspension of soft tissues of the midface with closure of the access incisions is required to prevent displeasing cheek mound ptosis. Reapproximation of the deep temporal fascia, limitation of the amount of temporalis muscle exposure, and careful dissection superficial to the superficial temporal fat pad may all decrease the actual or perceived amount of temporal wasting that is sometimes noted with bicoronal incisions.

Nasal obstruction and external nasal deformity are relatively common sequelae of severe fractures of the midface. Reduction of septal dislocations with Asche reduction forceps or a Boies elevator and placement of a temporary postoperative intranasal stent or septorhinoplasty may be required to clear the narrowed nasal airway. Failing to reestablish dorsal height may result in soft tissue contraction of the nasal soft tissue envelope, making secondary procedures more difficult. If necessary, dorsal projection can be obtained with routine dorsal augmentation measures. Secondary rhinoplasty may be needed to provide the patient with the best surgical result possible.

Conductive type anosmia, or more commonly, hyposmia, may be noted in both Le Fort II and III fracture patterns secondary to intranasal mucosal and cartilaginous disruption and edema. Sensorineural anosmia is more frequently a sequela of Le Fort III fractures, as a result of associated cribriform plate fracture with concomitant shearing of the olfactory filaments traversing the area. No accepted treatment exists for this problem.

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