Paparella: Volume IV: Plastic and Reconstructive Surgery and Interrelated Disciplines

Section 1: Plastic and Reconstructive Surgery

Chapter 19: Maxillary Fractures

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Incidence

Trauma is of paramount interest to health care professionals who must manage maxillofacial and multisystem injuries; to the victims who must deal with the physical, functional, and psychiatric sequelae of their injuries; and to society as a whole who must incur the responsibility of providing health care dollars. Trauma is the fourth ranking cause of death at all ages and the leading cause between ages 1 and 37 years. More than 100.000 deaths in the USA each year are attributable to such injuries, and approximately 50 per cent of these involve motor vehicle accidents. It is generally believed that a reduction of speed limits (ie, from 65 to 55 mph) is responsible for reducing the accident and death rates, and that lap belts are capable of preventing 27 per cent, and lap belt-shoulder harnesses 42 per cent, of serious injuries relating to motor vehicle accidents (Council Report, 1983). Such preventive measures are likely to decrease the incidence of serious traumatic injuries, but fatal and near-fatal injuries continue to be perpetrated by the highly mechanized, mobile, and socially pressured environment to which we are subject.

Etiology

Perhaps one of the most challenging areas in traumatology is that of maxillofacial injuries. Given the complexity of the facial skeleton and surrounding soft tissues, the potential for post-traumatic functional deficit and deformity, and the psychocosial stigmata attached to facial distortion, successful reconstruction mandates a careful treatment plan with a thorough understanding of the anatomy and surgical options available in maxillofacial trauma.

Maxillary fractures are considerably less common than nasal, mandibular, or malar fractures and constitute only 10 to 20 per cent of all facial fractures. The majority (three-quarters) victims are between the ages of 10 and 40 years and males are affected three to four times more often than females (Turvey, 1977). The male predilection probably occurs because there are more licensed male drivers, males have a stronger tendency toward driving while intoxicated, and males are more often involved in high-risk occupations and recreational and sporting activities. Most midfacial fractures relate to high-impact forces usually sustained in motor vehicle accidents or (less commonly) industrial accidents. Other causes include aggravated assault, sports injuries, and falls.

Mechanisms of Injury

Fundamental to all trauma is a transfer of energy, and in the case of maxillary fractures this usually represents a kinetic energy of motion. Since energy is neither created nor destroyed, the amount of energy (force) delivered to a given object is predicated on the magnitude and direction of that force, the impact characteristics of the two colliding bodies, and the ability of each to dissipate the energy. In a series of experiments by Nahum (1975), force tolerance ranges for the facial bones were determined and demonstrated to be in a relatively low range (150 to 300 pounds) for the maxilla, in comparison with the frontal bone (800 to 1600 pounds) and mandible (550 to 900 pounds anterior to posterior directed force). Tolerance values were found to be somewhat lower for females. When it is realized that a soft yielding surface absorbs energy (ie, a padded dashboard), whereas a rigid object (ie, a windshield or steering wheel) does not plastically deform and thereby dissipate energy well, it is not surprising that the most important mechanisms of fatal injury are represented by ejection from the vehicle, followed by impact on the steering assembly, instrument panel, and dashboard, respectively. Thus, knowledge of the position of the body, the direction of impact, and the use of restraints is helpful in predicting injury patterns.

Forward collisions account for approximately one-half of all motorist injuries. For drivers who fail to use lap and shoulder harnesses, such a collision is likely to result in their sliding forward with the face striking the windshield while the chest impacts the steering wheel. With the use of a lap belt alone, facial injuries associated with ejection are prevented, but facial trauma associated with convergence upon the steering wheel is likely. With the use of both lap and shoulder restraints, the incidence of midfacial fractures should be low, but there can be deceleration injuries to the great vessels and intrathoracic and intra-abdominal viscera, and flexion-extension injuries to the cervical spine. Although the front seat passenger is unlikely to be injured by a steering wheel, failure to use restraints increases the likelihood of dashboard and windshield injuries.

Unlike frontal collisions, in a side impact almost any part of the auto interior is a potential place for damage to occur. Depending on the angle and direction of the impact, the head may contact the striking car, by struck by other occupants, or hit the steering wheel, instrument panel, windshield, or windshield frame. In a pure driver-side broadside collision one can predict bony injuries to the temporoparietal skull, zygoma, nasal bones, and possibly mandible; midfacial fractures are less likely to occur.

Anatomic Considerations

The maxillary bones are paired structures that contribute much to vertical facial growth between the ages of 6 and 12 years. Each maxilla consists of a body and four processes: frontal, zygomatic, palatine, and alveolar. The body contains the maxillary sinus, which, as a result of pneumatic expansion, decreases the impact tolerance of the maxilla and thereby serves to cushion and protect other craniofacial structures. Areas of noted weakness and fissure lines (maxillary-zygomatic) and foramina or grooves for nerves of vessels (infraorbital).

The integrity of the alveolar process of the maxilla is in large part a function of the state of dentition. When teeth are present, the alveolar process is quite strong and provides sufficient support for the upper portion of the maxilla. Bony recession and alveolar atrophy are common sequelae in edentulous patients and predispose to LeFort I fractures following frontal-horizontal forces.

The occlusal plane of the maxilla lies roughly 45 degrees to the plane of the cranial base and is attached through a series of structural pillars or buttresses. These buttresses provide for strength, maintain maxillary position in relation to the cranial base above and the mandible below, and dissipate vertical forces (which occur in mastication) over a wide area. On the other hand, there is little protection from horizontal forces, and clinical studies (Stanley and Nowak, 1985) demonstrated that forces directed perpendicular to the axis of the vertical pillars cause midfacial sheer with posterior and inferior displacement of the maxillofacial complex along the sloping incline of the basisphenoid. Unlike other facial fractures, such as in the mandible, muscular forces are relatively unimportant in determining bony displacement. One possible exception is high maxillary fractures in which the pterygoid muscles may exert a backward displacement.

Four vertical buttresses, three of which are paired, have been described (Manson and colleagues, 1980). The nasomaxillary or anterior buttress extends from the anterior part of the alveolus along the piriform aperture and nasal process of the maxilla, through the anterior lacrimal crest to the superior orbital rim and frontocranial attachment. The zygomaticomaxillary or lateral buttress extends from the lateral part of the alveolus, above the anterior molar teeth, to the zygomatic process of the frontal bone superiorly, and to the zygomatic arch laterally. The pterygomaxillary or posterior buttress relates the maxillary tuberosity to the cranial base through the pyramidal process of the palatine bone and medial pterygoid plate of the sphenoid. Finally, an unpaired median buttress, or frontoethmoidal-vomerian pillar, connects the frontal bone to the medial palatal suture. The major horizontal buttresses include the maxillary alveolus and palate, the superior and inferior orbital rims, and the zygomatic process of the temporal bone.

Classification

Since his original report of the three great lines of midfacial weakness (lineae minoris resistentiae) in 1901, LeFort's classification system has withstood the test of time and is still used today. Although traumatic midfacial fractures infrequently occur in a pure LeFort form, and often present as part of a complex maxillo-facial injury pattern, the classification system provides a useful means of analysis and communication. Fractures are best described as incomplete, complete, hemi-LeFort, or pure with reference made to specific maxillary fracture patterns such as the medial maxillary fracture, and sagittal or parasagittal fractures of the hard palate.

The LeFort I or Guérin fracture is a transverse, low maxillary fracture involving traumatic separation of the palate from the body of the maxilla. The fracture line, when complete, traverses the inferior nasal septum, passes along the floor of the nose, and passes through the lateral aspect of the piriform aperture, the canine fossa, the floor of the maxillary sinus, and the anterolateral wall of the maxilla. After crossing the pterygomaxillary fossa, the fracture may continue through the inferior aspect of the pterygoid plates. The resulting bilateral palatomaxillary separation results in a "floating palate". This type of injury occurs in approximately 20 to 30 per cent of Le Fort-type fractures and is generally the result of an impact directed head on to the horizontal buttresses.

LeFort II or pyramidal fractures are the most common of the LeFort fractures, occurring in roughly 35 to 55 per cent of most reported series (Dawson and Fordyce, 1953;

Kuepper and Harrigan, 1977; Steidler and colleagues, 1980), and like LeFort I fractures are usually the result of horizontally directed impacts. The LeFort II fracture is frequently combined with the LeFort I fracture. By definition, the fracture line passes through the nasal bones, across the frontal process of the maxilla and the lacrimal bones, descending through the infraorbital rim (close to the zygomaticomaxillary suture line) and through the lateral-inferior wall of the maxillary sinus. The fracture crosses the pterygomaxillary fossa and often injures the pterygoid plates. This type of injury results in a "floating maxilla".

LeFort III fractures or craniofacial disjunctions represent the most severe form of maxillary injury and result in separation of the facial skeleton from the cranium. Fortunately, this type of fracture is not common, occurring in approximately 5 to 15 per cent of most reported series of maxillary fractures (Kuepper and Harrigan, 1977; Steidler and colleagues, 1980). Unlike LeFort I and II fractures, LeFort III fractures are usually produced from impacts angled obliquely to the horizontal buttresses, and experimentally have been reproduced by impacts directed at 30 degrees above the Frankfort plane (Stanley and Nowak, 1985). In LeFort III injuries the fracture line originates high on the nasal side of the frontonasal suture line, fractures the nasal bones, crosses the upper aspect of the frontal processes of the maxilla and lacrimal bones, and passes through the lamina papyracea and ethmoid sinuses. In the orbit the fracture line passes posteriorly to the inferior orbital fissure and divides into two main fracture lines. One line extends across the lateral orbital wall near the sphenozygomatic junction, resulting in frontozygomatic disjunction with continuation inferiorly to separate the zygomatic arch; the other descends across the posterior aspect of the maxilla to fracture the pterygoid plates high near the basisphenoid.

An unclassified fracture refers to a comminuted fracture with multiple fracture lines through the midface atypical of the LeFort classification. Combination fractures refer to LeFort fractures on the same side of the face, such as a left LeFort I and LeFort III fracture. A mixed fracture is represented by different fracture patterns on opposite sides of the face, such as a right LeFort II and a left LeFort I. A hemi-LeFort fracture involves the pterygoid plates with extension of the maxillary fracture only to the anterior midline. An incomplete LeFort fracture does not extend the entire course of the expected fracture line. A pure LeFort fracture is a complete fracture without other maxillary fractures.

Sagittal fractures of the maxilla and palate, although uncommon, are typically associated with comminuted maxillary and zygomatic fractures. The palate is usually split in the midline with extension anteriorly between the two central incisors.

Segmental fractures of the maxilla can also occur as part of a maxillary LeFort fracture or as an isolated injury. These fractures are sometimes difficult to distinguish from simple alveolar fractures, especially when they are confined to the alveolus and do not involve the sinus.

Medial maxillary fractures were initially described by May and Phipatanakul in 1973. These uncommon fractures are often confused with the more commonly seen nasal fractures and must be differentiated from naso-maxillary, blow-out, or even zygomatic fractures. The fracture lines involve the frontal process of the maxilla and medial infraorbital rim but exclude the nasal bones.

Diagnosis

Proper planning for treatment in midfacial trauma begins with a thorough history and physical examination. A careful interview should elicit information on the mechanism of injury (eg, velocity, angle, site and type of impact, use of seat-belt restraints), previous maxillofacial trauma, preinjury occlusal disharmonies, and any of dental prosthesis. The examination must systematically define the structural integrity of the orbital, nasal, and oral units, since any combination of LeFort or maxillary injury must by definition disrupt these regions.

Many symptoms are common to all LeFort fractures. Malocclusion, usually in the form of an anterior open bite deformity, often occurs secondary to premature occlusal contact of the molars. Epistaxis can develop when the mucosa is disrupted in the maxillary sinus, floor of the nose, or lower nasal septum in LeFort I fractures; and in the upper nasal septum or ethmoidal or maxillary sinuses in LeFort II and III fractures. Nasal obstruction occurs as a result of septal dislocations, mucosal swelling, and blood clots. The oral airway similarly may be compromised by bleeding; hematoma-edema formation in the soft palate, uvula, or oropharyngeal mucosa; or in the case of LeFort I fractures, by posterior displacement of the hard palate against the cervical spine. In such patients, respiratory obstruction is exaggerated in the supine position and should be avoided.

In the LeFort I injury, additional distinguishing features include lacerations of the upper lip and loose or fractured maxillary incisors. Isolated palatal mobility on anteroposterior rocking distinguishes LeFort I from LeFort II fractures in which such rocking results in midfacial movement along the infraorbital rim, or from LeFort III fractures in which there is a complete facial movement at the frontozygomatic suture line. Mobility of the upper jaw, however, may be absent in the case of severe impactions. Other useful signs of the LeFort I fracture are early oral bleeding, ecchymosis about the gingival buccal sulcus, localized tenderness about a palpable fracture line, facial edema, and (if the inferior floor of the maxillary sinus is involved) crepitation and subcutaneous emphysema.

LeFort II fractures may be diagnosed in the absence of a concomitant trimalar fracture by the findings of sensory hypesthesia-anesthesia in the distribution of the infraorbital nerve, and as an infraorbital step deformity exaggerated by protrusion-retrusion maneuvers. Signs that may be in common with the LeFort I fracture include gingival buccal sulcus ecchymosis and fracture line palpability; those in common with the LeFort III fracture include anosmia, cerebrospinal fluid (CSF) rhinorrhea, medial canthal disruption, and subconjunctival hemorrhage. LeFort III fractures are additionally distinguished by diastasis of the frontozygomatic or zygomaticotemporal sutures, and circumorbital ecchymosis.

Although less common than LeFort fractures, sagittal and parasagittal fractures should be considered in any patient sustaining maxillofacial trauma, especially in the presence of malocclusion. Sagittal fractures split the palate in the midline, whereas parasagittal fractures occur within 1 cm of the midline. In either case, physical findings may include tenderness and mobility about a palpable fracture line, entrapment of the upper lip between the two disjoined palatal segments, and independent movement of the segments on manipulation. The unstable upper arch is usually deviated anteriorly and laterally. These fractures should be distinguished from segmental alveolar fractures, which are represented by mobile, tooth-bearing maxillary fragments with at least two fracture lines.

Medial maxillary fractures are distinguished by the combined lateral nasal and medial maxillary depression, often involving the infraorbital rim. These patients demonstrate nasal obstruction, and experience epiphora from blockage of the lacrimal collecting system. These fractures are different from the hemi-LeFort II fractures, which present with mobility of one-half of the maxilla.

Radiology

Although roentgenographic evaluation of suspected maxillofacial fractures has proved an excellent diagnostic tool, clinical assessment by means of accurate history taking and physical examination should be emphasized and used to direct the choice of proper confirmatory radiologic studies. In many cases, initial radiographs in a patient with severe midfacial fractures are inadequate, often limited by poor patient compliance for proper positioning or by the nature of the injury itself. Ideally, more information should be obtained after the soft tissue swelling has abated and aeration of the sinuses has ensued.

A standard facial-sinus series should be obtained. The Waters view may show signs suggestive of a fracture, such as opacification or air-fluid levels within the maxillary sinus, thickening of the mucosa within the sinuses, orbital emphysema, fractures of the infraorbital rim, frontozygomatic suture diastasis, and irregularities in the lateral maxillary sinus wall. When the patient must remain supine, because of suspected or proven cervical spine injury, the reverse Waters view can be used by generally is not as informative. The lateral view can be useful in assessing retropharyngeal soft tissue swelling or hematoma consequent to posterior maxillary displacement. Caldwell views often demonstrate fractures of the orbital wall and delineate the structural integrity of the premaxilla. The submentovertex view is useful in looking at displacements of the anterior wall of the maxilla and fractures of the zygoma, which are often associated with LeFort III and palatal split fractures.

In many patients the full extent of bone injuries cannot be appreciated on pain films, and in cases of suspected fracture, computed tomography (CT) should be performed. CT scanning provides superior contrast resolution and is capable of detecting concomitant intracranial injuries often associated with the complex maxillofacial trauma. CT studies, however, can be limited by foreign bodies, artifact, and inability to obtain good coronal views when the patient is uncooperative or has cervical spine injuries. If the patient is suspected of having a complicated floor of the orbit or naso-orbital injury, polytomes should be used. Although resolution is not as good as on CT scans, and radiation exposure is greater than with the CT method, the technique does give excellent coronal views.

General Considerations

Before any definitive management is initiated for maxillofacial injuries, certain life-threatening conditions must be diagnosed and corrected. The greatest threat to the patient with serious maxillofacial trauma is airway obstruction, and this must be managed expediently. Possible causes of airway obstruction from maxillary fractures include intraoral bleeding, significant edema or hematoma formation, dislodged teeth or dentures, and posterior displacements of the maxilla. An airway can usually be established by clearance of any loose debris, removal of dentures, suctioning of clots, placing the patient in an upright or forward position, and using a nasopharyngeal airway. Some patients may require intubation, tracheostomy, or both. Less than 1 per cent of patients with extensive facial injuries require a tracheostomy (Baker and Schultz, 1975), but in patients with midfacial fractures extending across the nasal airway who will be treated by intermaxillary fixation, this figure reaches 50 per cent (Walker and Bertz, 1966). In the case of suspected or proven cervical spine injury, coniotomy with subsequent conversion to a tracheostomy represents a rational approach toward securing control of a rapidly deteriorating airway.

Intranasal or intraoral bleeding can be significant, but it is unusual to develop hypotension and shock consequent to this, and other causes besides maxillofacial injuries should be sought. In most cases, even when there is a laceration of the internal maxillary or greater palatine vessels, hemorrhage can usually be controlled by anterior and posterior nasal packs. Other temporary ancillary procedures include early closure of soft tissue wounds, local pressure, and temporary reduction of fractures.

After emergency care, diagnostic endeavors must establish any and all associated injuries. Cervical spine and intracranial injuries can be evaluated by crosstable lateral and CT films, respectively. Consultations regarding neurosurgery, ophthalmology, orthopedics, and general surgery may be indicated and should be placed early to establish a baseline and properly sequence management strategies. Approximately 30 per cent of patients with maxillofacial trauma have associated injuries; the skull, eye, and abdomen-thorax account for 3, 11, and 5 per cent, respectively (Nakamura and Gross, 1973). Severe soft tissue injuries of the face are present in approximately 15 per cent of all cases. Timing of the definitive repair should be delayed until the patient is stable, completely evaluated both radiographically and through specialty consultations, and until most of the edema has subsided (this usually takes 7 to 10 days). During this time, appropriate antibiotic coverage is desirable.

In planning for definitive repair, treatment goals should include (1) restoration of centric occlusion, (2) restoration of midfacial projection, (3) restoration of midfacial height, and (4) stabilization of the maxillary buttresses (to prevent late sequelae of midfacial collapse and facial elongation). To accomplish these objectives, it is necessary to evaluate the extent, relative displacement, and inherent instability of the fracture, and although clinical and radiographic information is important, most patients require direct operative exposure.

It may be difficult to determine centric occlusion, especially in cases of extensive combined maxillary and mandibular fractures. Assistance should be obtained by previous radiographic or dental records if available, or by direct inspection for wear facets. Proper restitution of maxillomandibular occlusion, and its stabilization by intermaxillary fixation, is the starting point in midfacial reconstruction. In one large series, 86 per cent of all LeFort fractures unassociated with other midfacial fractures were treated by manual repositioning of major fracture segments and intermaxillary fixation alone, with the surprisingly low complication rate of 1.8 per cent (Kuepper and Harrigan, 1977). Most authorities, however, consider this treatment too conservative.

The establishment of proper midfacial projection is predicated on reconstructing horizontal and vertical dimensions of the mandible. Because the mandible relates to the cranial base, and therefore constitutes a stable point of reference in the absence of fracture, craniomandibular relation can be used to determine maxillomandibular relation by defining the position of original occlusion. When complex mandibular fractures preclude the reestablishment of a stable lower arch, it is possible to reconstruct from above downward (maxilla followed by mandible), but error is more likely in this situation.

In general, reconstruction from stable to unstable parts is the rule. After occlusal relationships have been established, maxillary fixation is usually performed by a cranial to caudal reconstruction. Because of these two reference points, the mandible and cranium, the opportunity for error is minimized.

Restoration of midfacial height is important and accomplished through adequate reduction and reconstruction of the medial and lateral maxillary buttresses. Reduction of fractures and interfragmentary wiring should proceed from an intact frontal cranium to the high midface, and then to the low midface with fixation of the buttresses. In cases of gross comminution of extensive bone loss, buttress reconstruction may be effected with miniplates or primary bone grafts, such as split-rib or split-calvaria grafts.

Types of Fracture

LeFort I Fractures

The objectives in treating the LeFort I fracture are threefold: (1) restoration of centric occlusion, (2) reduction and stabilization of the palatal segment to the closest stable superior maxillary segment, and (3) reduction of any septal dislocations. Traditionally, standard treatment has consisted of reduction of the mobile segment in some form of intermaxillary fixation with suspension for 4 to 6 weeks. If, however, the fracture is relatively stable after the reduction, intermaxillary fixation with arch bars may be all that is required. For unstable fractures, interosseous fixation, internal suspension, or both may be used to complement intermaxillary fixation.

If the LeFort I fragment is impacted, reduction can be obtained by application of digital reduction or Rowe disimpaction forceps. Intermaxillary fixation in dentulous patients can be established by placement of Erich arch bars and use of orthodontic latex elastics to exert dynamic traction. In edentulous patients, arch bars can be affixed to the dentures; if dentures are not available, Gunning splints can be fabricated and used to obtain intermaxillary fixation. Alternatively, careful anatomic reduction and reconstruction of the anterior buttress through interosseous wiring or internal plate fixation may obviate the need for intermaxillary fixation in the edentulous state.

Further stabilization is usually accomplished by internal suspension from the piriform aperture and/or zygomatic arches bilaterally. Critics of circumzygomatic wiring claim that this form of suspension, besides producing a vertical impaction force, exerts a notable posterior vector that has a potential for premature molar contact and an anterior open bite deformity (Gruss and Mackinnon, 1986; Manson and colleagues, 1985; Sofferman and colleagues, 1983). Although midface shortening and retrusion are possible sequelae, it appears that most cases of midfacial collapse are probably secondary to inadequate intermaxillary fixation or to excessive tightening and compression of comminuted maxillary buttresses. For the most common suspension technique, intermaxillary fixation is first obtained, and a 24-gauge wire is then usually secured from the zygomatic arches to the arch bar opposite the first molar. Through a small stab wound above the zygoma, a Dingman passing needle or passing awl is introduced deep beneath the zygoma and into the buccal cavity. The needle or awl is then withdrawn and passed just external to the zygoma, again into the buccal cavity. The wires are subsequently secured directly or through an intervening loop of fine wire to the upper arch bar or denture. Finally, the nasal septum is reduced, and if unstable it may be splinted by Silastic sheets and supported internally by packing.

Postoperatively, the wires are adjusted to appropriate tension and the patient is maintained on a liquid diet. The suspension wires and intermaxillary fixation are generally released in 4 to 6 weeks and the patient is started on a soft diet. If the patient remains asymptomatic over the following week, the arch bars may be removed and the patient progressed to a regular diet.

LeFort II Fractures

In treating LeFort II injuries, reduction proceeds in a manner similar to that for LeFort I fractures. Two Rowe disimpaction forceps are often used to simultaneously rock the midfacial segment forward into proper projection. After centric occlusion has been established and stabilized through intermaxillary fixation, one can explore the zygomaticomaxillary buttresses through buccal sulcus incisions and reconstruct them with interosseous wire, or in the case of extensive bone loss, by primary bone grafting and miniplate fixation techniques. Alternatively, one can stabilize horizontal buttresses (ie, the infraorbital rim) by interosseous wiring applied through a lower lid, subciliary, or transconjunctival approach. This method is useful if there is a suspicion of orbital floor injury and a need for orbital floor exploration.

If the midface is still unstable after the reduction and internal fixation, or if there is concern about later lengthening and retrusion, the use of internal suspension is warranted. Assuming that the zygoma is intact, circumzygomatic wiring may be used as in LeFort I fractures. Vertical positioning of the wires is important to prevent posterior dislocation of the maxilla and an open bite deformity.

Associated nasal septal fractures are usually amenable to closed reduction techniques, which may be accomplished through use of Walsham and Asch forceps. Extensive nasoethmoidal fractures are not uncommon and require proper reduction and a search for associated medial canthal disruption. Often the comminuted nasal segments may be stabilized by nasal compression plates, but in the case of medial canthal tendon injury, open repair through a medial orbital incision is warranted.

LeFort III Fractures

Surgical management of LeFort III fractures involves an extension of the principles discussed for LeFort I and II fractures. Reduction of the maxillary segment is performed in a similar manner, but a greater force may be required for disimpaction. Since LeFort fractures are often complicated by sphenoid fractures, and reduction can injure the optic nerve, one must be careful to maintain strong posterior to anterior force during the reduction process.

After reduction, occlusal relationships should be established with intermaxillary fixation, and vertical height and projection of the maxilla should be managed appropriately. Since this fracture rarely occurs as a unit and is often associated with trimalar fractures, open reduction and internal fixation through buccal sulcus, lateral brow, and some form of lower eyelid incision invariably becomes necessary. If interosseous wiring is to include the nasofrontal complex, a medial orbital incision is required. The craniofacial disjunction is further stabilized laterally by frontozygomatic wiring, and in the case of associated malar fractures, by interosseous fixation of the infraorbital rim. The orbital floor should be explored and treated by reduction and reinforcement, as with any inferior wall injury.

Internal suspension through circumfrontal wiring is often used to prevent the late sequelae of facial elongation and retrusion. For this technique, a 24-gauge wire is passed by needle or awl from the zygomatic process of the frontal bone, behind the zygoma and along the lateral wall of the maxilla, to the upper arch bar or denture opposite the region of the first molar. As with circumzygomatic wires, the wire can be directly secured to the upper arch bar or denture, or through an intervening fine wire loop.

Finally, attention must be directed toward repair of the associated nasoethmoido-orbital component of the fracture. Many techniques are available to correct damage to the lacrimal collecting apparatus and medial palpebral ligament. Cribriform plate and anterior fossa injuries must be immediately diagnosed and treated appropriately.

When internal suspension and direct interosseous wiring do not appear to stabilize the maxillofacial unit, consideration should be given to external skeletal fixation. This technique is often indicated for (1) unstable midfacial fractures associated with bilateral fractures of the mandibular condyle, with or without symphyseal fractures; (2) severe craniofacial disjunctions or pyramidal fractures with extensive bony comminution and displacement; and (3) severe palatal tipping fractures, impacted maxillary fractures that require continuous traction for reduction, or fragment stabilization. The types of external fixation devices generally in use today include the Irby, Georgiade, Morris, or Perry halo frames; when a headframe is unavailable, a biphase appliance using intradiploic cranial screws may be utilized. Other methods are possible, such as the plaster of Paris head cap or orthopedic bed traction, but because of availability of specifically designed adjustable halos, they are rarely used today.

Medial Maxillary Fractures

This type of fracture can be treated by closed reduction techniques, passing a heavy curved clamp into the nose and elevating the frontal process of the maxilla and lacrimal bone. Unfortunately, however, stability is difficult to obtain, and the bone fragments are best stabilized by interosseous wires or internal fixation techniques. The procedure can be completely carried out by a degloving approach to the maxilla. If the fracture should remain unstable after interosseous wiring, internal packing should also be considered.

Palatal Fractures

Sagittal and parasagittal fractures of the maxilla can often be managed by reduction and internal fixation with an arch bar (preferably the Jelenko type), but occasionally a stable repair requires open reduction and internal or external fixation techniques. Lateral displacements at the midpalate can be treated by intermaxillary fixation with open reduction and internal fixation at the piriform aperture as well as at the zygomatic buttress. In unstable fractures, and in patients with palatal tipping, a palatal splint or intermolar bar is necessary. Eight to 12 weeks may be required for adequate stabilization and healing of the more extensive palatal fractures.

Complications

Undesirable sequelae consequent to maxillary fractures encompass a broad range of potential deficits and deformities, which include complications of bone healing such as nonunion and malunion. Other unwanted results are sinusitis, hypesthesia, facial pain, dacryocystitis, and nasal obstruction.

Fortunately, nonunion of the maxilla is rare, but when it does occur it is often a problem of diagnosis or incomplete reduction and fixation of maxillary fragments. The maxilla, being primarily cancellous bone supplied by an extensive primary and collateral circulation, heals rapidly, and since there are only a few muscular attachments capable of distraction, stabilization can be easily obtained. Nonunion and primary fibrous union (a form of delayed union) may be prevented by (1) avoiding excessive periosteal stripping, (2) achieving stable reduction and alignment of fragments, (3) providing adequate immobilization, (4) controlling infection, and (5) correcting nutritional deficiencies. Primary bone grafting should also be considered when there is a loss of bone and investing periosteum.

Malunion is probably the most frequent complication of midfacial fractures and may be represented by a spectrum of contour defects and facial asymmetries. The most extreme form, dishface deformity, which follows LeFort II and III injuries, is characterized by retrodisplacement of the midface with a concave facial profile, facial elongation, and an Angle's class III malocclusion. The deformity develops from incomplete reduction and immobilization, but the immediate cause if often failure to reconstitute the pretraumatic mandibular arch before intermaxillary fixation, or overzealous use of maxillary suspension. Common predisposing factors after midfacial injury include bicondylar fractures of the mandible, excessive compression of comminuted fragments, and the use of intermaxillary fixation and maxillary suspension in the face of weak maxillary buttresses.

Of the other complications, LeFort I fractures can result in occlusal disharmonies, such as an anterior open bite deformity or crossbite, septal deformities, and oral-antral fistulas. LeFort II fractures can result in nasal-septal distortions, recurrent sinusitis, malocclusion, epiphora, dacryocystorhinitis, anosmia, infraorbital nerve anesthesia, CSF rhinorrhea with meningitis, and telecanthus. LeFort III injuries have the potential to produce the same sequelae as those seen after LeFort II injuries but with a greater predicted frequency. Moreover, with LeFort III fractures there is a greater predisposition to intracranial and intraorbital injury.

Pediatric Consideration

Facial fractures in the pediatric population are uncommon, accounting for less than 10 per cent of maxillofacial trauma in the general population (Maniglia and Kline, 1983). In the younger age groups of 1 to 6 years, motor vehicle accidents tend to be the most frequent cause; in children over 6 years of age, falls and injuries by blunt objects, followed by motor vehicle accidents, account for most facial fractures. In comparison with nasal and mandibular fractures, midfacial fractures are rare, with an estimated incidence of 0.5 per cent (Kaban and colleagues, 1977).

Certain structural features of the maxilla account for this low incidence. The midfacial skeleton in young children is less prominent than in adults, with a craniofacial ratio of 8:1 compared with 2.5:1 in adults. Children's facial bones are resilient, the osseous suture lines are flexible, and there is a relative increase in soft tissue protection covering the facial skeleton. The small size and weight of the child also account for low inertial forces of impact. For these reasons, when severe maxillofacial trauma is seen in pediatric patients, a high index of suspicion must be maintained toward possible intracranial and cervical spine injuries.

Radiologic and clinical assessment in the pediatric group can be difficult owing to problems in positioning and attaining cooperation. The presence of unerupted teeth may overshadow the low transverse maxillary fractures, and poor pneumatization of the paranasal sinuses may complicate radiologic interpretation.

In treating fractures of the maxilla in children, a conservative attitude and conscience toward possible interruption of dental and facial growth centers should be maintained. Because union of a displaced fracture occurs earlier in children than in adults, reduction and immobilization must be performed earlier, generally within 5 to 7 days of injury. For young children with a nondisplaced low maxillary fracture, immobilization for 2 to 3 weeks with a Barton bandage may be all that is required. In displaced low maxillary fractures, a maxillary arch bar with suspension may often be adequate; in the case of mixed dentition, fabrication of a palatal splint with suspension stabilization is an alternative method. For high maxillary fractures, management generally parallels that in adults. Revisional surgery is carried out conservatively, delaying reconstruction of minor deformities until adulthood. On the other hand, any major disharmonies and dysfunction should be corrected regardless of the child's age.